# GROWING UP IN A DIGITAL WORLD - SOCIAL AND COGNITIVE IMPLICATIONS

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PUBLISHED IN: Frontiers in Psychology and Frontiers in Education

frontiers Research Topics

ISSN 1664-8714
ISBN 978-2-88971-721-7
DOI 10.3389/978-2-88971-721-7

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# GROWING UP IN A DIGITAL WORLD - SOCIAL AND COGNITIVE IMPLICATIONS

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**Citation:** Heimann, M., Bus, A., Barr, R., eds. (2021). Growing up in a Digital World - Social and Cognitive Implications. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-88971-721-7

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frontiers in Psychology

EDITORIAL
published: 30 September 2021
doi: 10.3389/fpsyg.2021.745788

# Editorial: Growing Up in a Digital World - Social and Cognitive Implications

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**Keywords: early childhood, digital media, learning, language, book reading, joint media engagement, technoference, robotics**

**Editorial on the Research Topic**

**Growing Up in a Digital World - Social and Cognitive Implications**

OPEN ACCESS

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***Specialty section:***
*This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology*

***Received:*** *22 July 2021*
***Accepted:*** *06 September 2021*
***Published:*** *30 September 2021*

***Citation:***
*Heimann M, Bus A and Barr R (2021) Editorial: Growing Up in a Digital World - Social and Cognitive Implications. Front. Psychol. 12:745788. doi: 10.3389/fpsyg.2021.745788*

Digital media availability has surged over the past decade. Most of us regularly check our emails, video chat, follow social media, search for new information, and play games. We frequently swap the real world for the digital world. It is the new "normal!" Children growing up today use digital media for learning and entertainment and to make social connections. The increasing usage of digital media has caused grave concern among parents and teachers. Rapid growth in access has been accompanied by similarly rapid growth in research on the effect of digital media. A search conducted in early July 2021 that included four major databases—Scopus, PubMed, PsycInfo, and ERIC—returned 1,777 hits when combining the search terms "digital media" and "screen time" with the age specifiers "infancy" and "preschool" (see **Figure 1**). A vast majority of the identified output, 1,269 hits, is from publications dated January 2016 to December 2020. Phrased differently, the mean average number of publications per year was 0 during the 1990s, 13 during the first decade of the twenty first century, and 176 from 2011 to the end of 2020. However, these publications often failed to consider the family context and socio-cognitive implications of digital media. As a result, there are many unanswered questions such as: What role do factors like content, context, and culture play in determining the impact of digital media, for good or for ill, on children's learning and development? The current Research Topic aims to tackle some of these questions.

The book includes 18 papers organized into three sections, one that focuses on book reading and language, one that covers potential risks associated with early media use, and one group of studies brought together under an umbrella we call New Developments. Some papers cut across sections and could have been included in more than one section. We are pleased to report that a majority of the papers result from international collaborations representing work conducted in nine countries. Six papers are from North America (Canada and USA), 10 from Europe (Germany, Italy, Norway, Sweden, and United Kingdom), and two from Asia (Israel and Singapore).

## BOOK READING AND LANGUAGE

Digital media lends itself to storytelling, leading to an expansion in the ways children encounter stories. Apart from oral and traditional print books, even the youngest children have unprecedented access to film, apps, and games. The result is that most young children come across stories in formats other than traditional paper books. Therefore, it is not surprising that quite a few contributions focused on how these newly formatted stories relate to traditional book reading.

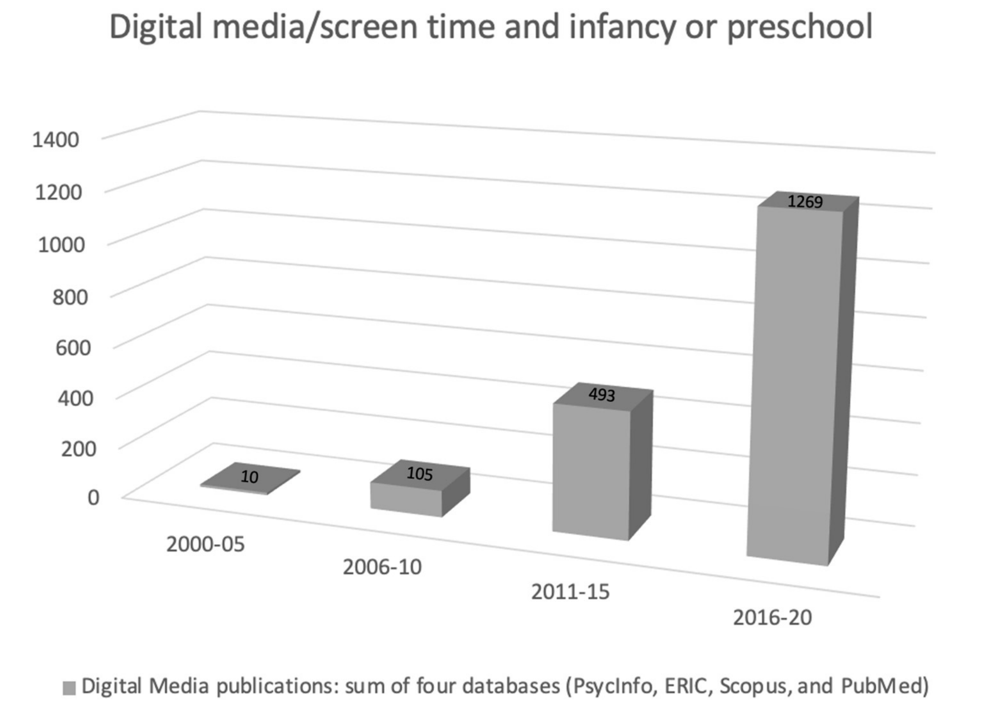


**FIGURE 1 |** Returned hits from a search combining the terms "digital media" and "screen time" with "preschool" or "infancy." Search date July 3, 2021.

The current set of studies targets several sub-questions inherent to the new ways of encountering stories. The Courage et al. study tests whether 2- and 3-year-olds can operate a tablet purposefully to achieve a goal and, for instance, learn new information from a picture book app compared to a matched paper book. Others focus on the impact the digital book has on adult guidance. Müller-Brauers et al. zoom in on the narrative potential of a commercial digital picture book app and found that despite the helpful narrative animations provided by the app, most parents failed to fully exploit the narrative potential. In the same vein, Hoel et al. explore how early childhood educators prepare young children to participate in a shared digital-book reading session before the session and how successful they are in using typical features of digital books.

Crawshaw et al. explore a new storytelling technique, the film-like format, and how that contributes to story comprehension; to this end, they compare what children retain from a story after sharing a wordless picture book with the parent or watching a video of the same wordless story. Gaudreau et al. wonder how vital the physical presence of the adult is for comprehending a picture book. They compare the effects of a prerecorded pseudo-contingent condition with a video chat or live condition and report that 4-year-old children can comprehend a book equally well when read over video chat than when presented live.

## POTENTIAL RISKS

Contributors examined how the content and context of media exposure were associated with decreases in the quality of play and language interactions, sleep, and focused attention. Two short-term longitudinal studies by Gueron-Sela and Gordon-Hacker and McHarg et al. examined multiple dimensions of media exposure that predicted later poorer attention and executive functioning outcomes. The use of longitudinal designs and the more detailed media exposure measures are important current directions.

Three studies used the CAFE media assessment questionnaire, which is part of the CAFE set of tools described by Barr et al. In Italy, Bellagamba et al. found that Italian children were exposed to media at similar levels to English speaking children from the US and the UK. Higher levels of media exposure were associated with poorer sleep habits. In Sweden, Sundqvist et al. examined how a 2-year-old's language use across the day is associated with daily media use. More direct exposure to media without active parent involvement was associated with poorer language outcomes. However, joint media engagement and book reading were associated positively with language. In Germany, Konrad et al. found that parental quality decreased when parents received a message on their phone during a free play session. Some parents also completed a paper version of the questionnaire and the change in interactional quality was the same suggesting that texting may be similar to other everyday interruptions. These findings suggest that complex patterns of media usage are associated with several domains.

## NEW DEVELOPMENTS IN DIGITAL MEDIA RESEARCH

This broad heading does not imply absolute uniqueness, but it is our view that these papers represent new and evolving subfields. Sun and Yin discuss how variation in input affects bilingual children's language learning. For bilingual children in Singapore, multimedia resources are more important for Mandarin learning than for English. This finding is explained by an unbalanced bilingual environment that provides poorer input for Mandarin learning than for English.

How do children evaluate information from different types of digital media? Hassinger-Das et al. studied this in a group of 117 children aged 3- to 8-years. YouTube videos are more attractive than smartphone or TV videos. This occurred despite the finding that the children tended to believe the YouTube information to a lesser degree.

Three studies focus on new aspects of co-media use. First, in an innovative study, Dore et al. analyses non-linear dynamics of how joint media engagement (JME) affects language development in 6- to 8-year-old children. Surprisingly, it is not until the number of hours children spend with digital stories (films, games, apps) exceeds 5 h per day that new media have a demonstrably negative impact on language development. Their findings pave the way for a more nuanced perspective on the effect of digital media in young children.

Low JME seems to be especially detrimental for children with high media use. In an experimental study of 2-year-olds, Heimann et al. report that JME did support learning from 2D media although not to the level of a 3D presentation. Finally, Ochoa and Reich show the influence of income and education in an interview study of Latin families. Parents graduated from high school stress the importance of co-using media but not parents with lesser education.

A different and new aspect of how children are affected by digital information is presented by Tolksdorf et al. who compared 4–5-year-old children's social interaction with a social robot and a human person. The children used social referencing in both interactions but significantly more so when interacting with the robot.

## FUTURE DIRECTIONS AND THEORETICAL IMPLICATIONS

In sum, the papers demonstrate both the potential risks and benefits of early media exposure. If the content and context are right, digital media might provide a rich window to learning in new and exciting ways; to explore the world and social connections. Studies on the role of JME suggest promising avenues in which to work with families to use media effectively. The content also matters. Books, for instance, take new exciting formats due to technology and new storytelling techniques may open up opportunities to enjoy and comprehend stories.

Due to rapid technological advances, however, there remain several gaps in the literature. For example, modern media are mobile, interactive, and often short in duration, making them difficult to remember when parents, teachers, relatives, or older children respond to questions about media use. Although standardized measures of media usage are still being developed, it was encouraging that many of the included studies used more comprehensive multi-dimensional exposure measure. But researchers should also move beyond the exclusive use of parent reports and integrate direct observation of behavioral, physiological, or neural responses and use longitudinal approaches to capture the trajectory of exposure patterns.

Although we were able to solicit manuscripts from multiple countries, the samples recruited for the Research Topic were still WEIRD. Thus, we need to know more about cultural variation and for whom does media work. Notably, only Ochoa and Reich and Sun and Yin directly examined cultural implications. Future research should consider how patterns of media use are similar and differ between countries as a function of different parenting practices and include detailed multiple-dimensional media measurement.

Digital media provides exciting new opportunities for learning that have not been fully explored. In the current Research Topic, researchers examined different approaches to storytelling and social interactions. However, most research is based on standard materials and does not experiment with new technology-enabled possibilities. For instance, most contributions to this collection of papers targeting book reading do not control the enhancements in the target books but use what the commercial market offers. The fact that commercial design is more or less accidental may partly explain why findings are often inconsistent and hard to interpret. Digital book reading research will improve if researchers use materials grounded on conceptual frameworks. For example, Kucirkova and Littleton attempt to advance the digital-book format by theorizing about the distance between the familiar and the novel words of the story and propose to narrow the gap between reality and the interpretations of reality by adding other senses (e.g., taste and smell).

Instead of materials available on the commercial market, it might be essential to create materials that align a conceptual framework. None of the studies produced new technology to explore the hidden potential of technology. Research grounded in multimedia learning that tests how the format optimally benefits young children's story comprehension and incidental word learning is sorely needed. To achieve that goal, we need new collaborations between app developers, computer specialists, literacy educators, and specialists in digital learning, which seem indispensable to forward our insights on effective use of technology during early childhood.

Finally, we hope that the collection of papers will serve as a window to our current state of knowledge, inspire new researchers to enter the field, and motivate new collaborations among those already active.

## AUTHOR CONTRIBUTIONS

MH, AB, and RB contributed equally to the writing of the Editorial and all authors approved the submitted version.

## FUNDING

This research was in part supported by grants from the Swedish Research Council for Health, Working Life and Welfare (2016-00048) to MH.

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 31 May 2021
doi: 10.3389/fpsyg.2021.564479

# Toddlers Using Tablets: They Engage, Play, and Learn

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Although very young children have unprecedented access to touchscreen devices, there is limited research on how successfully they operate these devices for play and learning. For infants and toddlers, whose cognitive, fine motor, and executive functions are immature, several basic questions are significant: (1) Can they operate a tablet purposefully to achieve a goal? (2) Can they acquire operating skills and learn new information from commercially available apps? (3) Do individual differences in executive functioning predict success in using and learning from the apps? Accordingly, 31 2-year-olds ($M$ = 30.82 month, $SD$ = 2.70; 18 female) were compared with 29 3-year-olds ($M$ = 40.92 month, $SD$ = 4.82; 13 female) using two commercially available apps with different task and skill requirements: (1) a shape matching app performed across 3 days, and (2) a storybook app with performance compared to that on a matched paper storybook. Children also completed (3) the Minnesota Executive Functioning Scale. An adult provided minimal scaffolding throughout. The results showed: (1) toddlers could provide simple goal-directed touch gestures and the manual interactions needed to operate the tablet (2) after controlling for prior experience with shape matching, toddlers' increased success and efficiency, made fewer errors, decreased completion times, and required less scaffolding across trials, (3) they recognized more story content from the e-book and were less distracted than from the paper book, (4) executive functioning contributed unique variance to the outcome measures on both apps, and (5) 3-year-olds outperformed 2-year-olds on all measures. The results are discussed in terms of the potential of interactive devices to support toddlers' learning.

**Keywords: apps, attention, e-books, executive functions, spatial skill learning, toddlers, touchscreen device**

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***Specialty section:***
*This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology*

***Received:*** *21 May 2020*
***Accepted:*** *26 April 2021*
***Published:*** *31 May 2021*

***Citation:***
*Courage ML, Frizzell LM, Walsh CS and Smith M (2021) Toddlers Using Tablets: They Engage, Play, and Learn. Front. Psychol. 12:564479. doi: 10.3389/fpsyg.2021.564479*

## INTRODUCTION

The speed with which interactive mobile media technology has evolved and the extent of its adoption into homes and schools has raised enthusiasm and concern among parents and professionals in medicine, science and education (Kucirkova and Zuckerman, 2017; Rideout, 2017; Pila et al., 2019). As these new technologies offer the potential for extraordinary connectivity but also significant distraction and pre-occupation, many of the questions that were raised about the effects of television and video on very young children's cognitive and social development are being asked again about tablets, smartphones, and gaming devices (see Barr and Linebarger, 2017; Blumberg and Brooks, 2017). One reason for this renewed inquiry is that because of their portability and touch screen capability in particular, these devices are potentially far more intrusive into children's daily lives than is television. A second reason is that unlike television, touchscreen devices are interactive media and are fairly easy for young children to operate on their own. The devices can easily engage their attention, respond contingently to them, and elicit verbal replies or actions, all of which could support or enhance learning, even in toddlers, when used judiciously with well-designed content (Hirsh-Pasek et al., 2015; Radesky et al., 2015). Some apps also allow for cooperative use that could foster joint attention and engagement with others during play or learning activities (Wholwend, 2015; Lytle et al., 2018; McClure et al., 2018).

A report from *Common Sense Media* confirmed the ubiquity of these devices in the everyday lives of very young children (Rideout, 2017). At that time, an estimated 98% of homes in the United States with children under the age of 8 years had at least one mobile device such as a tablet, smartphone, e-reader, or gaming console. Among children under 2-years of age in the sample, 46% had experience with a touchscreen device. Kabali et al. (2015) reported a 75% usage rate in a sample of children between 12 and 36 months old from low-income, minority group families. More recently, Levine et al. (2019) reported a 60% rate of usage in a sample of children under 36-months of age. Rates reported in several European and Asian samples were similarly high (Ahearne et al., 2015; Cristia and Seidl, 2015; Bedford et al., 2016; Chang et al., 2018; Chindamo et al., 2019). Although the methodology, sample sizes, demographics, and the age ranges varied across these reports, it appears that internationally, more than half of children under 3 years are regular users of interactive media devices. Collectively, these studies also indicated that although traditional television is still their media platform of choice, the amount of time that infant and toddler users spend with interactive devices is increasing and ranges from about 10 to 45 min per day. Parents report in surveys and interviews that children used the devices mainly to access TV and video content through streaming services and YouTube, and to a lesser extent, for interactive e-storybooks, games, and other apps–about 50% of the time when on their own (Nevski and Siibak, 2016; O'Connor and Fotakopoulou, 2016; Rideout, 2017; Levine et al., 2019).

## Mobile Media Technology and the Youngest Users: What Do We Know?

There is evidence that the judicious use of interactive mobile devices can be beneficial to the acquisition of language, literacy, and STEM concepts in older preschool and kindergarten children (e.g., Berkowitz et al., 2015; Bus et al., 2015; Alade et al., 2016; Huber et al., 2016; Herodotou, 2017). These findings have raised the question of whether similar benefits might also be possible for infants and toddlers. Survey data indicate that although most parents have mixed views about giving toddlers access to mobile media, many acknowledge that tablets and other devices are here to stay and that even these very young children need to become familiar with them and to acquire basic user skills. When asked, about half of them also report that well-designed apps can enable new and independent learning, promote creativity, provide entertainment, and can sooth or distract children when distressed (Nevski and Siibak, 2016; O'Connor and Fotakopoulou, 2016; Radesky et al., 2016; Rideout, 2017; Levine et al., 2019). Some parents also see benefit in using video chat apps to maintain communication with absent family and friends (McClure et al., 2015; Chassiakos et al., 2016).

Consistent with these beliefs and expectations, there is experimental evidence that infants and toddlers can learn to imitate simple actions, recognize new words, and solve certain problems (e.g., object retrievals) from interactive video material including video chat (Zack et al., 2013; Roseberry et al., 2014; Choi and Kirkorian, 2016; Kirkorian et al., 2016; Myers et al., 2017; Strouse and Ganea, 2017b). This is most likely to occur when the content directs their attention to important information, increases engagement, and provides them with a sense of achievement. However, there is also evidence from some of these studies that none of this occurs easily or necessarily transfers to new objects or contexts without responsive and contingent support from an adult who scaffolds the toddler during the activity (see Zack and Barr, 2016; Strouse and Ganea, 2017b; Kirkorian, 2018; Troseth et al., 2018). It is important to note that experimental studies are designed to answer particular research questions about learning from interactive media and researchers develop their own testing materials and protocols for this. The control of content and context that this enables makes it preferable to commercially available material, although generalization to real-world apps and viewing conditions is constrained. However, much of children's exposure to touchscreens at home occurs with commercially available apps, and in varied contexts with or without others. Learning outcomes among children under 3 years using these materials in less controlled conditions is unclear.

Researchers, educators and parents who have expressed concerns about providing touchscreen devices to infants and toddlers point to evidence that children younger than about 3 years have a "transfer deficit." What this means is that they have difficulty generalizing what they learn in one modality (e.g., from a "live" person or a 3D object) to another modality (e.g., a screen or a 2D representation), although this can be ameliorated by adding contingency, responsiveness, and repetition to the learning context (see Choi et al., 2017; Kirkorian, 2018; Barr, 2019). There are other concerns about potentially harmful associations between toddlers' use of touchscreens and certain negative developmental outcomes. These include the disruption of stable sleep patterns (Cheung et al., 2017; Chindamo et al., 2019), poor expressive language (van den Heuvel et al., 2019; but see Taylor et al., 2018), and other more general aspects of healthy development assessed by standardized tests (e.g., motor skill, communication, problem solving, personal-social-emotional behavior) (Chassiakos et al., 2016; Madigan et al., 2019). In contrast to most experimental studies, these correlational and survey data are based largely on commercially available content that children use at home under various conditions.

## Toward Resolving Some Basic Questions

The impact of interactive touchscreen use on learning and development in children under 3-years of age is a complex and evolving story (see Reich et al., 2016; Herodotou, 2017). Evidence from research with older preschoolers indicates that only by considering the conjoint effects of the app or video content, the viewing context, and individual child characteristics will fundamental questions be resolved (Barr and Linebarger, 2017; Blumberg and Brooks, 2017; Kucirkova and Zuckerman, 2017). From this broad research agenda, three basic questions suggested by the literature on children younger than 3 years guided the current study. First, there is little information on just how effectively toddlers can operate an interactive touchscreen device. Observations indicate that they are highly attentive to screens and seem able to tap, drag, and swipe to activate simple features even before they have fully developed fine motor control (Aziz et al., 2014; Ahearne et al., 2015; Hourcade et al., 2015; Nacher and Jaen, 2015; Bedford et al., 2016; Samarakoon et al., 2019; Souto et al., 2020). However, random touching and tapping to produce any interesting effect might developmentally precede deliberate, purposeful activation of an app or feature to achieve a specific goal (Adolph and Franchak, 2017). Second, once toddlers can engage purposefully with touchscreen devices, the next questions concern whether, what, and under what conditions they can learn content from them (see Lovato and Waxman, 2016; Kucirkova and Zuckerman, 2017). Although 2-year-olds can acquire new information from traditional screen media when the content is well designed and age-appropriate and when learning is scaffolded (Kirkorian, 2018; Barr, 2019), there is little evidence on additional benefits or detriments from using the newer interactive devices with toddlers (Reich et al., 2016). Third, as the use of interactive devices can tax toddlers limited cognitive resources (Zack et al., 2013; Fisch, 2017; Russo-Johnson et al., 2017), the maturity of their executive functions might predict device success for any particular child. Executive functions are a set of interrelated cognitive processes (inhibition, working memory, cognitive flexibility) that enables self-regulation of thought, feeling, and behavior in a range of activities (Diamond, 2013). As such, they are relevant to understanding how children operate and learn from interactive devices. Those with more mature executive functions might be better able to adapt to the extra cognitive load, keep more information in mind, sustain their attention to a goal, and resist distraction.

## Overview of the Current Study

The study addressed three basic research questions about toddlers use of, and learning from an interactive tablet device: (1) Can they engage with or operate it purposefully to attain a goal? (2) Can they learn operating skills and content from selected commercially available apps? (3) Do individual differences in their executive functions predict success in using, and learning from the apps? To address the first two questions, a group of 2-year-old toddlers was compared with a group of 3-year-olds on their performance using two different, commercially available apps in the supportive presence of an adult. One app primarily drew upon their visuospatial and motor skill in using a tablet to solve a series of shape matching puzzles over three learning opportunities. The second app required less visuospatial and motor skill but drew primarily on their story comprehension and their retention of information from an electronic storybook. The third question on individual differences was addressed with the Minnesota Executive Function Scale (MEFS) (Carlson and Zelazo, 2014), a tablet-based version of the standard Dimensional Change Card Sort Test (DCCS) of executive functioning.

As each app had its own task, skill, and cognitive requirements, the data from each one was expected to make its own contribution to the literature on the efficacy of toddlers' use of interactive devices. Each app had its own procedure, dependent measures, and plan for analysis as detailed below. The particular shape matching and storybook apps were selected because of the importance of the particular cognitive content that they required. Specifically, in their traditional or concrete formats (e.g., blocks, shape sorters; paper storybooks), there is evidence that both early play and experience with shapes and with shared storybook reading strongly predict spatial and mathematical understanding and emergent literacy, respectively, at school entry and beyond (Mol and Bus, 2011; Verdine et al., 2014a, 2016; Bus et al., 2015; Zosh et al., 2015; Huber et al., 2019; Kucirkova, 2019). As newer digital formats become increasingly available, whether they also provide toddlers with these central foundations for school readiness will become an important question. Moreover, both the shape matching and storybook apps were expected to draw on children's executive functions such as selective attention, working memory and resistance to distraction, demands that could put them at a performance disadvantage on many e-learning tasks (Verdine et al., 2014b; Fisch, 2017; Russo-Johnson et al., 2017). Although advances in executive functioning are related to age, there are individual differences within age that result from various neurobiological, genetic, and social factors (Johansson et al., 2015; Bell and Cuevas, 2016).

Finally, the focus of the study was on the 2-year-olds, as little is known about the efficiency of touchscreen interactions in children this young. The literature that there is suggests that 24 months is about the earliest age that the beginning of purposeful use might be expected. However, this has not been examined using commercially available educational apps. This gap is significant as many apps in the marketplace target toddlers, often with unsubstantiated claims of their potential for learning (Shuler, 2012; Samarakoon et al., 2019). Toddlers may be especially vulnerable as they have more difficulty in learning from screens than from a "live" or a concrete equivalent source. The 3-year-olds, having largely moved beyond the transfer deficit and with more mature fine motor skills, were included as a comparison group against which to benchmark toddlers' performance. Although 3-year-olds should perform better that 2-year-olds on these or most tasks, the age range spans an important transition in the development of screen learning.

# MATERIALS AND METHODS

## Participants

Parents of 2- and 3-year-olds enrolled in local childcare centers were invited to participate in the study and 71 provided consents. Eleven children were excluded because (a) they were unwilling to participate ($n = 7$), (b) technical difficulty during the procedure ($n = 2$), (c) they were outside the target age range ($n = 1$), or (d) had a cognitive impairment ($n = 1$). A total of 60 children (29 boys, 31 girls) comprised the final sample. The mean age was 35.87 months (*SD* = 6.60) and ranged from 26.51 to 46.77 months. Children were divided on a median split (35.37 month) into an older age group (29, 3-year-olds; *M* = 40.92 month, *SD* = 4.82; 13 female) and a younger age group (31, 2-year-olds; *M* = 30.82 month, *SD* = 2.70; 18 female). Most children (*n* = 52, 86.7%) self-reported previous experience with a tablet that they used for "games." Children were from a well-educated sample of parents, of whom 91% had a university degree. Consistent with the local population from which the sample was drawn, 86.7% of them were White European, with the remaining participants of African (6.7%) and Asian (6.6%) heritage. The children in the final sample were typically developing with no known developmental issues.

## Materials and Measures

The shape matching and storybook apps and the MEFS were presented to the participants on an 9.7-inch Apple 3 iPad tablet. A tablet device was selected because it is in most common use among very young children for play and learning, either when alone or with others (Bedford et al., 2016; Rideout, 2017). Although smartphones and other gaming platforms are interactive and share many tablet features, the tablet's larger screen interface make it best suited to toddlers' immature fine motor skill and control (Bedford et al., 2016; Brakke and Pacheco, 2019). The shape matching and storybook apps were selected to examine research questions 1 and 2.

### Shape Matching Materials

A systematic search of relevant websites was conducted to find an age-appropriate, shape matching app that also appeared to meet the criteria for an educational app–active, engaging, meaningful to the user, and interactive (e.g., Hirsh-Pasek et al., 2015; Dore et al., 2019). The final selection was made from the TinyHands series, targeted to 2- and 3-year-olds (see **Figure 1**). The task consisted of a number of shapes, each to be dragged from the perimeter of the display and dropped into its corresponding location on the screen. The shape matching puzzles had three levels of difficulty: Level 1 had two shapes with 18 pieces to be placed, Level 2 had 3 shapes with 16 pieces, and Level 3 had 4 shapes with 13 pieces, for a total of 47 pieces. The pieces in Level 1 were canonical whereas those in Levels 2 and 3 were embedded; familiar items shaped approximately like one of the background shapes (e.g., a Christmas tree that fitted in the triangle location) (see Verdine et al., 2016). When a shape was correctly placed it "faded" onto the background and a brief musical trill was heard. Incorrectly placed pieces elicited a "thump" sound and drifted back to their initial location on the screen. Once all the pieces were placed, a cartoon rocket towing balloons flew across the screen. The child could pop the balloons with repeated finger tap gestures. Although available from the App Store (TinyHands)[1], none of the children reported familiarity with it when asked. In addition to the app, a conceptually similar wooden shape matching puzzle was used as a pre-test to control for each child's level of prior knowledge of common shapes and their skill in fitting each piece into its corresponding location on a board. As shape matching toys are commonly available, some participants might have had more prior experience with them than others. The wooden shape puzzle was an 8 pieces, commercially available toy (Melissa and Doug™, Inc.), age appropriate for toddlers and preschoolers (see **Figure 1**). For both the app and wooden versions of the puzzles, although not directly comparable, children were asked to match a common shape (e.g., circle, triangle) with its corresponding location on a background.

### Storybook Comprehension Materials

Similar considerations went into the selection of the storybook app. In addition, the storybook app had to be available in a print format with near identical images and text so that the two formats could be compared directly. A commercially available storybook available in paper and electronic formats was selected: *Rumble in the Jungle* written by Giles Andreae and illustrated by David Wojtowycz. The book provides a humorous description in verse of the activity of familiar jungle animals as they roam about in the night. It is colorfully illustrated and age appropriate for 2- and 3-year-olds. The two book formats were closely matched in length, text, and illustration (see **Figure 2**). The paper book had 18 pages; the e-book had 12 pages (screens). The two formats presented identical images in composition and number and each story had 377 words of text. The functional page/screen size of the e-book was smaller (8 in × 6 in) than the paper version (11.77 in × 10.5 in) and showed only one page at a time. In addition, the e-book had several multimedia and interactive features per page. Multimedia features included a variety of integrated sounds and animations (background music, highlighted text) that enhanced the narration during reading. The interactive features also provided additional information or options to augment the story (e.g., animal sounds or movements) but also required the child to switch attention away from the narration to activate the feature with a finger tap (see Takacs et al., 2015). None of the interactive features were essential to follow the story narrative and all were consistent with the story content. Children navigated the e-book by tapping an arrow on the screen.

### The Minnesota Executive Function Scale

The MEFS (Reflection Sciences, Inc.) is a tablet-based sorting task modeled on the DCCS (Zelazo, 2006), a widely used test of executive function for preschool children (see **Figure 3**). Performance on the DCCS (and MEFS) provides an index of the cognitive flexibility component of executive function, but also draws on working memory and inhibition components. In the standard version of the DCCS, children sort a series of bivalent test cards (e.g., blue trucks, red flowers) into boxes, first according to one dimension (e.g., color), and then according to the other (e.g., shape). Most 3-year-olds perseverate during the post-switch phase on the standard task, continuing to sort by the initial dimension. By 5 years, most children switch sorting dimensions when instructed to do so. In the MEFS, bivalent stimuli are presented on a tablet screen and children sort virtual cards into virtual boxes with a finger, first according to one dimension (e.g., color) and then the other (e.g., shape). The task has seven levels

[1] tinyhandsapps.com

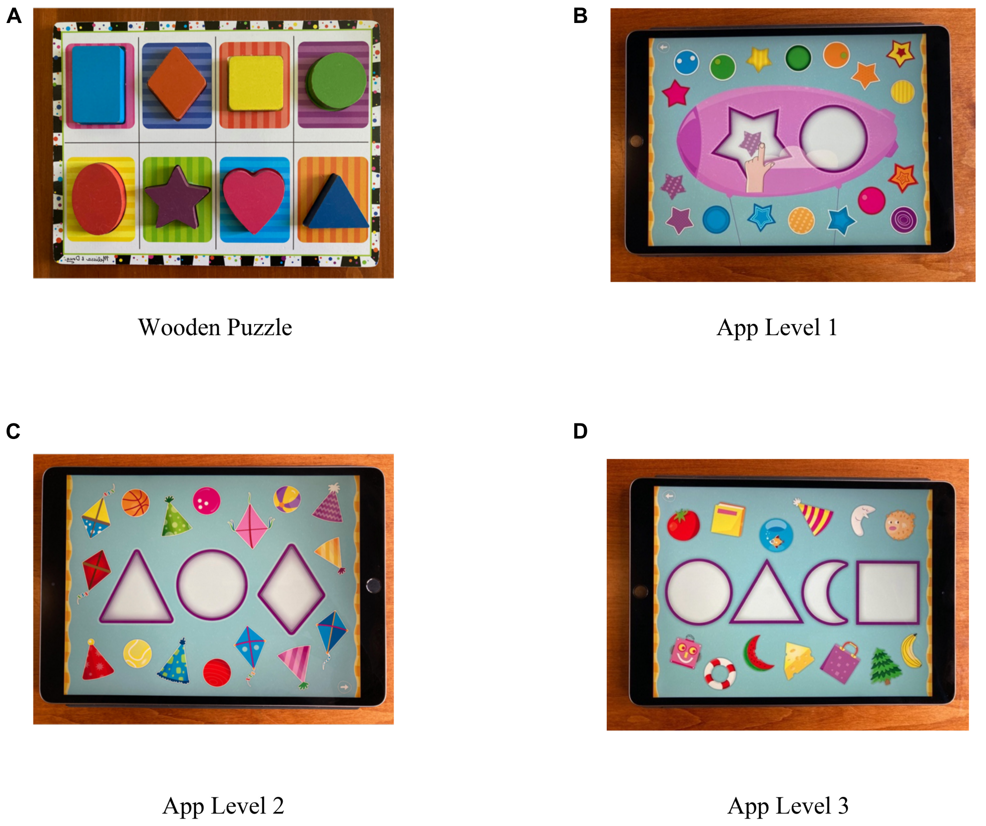


**FIGURE 1 |** Wooden **(A)** and electronic **(B–D)** shape matching puzzles. The wood puzzle is from the *Melissa and Doug Toy Company*, Wilton, CT, United States. The electronic puzzles are apps from TinyHands, tinyhandsapps.com.

of difficulty and takes 4–5 min. If the child cannot drag and drop successfully, but can otherwise indicate the correct box, credit is given for the choice. The reliability and validity of the MEFS for children ages 2–13 years have been reported (Carlson, 2017). The MEFS software algorithm scores and summarizes the data from children's responses and provides a global measure of executive functioning.

## Procedure

Children were pre-tested on the shape matching wooden puzzle on Day 1 followed by a series of three shape matching app puzzles and the storybook reading. The shape matching puzzles were completed again on Days 2 and 3. Every attempt was made to keep the time between the successive days uniform. However, the time between Days 1 and 2 and between Days 2 and 3 ranged from 1 to 3 days ($M$ = 1.52, SD = 0.56; $M$ = 1.47, SD = 0.53, respectively), although this did not differ by age group. Children were tested with the MEFS on Day 2 to ensure that they all had practice in using the tablet. The study took place at the childcare centers in a quiet room with a child-sized table and chairs. They were tested individually with a researcher seated beside them to explain and guide the procedure. The puzzle tasks and storybook reading were video recorded for later off-line coding. The study protocol was approved by the institutional research ethics committee.

### Day 1

After establishing rapport with the child, the researcher explained that they were going to do some puzzles. First, the child was asked to complete the wooden shape matching puzzle. The researcher introduced the task and provided an example (e.g., "The heart piece goes in the heart-shaped spot") and placed the shape. The child was asked to place the remaining seven pieces. Next, the researcher opened the iPad and asked if he or she had ever used a tablet device and for what purpose. At each of the three levels of the shape matching app, the researcher pointed out how many different shapes there were (i.e., two, three, or four, respectively) and provided an example of dragging a shape to its correct location. A "ghost hand" also dragged and dropped a sample "ghost" shape into each location. The child was then asked to place the shapes. They were praised for correct placements and prompted if they were having difficulty (e.g., repeatedly placing the same piece in an incorrect location). Prompting was kept to a minimum and consisted of pointing out the correspondence between the shape and its location, instructing how to drag and drop the shapes, or refocusing the child's attention. Every attempt was made to keep such scaffolding standardized and to use similar wording and tone across children. However, there was of necessity some variation in this in order to adapt to the particular child and situation. The researcher then moved on to Levels 2 and 3 of the shape matching app and followed the same procedure.


**FIGURE 2 |** Electronic **(A)** and paper **(B)** illustrations from *Rumble in the Jungle* written by Giles Andreae and illustrated by David Wojtowycz. London, United Kingdom: Orchard Books, 2009.

The next activity was to read the child a story from either the paper or the electronic storybook. The book format was assigned alternately as children became available for testing with the caveat that there be approximately an equal number of each format in each age and gender group. At the beginning, children were asked whether they had heard the *Rumble in the Jungle* story before but none had. Those assigned to the e-storybook group were then instructed how to use the tablet touch screen and to turn the pages. The adult demonstrated the interactive features and encouraged the child to activate them and to look for others during the reading. The story was presented using the "Read to Me" option that was narrated by software voices but allowed the child to view and turn the pages at will. If the child did not turn the page after about 15 s and did not appear to be engaged, the researcher prompted "Ok, let's turn the page now." If the child was engaged with the features, he or she was allowed to continue for up to 2 min at which time the child was prompted to move on ("Let's see what's next"). The paper book reading followed a similar procedure. The researcher read the story at the same pace as the e-book narration and allowed the child to examine the story illustrations and to turn pages. As with the shape app, scaffolding was kept to a minimum and standardized in wording and tone and but varied somewhat to adapt to the child and the situation. No dialogic prompts were provided. Immediately


**FIGURE 3 |** A 3-year-old boy completes a version of the Minnesota Executive Function Scale. Images show the *Minnesota Executive Function Scale* by Carlson and Zelazo (2014), Saint Paul, MN: Reflection Sciences, LLC. Copyright 2014 by Reflection Sciences, LLC. Reprinted with permission.

after the readings, the child was asked five recognition questions about the story. A series of illustrations from the paper book were photographed and laminated as 4 × 6-inch cards. Each child was shown a subset of 4 cards and asked to identify which card matched a question such as "Which of these animals swings from the trees?" The wording of the questions came directly from the storybook text. The entire testing session took about 35 min.

### Day 2

The researcher repeated the shape matching app instructions and proceeded to guide the child through the three levels as on Day 1. Following this, the researcher administered the MEFS using the standardized protocol (Carlson and Zelazo, 2014). Children began at an age-appropriate level assigned by the MEFS software according to the age information provided, and proceeded to harder or easier levels depending on performance. As seen in **Figure 3**, the screen displayed two boxes showing two different animals with different colored backgrounds. The researcher turned over a card in the middle of the touch screen that matched the boxes by color or by shape and demonstrated the appropriate sorting rule (by color or by animal). The child was given two practice trials with feedback. In Part A, children sorted by the rule used in the practice trials (e.g., shape). If the child correctly sorted 4 of the 5 cards, he or she moved on to Part B and was instructed to sort by the other dimension (e.g., color). If the child didn't pass Part A, or failed to sort correctly on Part B, they moved down one level and continued to move down until they passed a level. If the child passed Part B, he or she moved up to the next level, and continued until a failure. Final scores were calculated using the MEFS software algorithm based on accuracy and reaction times (range = 0–100). The Day 2 procedure took about 30 min.

### Day 3

On day 3, the child once again completed three levels of the shape matching puzzle app. The Day 3 procedure took about 10 min.

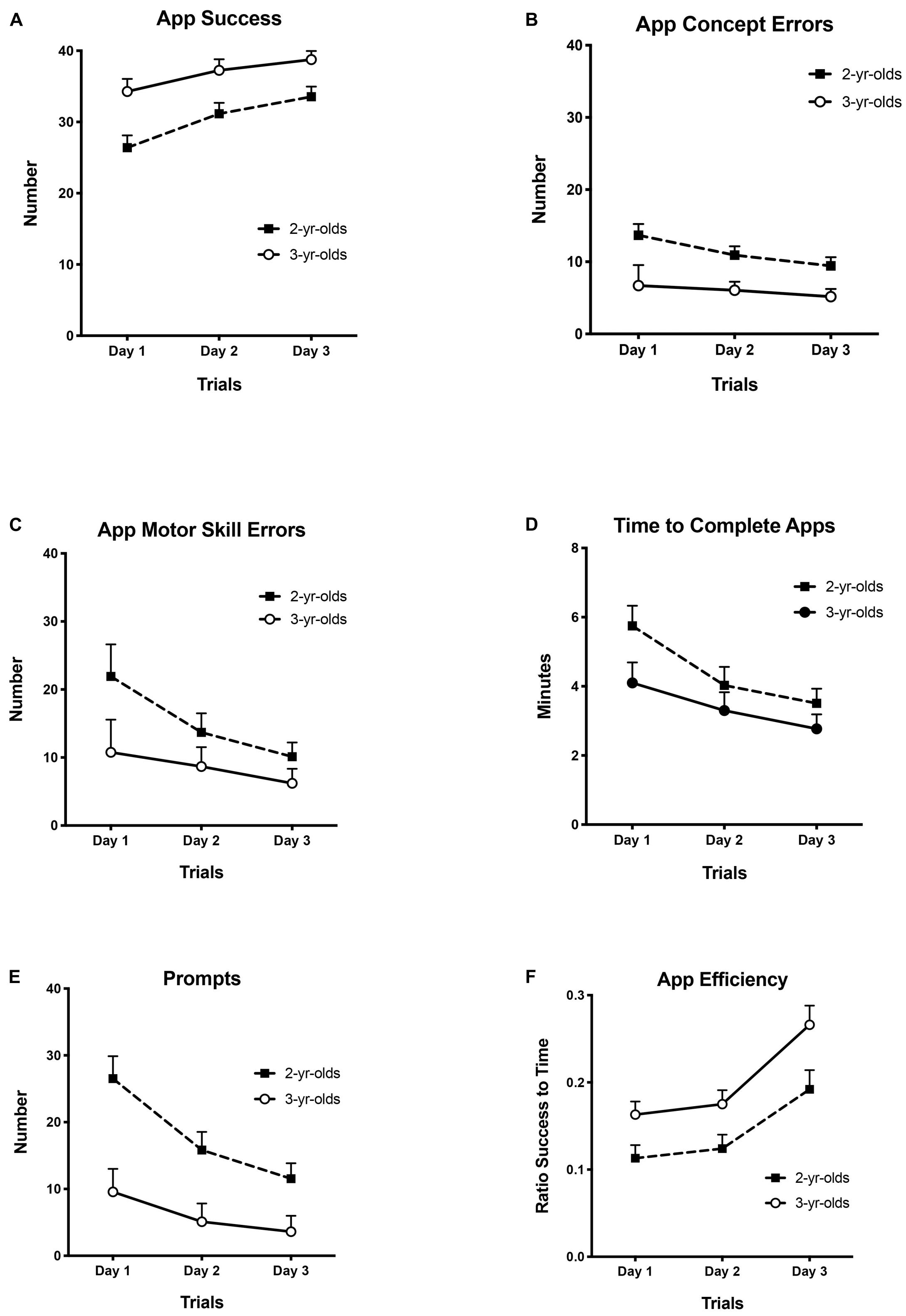


**FIGURE 4 |** Adjusted means and standard errors for shape matching app performance by age and trials: Number of **(A)** successes (max = 47), **(B)** concept errors, **(C)** motor skill errors, **(D)** completion time in minutes, **(E)** number of prompts, and **(F)** efficiency ratio.

## Data Coding

The first two research questions were addressed using tasks presented in app format on a tablet device. Each of the activities had its own dependent measures that were used to infer children's ability to operate the device purposefully to attain a goal and to learn skills and/or content from the app. These were coded for the analyses from the video recordings as follows:

### Gestures and Hand Use

In the digital context, a gesture is any physical movement that can be detected and responded to without the use of a pointing device such as a mouse. When the movement is a touch or a tap, it is referred to as a touch gesture (Saffer, 2009; Villamore et al., 2010). In the current study, the following Touch Gestures adapted from Aziz et al. (2014) were coded from the shape matching and the storybook app data as either present or absent: tap, drag/slide, drag and drop, flick/swipe, double or repeated tap, long press, hit. The data were also coded for children's Manual Interactions with the screen, or the manner in which they used fingers or hands to engage with the target object (e.g., single or multiple fingers). These manual interactions were used to provide a Navigation Skill score, a global measure that reflected the child's control over the app as evident in the strategy used to move the target from its starting position on the screen to the goal. Navigation Skill was coded as (1) low, (2) moderate, or (3) high. A description of these three coding categories can be seen in **Table 1**.

### Shape Matching Puzzle Measures

The primary dependent measures of interest for goal attainment on both wooden and app versions were (1) the number of successful placements of the shapes on the first try, (2) the number of concept and (3) motor skill errors made in placing the shapes, (4) the time to complete each puzzle, (5) puzzle efficiency–the ratio of successes to the completion time, (6) the number of prompts the child received during the puzzle completion, and (7) for the app puzzle only, skill in navigating the pieces around the screen coded from 1 (low) to 3 (high). As the wooden shape puzzle was used as a covariate to control for prior user experience, it was completed only on Day 1. The shape matching puzzle app had three levels of difficulty and these were completed on Days 1, 2, and 3, for a total of nine puzzles with 141 pieces (47 per day) to be placed. For the judged measures 25% of the videos selected at random within each age group and were coded by an independent researcher to establish the reliability of the observations using intra-class correlations. These were calculated for numbers of successes, concept and motor errors, prompts, and for skill in navigating the screen. Intra-class correlations ranged from acceptable to excellent: 0.84 for success, 95% CIs (0.52–0.94); 0.98 for concept errors, 95% CIs (0.96–0.99); 0.97 for motor skill errors, CIs (0.95–0.99); 0.98 for prompts, 95% CIs (0.95–0.99); 0.75 for navigation skill 95% CIs (0.30–0.91). For the analyses, the three app puzzles scores were collapsed across difficulty level each day, yielding a total score for Days 1, 2, and 3 as follows:

#### *Puzzle success*

For the wooden puzzle and for all three levels of the app puzzle, a response was coded as a success only if the child placed a shape in its corresponding correct location on the first try. That is, the child had the conceptual understanding that a particular shape matched a particular location, could see the correspondence between the two, and had the motor or manual skill to place it without difficulty.

#### *Puzzle errors*

Errors in shape placement on both puzzle tasks were coded as either a concept error or as a motor skill error. A *concept error* occurred when the child attempted to fit a particular piece into an incorrect location, indicating that he or she did not appear to see (or forgot) the correspondence between the shape and its location. A *motor skill error* was coded for the wooden puzzle when the child placed a shape at the correct location, but could not orient it to fit. This indicated that the child knew the shape-location correspondence but lacked the motor skill to place it precisely. If the child had to manipulate the shape very slightly to fit it, this was not coded as an error, whereas separate attempts to place the piece incorrectly (i.e., raised it off the wooden background), in either the same or different locations, were coded as separate motor errors. For the app puzzle, a motor skill error occurred whenever the child began to drag the piece forward along an irregular trajectory or dropped it while dragging it to its location, or attempted to "fling" rather than drag it. These were all coded as separate motor skill errors.

#### *Puzzle prompts*

Once the child tried to place a puzzle piece in either the wooden or electronic puzzle, but was making repeated errors or beginning to show reluctance or frustration, the researcher provided a verbal prompt to keep the session moving along and to motivate the child (e.g., "Let's try again," or "Just move the shape gently with one finger" or "You're doing really well") or refocusing his or her attention, (e.g., "Let's try another shape" or "Where does this one go"). Prompts could also include pointing out the correspondence between the puzzle piece and its location (e.g., "What shape is a Christmas tree?" or "Is the soccer ball shape like a circle or a square?"). Only instructive prompts were included in the analyses. An instructive prompt could vary in length, but was directed to assist with the placement of one particular piece.

#### *Puzzle time and efficiency over trials*

The *time* to complete the puzzle was recorded from when the child first tried to place a shape to when the last piece of the particular puzzle was placed in its location. Puzzle *efficiency* was a ratio of the successful puzzle placements to the time it took to complete the puzzle. For the shape matching app, the assumption was that across trials an efficient child would place more pieces successfully and do so in less time.

### Storybook Comprehension Measures

The primary dependent measure was the number of correct recognition questions that the children answered about the contents of the paper and e-storybooks. Either a verbal answer or a point to the correct picture was coded as correct. Other

**TABLE 1 |** Coding scheme for children's touch gestures, manual interactions, and navigational skill when using the shape matching and storybook apps.

| Coded Behavior | Description |
|---|---|
| Active search/look | Scan screen, focus on a target, shift focus to goal |
| [1]**Touch Gestures:** | |
| Tap | Quick up and down motion with a finger; lightly strikes screen |
| Drag or slide | Place finger on target and move in the desired direction without lifting the finger from the screen |
| Drag-and-drop | Place finger on target and move in the desired direction without lifting finger from screen then drop target at the goal |
| Repeat or double tap | Several quick taps in succession on screen |
| Long press | Touch and hold the target with finger motionless until an action occurs |
| Swipe or flick | Place finger(s) on screen and quickly flick target in the desired direction |
| Hit | Quick single slap on the screen with the hand |
| [2]**Manual Interactions:** | |
| Full or both hands | Uses full or both hands or palm; hit or slap screen to move or activate target |
| Multiple fingers, thumb | Uses multiple fingers or thumb to move target; grasp as if to pick up target |
| Single finger | Uses forefinger to move target |
| [3]**Navigation Skill:** | |
| Low (1) | Mixed use of the full hand, palm or heel of the hand, multiple fingers, or thumb to move target to goal; frequent drops |
| Moderate (2) | Mixed use of single and multiple fingers or thumb to move target to goal; less frequent drops |
| High (3) | Almost exclusive use of forefinger to move target to goal; infrequent drops |

*[1] Touch Gesture: an action of the fingers or hand directed to a target object on the screen.*
*[2] Manual Interaction: how the child uses the fingers or hands to engage with the target.*
*[3] Navigation: the strategy used to get the target from its starting position to the goal.*

measures of interest were the number of distractions during each reading and the time taken to complete each book reading. A distraction was coded when the child looked off-task away from the book or made a comment that was not related to the story (e.g., "I hear them playing"). A "look" was counted each time the child's gaze was directed off task, regardless of its length (Lauricella et al., 2015). As with the shape matching puzzle, 25% of the videos were scored for the frequency of off-task distractions, intra-class correlation was 0.96 for looks off-task, 95% CIs (0.94–0.97). Looks toward the adult were not considered a distraction as such social referencing is a typical part of a storybook reading interaction with young children (Richter and Courage, 2017). The time to complete the story was measured from the reading of the title page to the end of the last page.

### Executive Functioning (MEFS)

All coding was done by the software provided with the testing materials and license. Measures provided were the Baseline level–selected by the program based on the child's age information; the Highest Level Passed–the last level where the child passed both parts A and B of the test; Ceiling Level–the highest level where the child fails either Part A or B; national norms in standard scores and percentiles, and an RT-Adjusted scores (0–100) based on an algorithm that takes both response accuracy and reaction time into account. Only the RT-Adjusted scores (i.e., MEFS total scores) were used in the analyses here.

## RESULTS

Consistent with the inclusion of two different app activities–shape matching and an e-storybook–the two data sets were independently analyzed and are reported sequentially below.

## Gestures and Hand Use

Examination of the video data revealed that, with adult support 100% of the children were able to actively search the screen array and produce the basic touch gestures (search/look, tap, slide, drag-and-drop) needed to engage with and solve the shape matching app puzzles. However, non-essential gestures, swipe/flick, hit, repeated tap, grasp, were also observed in 58.06, 19.35, 9.67, and 3.22%, respectively, of the toddlers. These non-essential gestures were rare in the older children; 20.69% showed swipe and 0% for hit, repeated tap or grasp. Observation of toddlers' manual interactions showed that 70.97% used multiple fingers and 38.72% used their full hand to move the shapes. Among 3-year-olds, 24.33% used multiple fingers and none used the full hand. Consistent with this was children's improvement in navigation skill rated from (1) low, to (2) moderate, to (3) high over the 3 days. A non-parametric Friedman Test of differences among repeated measures was conducted for each age group and the results yielded significant Chi-square values for both groups $\chi^2(2) = 27.11$, $p < 0.001$; $\chi^2(2) = 14.00$, $p = 0.001$, respectively. Wilcoxon Signed Rank follow up tests within each age group indicated that 2-year-olds' navigation skill increased incrementally over the three trials; from Days 1 to 2 and from Day 2 to 3: $Zs(31) = -3.00$, $p = 0.003$ and $-3.32$, $p < 0.001$. The 3-year-olds improvement was significant between Day 1 and 2: $Zs(29) = -2.828$, $p = 0.005$ but stabilized after that: $Zs(29) = -1.342$, $p = 0.180$.

## Shape Matching Activities

### Wooden Puzzle

Both age groups performed well on the wooden puzzle pre-test with the 3-year-olds making 94.43% correct placements on Day 1 and the 2-year-olds with 85.43% correct placements (see

**Table 2**). A series of independent sample $t$-tests showed that the older children had significantly more successes out of the 7 pieces than did the younger children, $t(58) = 2.50$, $p = 0.015$, $d = 0.62$. They made significantly fewer concept $t(58) = 2.92$, $p = 0.005$, $d = 0.71$ and motor skill $t(58) = 2.40$, $p = 0.002$, $d = 0.78$ errors, required fewer prompts $t(58) = 3.85$, $p = 0.001$, $d = 0.90$, had faster completion times $t(58) = 4.27$, $p < 0.001$, $d = 0.95$, and greater efficiency scores $t(57) = 4.43$, $p < 0.001$, $d = 0.91$ than did the younger children.

## App Puzzle

A series of 2 × 3 [Age Group (2 and 3 years) × Trials (Days 1, 2, 3)] repeated measures analyses of co-variance (ANCOVA) were conducted on the six primary dependent variables of interest. As with the wooden puzzle, these were: successful placement, concept errors, motor skill errors, completion times, puzzle efficiency, and the number of prompts provided by the adult. Age group (2 and 3 years) was a between-subjects variable and trials (Days 1, 2, 3) was within subject. To control for children's previous experience with shape puzzle toys at home, their pre-test performance on the comparable baseline wood puzzle measure was the covariate in each of the ANCOVAs. Where outcome variable distributions were skewed (concept errors, motor errors, completion times, adult prompts), normalization was achieved with log10 transformations of the data. Bonferroni corrections were used to adjust for the number of comparisons in all of the analyses. The effect of gender was assessed with an ANCOVA for the six measures of interest and was not significant in any case ($p$-values for the models ranged from 0.211 to 0.901). Therefore, the data were collapsed across gender in the main analyses. The adjusted means and standard errors for the six outcome measures on the shape app over trials are shown in **Figure 4**.

### *App success*

The dependent measure was the total number of shapes out of a maximum of 47 that children placed correctly on the first try on each of the three successive days. The results of the ANCOVA showed that the covariate was not significant: $F(1, 56) = 2.39$, $p = 0.127$. There was a significant main effect of age $F(1, 56) = 8.84$, $p = 0.004$, $\eta^2 = 0.136$, that reflected the fact that the older group had more successful placements than did the younger group There was also a significant main effect of trials $F(2,112) = 4.79$, $p = 0.010$, $\eta^2 = 0.079$. *Post hoc* pair-wise comparisons indicated that children's performance improved significantly across trials; there were more successes on Day 3 than on Day 2 ($p = 0.001$) and more on Day 2 than on Day 1 ($p < 0.001$). Successes on Days 3 and 1 also differed significantly ($p < 0.001$) (see **Figure 4A**).

**TABLE 2** | Means and standard deviations of children's performance on the wooden puzzle pre-test by age and variable.

| Age | Measure | Success | Concept Errors | Motor Errors | Prompts | Time (sec) |
|---|---|---|---|---|---|---|
| 2 years | M | 5.98 | 1.35 | 1.29 | 2.19 | 59.61 |
| | SD | 1.21 | 1.84 | 1.34 | 2.98 | 29.74 |
| 3 years | M | 6.61 | 0.41 | 0.42 | 0.59 | 34.66 |
| | SD | 0.66 | 0.68 | 0.62 | 0.98 | 10.74 |

*Maximum score = 7 as one piece was used to demonstrate.*

### *App concept errors*

The dependent measure was the total number of first incorrect shape placements made on each day. The ANCOVA showed that the covariate was not significant $F(1, 56) = 0.962$, $p = 0.333$. There were significant main effects of age $F(1, 56) = 9.14$, $p = 0.004$, $\eta^2 = 0.191$ and trials $F(2, 112) = 8.59$, $p < 0.001$, $\eta^2 = 0.177$. *Post hoc* pairwise comparisons indicated that although, older children made significantly fewer concept errors than did younger children, both age groups decreased the number of errors they made on the app puzzle from Days 1 to 2 ($p = 0.007$) and from Days 1 to 3 ($p = 0.001$) but showed no further decrease from Days 2 to 3 ($p = 0.072$) (see **Figure 4B**).

### *App motor skill errors*

The dependent measure was the number of incorrect shape placements made because of a motor skill error on each of the three successive days. The ANCOVA showed that the covariate was significant: $F(1, 55) = 6.22$, $p \leq 0.001$,$\eta^2 = 0.102$, meaning that prior experience reflected in the wooden puzzle pre-test had a significant effect on app motor errors. There was also a significant main effect of trials $F(2, 110) = 20.37$, $p < 0.001$, $\eta^2 = 0.270$, showing that in general, children made fewer errors across trials. This main effect was qualified by a significant Trials × Age interaction $F(2, 110) = 3.55$, $p = 0.032$, $\eta^2 = 0.061$. *Post hoc* independent sample $t$ tests indicated that although the older children made significantly fewer motor errors than did the younger children on both Day 1, $t(57) = 2.20$, $p = 0.032$; $d = 0.55$; and on Day 2, $t(57) = 2.29$, $p = 0.025$, $d = 0.58$, by Day 3, there was no significant difference between the two ages $t(57) = 1.77$, $p = 0.084$ (see **Figure 4C**).

### *App times*

The dependent measure was the total amount of time that children took to complete the app puzzles on each of the 3 days. The results of the ANCOVA showed that the covariate was significant: $F(1, 56) = 19.86$, $p \leq 0.001$, $\eta^2 = 0.262$, meaning that prior experience with the wooden puzzle pre-test had a significant effect on app completion time. There was a significant main effect of age $F(1, 56) = 4.33$, $p = 0.042$, $\eta^2 = 0.072$, as older children took significantly less time to complete the app puzzles than did the younger children. There was no significant main effect or interaction involving trials $F(2, 112) = 1.61$, $p = 0.204$; $F(2, 112) = 1.03$, $p = 0.360$, respectively. However, examination of the adjusted means indicated a systematic decrease in time to complete the app across the three trials in both age groups (2 year-olds: $M$s = 5.75 min, 4.03 min, and 3.51 min, respectively; 3-year-olds: $M$s = 4.10 min, 3.30 min, and 2.77 min, respectively). Consistent with this, if the planned pairwise comparisons are considered, they further supported the prediction that completion times decreased markedly across days; longer on Day 1 than on Day 2 ($p < 0.001$), and longer on Day 2 than Day 3 ($p = 0.001$). Days 1 and 3 also differed significantly ($p \leq 0.001$). See **Figure 4D**.

### Prompts during app use

The dependent measure was the total number of prompts provided by the researcher during the app puzzles on each day. The ANCOVA showed that the covariate was not significant $F(1, 56) = 3.10$, $p = 0.084$. There were significant main effects of age $F(1, 56) = 10.19$, $p = 0.002$, $\eta^2 = 0.154$ and trials $F(2, 112) = 16.19$, $p < 0.001$, $\eta^2 = 0.224$. *Post hoc* pairwise comparisons indicated that although older children needed significantly fewer prompts than did younger children, both age groups were given significantly fewer prompts across successive days, Days 1 to 2 ($p < 0.001$) and Days 2 to 3 ($p < 0.001$). Day 1 also differed significantly from Day 3 ($p < 0.001$) (see **Figure 4E**).

### App efficiency

The measure was a ratio of the successful placements to the time taken to complete the puzzles on each of the three successive days. The ANCOVA showed that the covariate was significant: $F(1, 56) = 13.60$, $p = 0.001$. There were also significant main effects of age $F(1, 56) = 5.58$, $p = 0.022$, $\eta^2 = 0.091$, and trials $F(2, 112) = 7.24$, $p = 0.001$, $\eta^2 = 0.114$. *Post hoc* pairwise comparisons showed that apart from the older children being significantly more efficient on the app puzzle than were the younger children, both ages became increasingly efficient across trials from Days 1 to 2 ($p < 0.001$) and from Days 2 to 3 ($p < 0.001$) Days 1 and 3 also differed significantly ($p < 0.001$) (see **Figure 4F**).

In sum, both age groups of children showed goal-directed performance with the shape matching app puzzles and improved their performance over the three days of testing. Older children generally performed better than the younger children; they had higher success scores, made fewer conceptual and motor skill errors, were faster and more efficient using the app, and required fewer prompts from the adult. Moreover, on all 3 days, there was significant negative Pearson *r* correlations between app success scores and both conceptual and motor skill error scores, *r*s(59) ranged from −0.552 to −0.763, all $p < 0.001$.

## Storybook Comprehension

The e-book app made little demand on children's motor skill beyond simple active looking or search and tap gestures. All children were able to do this to turn the pages and to seek out and activate the interactive features. To evaluate children's retention of story content, a 2 × 3 [Age Group (2 and 3 years) × Book Format (electronic, paper bound)] analysis of variance (ANOVA) was conducted on the recognition of story information data. The results showed a significant main effect of age $F(1, 56) = 32.74$, $p < 0.001$, $\eta^2 = 0.369$, indicating that the 3-year-olds had higher recognition scores than did the 2-year-olds. There was also a significant main effect of book format $F(1, 56) = 7.44$, $p = 0.008$, $\eta^2 = 0.117$. Children recognized more information from the e-book than the paper book. The means and standard deviations for each age and book format are shown in **Figure 5** and reflect the fact that the 2-year-olds recognized more of the story content items following the e-book ($M = 2.65$, SD = 1.27) than the paper book ($M = 1.64$, SD = 1.00), as did the 3-year-olds ($M = 4.36$, SD = 1.03; $M = 3.61$, SD = 1.41), respectively.

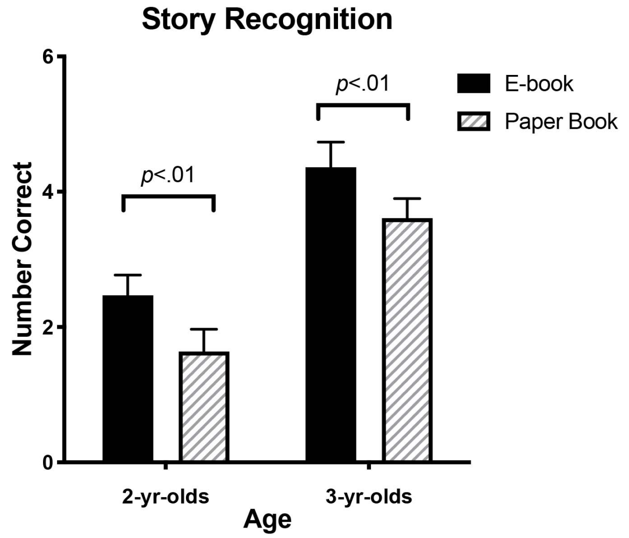


**FIGURE 5 |** Means and standard errors for children's recognition memory scores by age and book format.

The e-book took significantly longer to complete than did the paper book for both age groups. For the 2-year-olds: e-book $M = 7.39$ min, SD = 1.72; paper book $M = 5.55$ min, SD = 1.67; $t(28) = 3.31$, $p = 0.003$, $d = 0.71$. For the 3-year-olds: e-book $M = 5.97$ min, SD = 0.71; paper book $M = 5.25$ min, SD = 0.98; $t(27) = 2.10$, $p = 0.046$, $d = 0.48$. Moreover, the children were more attentive to the e-book than to the paper book, as reflected in the lower number of distractions (i.e., looks away from the book or off-task comments) they showed during the readings. These data were analyzed in a 2 × 2 (Age Group [2 and 3 years] × Book Format [electronic, paper] analysis of variance (ANOVA). The results indicated only a significant main effect of book format $F(1, 57) = 6.44$, $p = 0.014$, $\eta^2 = 0.113$. Children at both ages in the paper book condition were more distracted off task during the readings than were those in the e-book condition e-book $M = 4.89$, SD = 5.63; paper book $M = 8.90$, SD = 7.59. Consistent with this, children were highly engaged in using the interactive features of the e-book, although a direct comparison with the paper book was not possible. Overall, they frequently activated the features ($M = 27.89$, SD = 16.23 times; range from 7 to 78) during the e-book reading. There was no age difference (2 year: $M = 28.82$, SD = 14.24; 3 year: $M = 26.30$, SD = 19.90) in the number of activations $t(25) = 0.384$, $p = 0.704$.

## Executive Functions

The role of children's executive functioning in their successful performance on the two tablet-based tasks was assessed with separate multiple regression analyses of those data. The outcome measure of executive functioning was the RT-Adjusted score as calculated from the MEFS software. Preliminary evaluation of the assumptions underlying the use of regression (adequate sample size, normality of the outcome variable distribution, multi-co-linearity, outliers, and linearity) were found to have been met.

### Shape Matching App

To examine the role of children's executive functioning and age on their total puzzle success score summed across the 3 days on the shape matching app, a hierarchical linear regression was conducted. Children's age in months and their MEFS total scores were the predictors in the analysis of their cumulative puzzle success summed across the 3 days. Success on the wooden puzzle pre-test was the control variable and was entered into Block 1 of the regression. This model was significant $F(1,51) = 5.48$, $p = 0.023$ and explained 9.7% of the variance in the app puzzle success data. With age in months and executive functioning entered as predictors in Block 2, the total variance explained by the model as a whole increased to 47.2%. The inclusion of those predictor variables explained an additional 37.5% of the variance in cumulative success after controlling for puzzle pre-test success, $R^2$ Change = 0.375, $F(2,49) = 17.37$; $p < 0.001$. In the final adjusted model, MEFS made a unique and significant contribution, $t(49) = 3.54$, $p < 0.001$, $\beta = 0.488$ whereas age in months did not, $t(49) = 1.27$, $p = 0.205$, $\beta = 0.180$ (see **Table 3**). In sum, with puzzle pre-test success controlled, results of the regression indicated that the maturity of children's executive functions was a better predictors of puzzle app success than was age alone.

### Storybook App

To examine the role of children's executive functioning, book format, and age in months on their total story recognition scores, a hierarchical linear regression was conducted. A book format × executive functioning interaction term was also computed. Children's age in months, their book format assignment, and their MEFS total scores were the predictors of recognition and entered into Block 1 of the regression. The model was significant $F(3,52) = 14.99$, $p < 0.001$ and explained 47.9% ($R^2$ = 47.9%) of the variance in the recognition data. The addition of a book format × executive functioning (MEFS) interaction into Block 2 did not add significantly to the total variance explained by the model as a whole, $R^2$ Change = 0.001, $F(1,48) = 0.052$; $p = 0.821$. In the final adjusted model, age made the largest unique and significant contribution, $t(49) = 2.65$, $p = 0.011$, $\beta = 0.375$. Total MEFS score also made a unique, significant contribution to the model $t(49) = 2.58$, $p = 0.013$, $\beta = 0.360$, as did book format $t(49) = 2.32$, $p = 0.024$, $\beta = 0.248$ (see **Table 4**). In sum, children's increasing age and executive function maturity and their storybook assignment to the e-book condition all contributing to successful recognition.

**TABLE 3 |** Hierarchical regression analysis for the variables predicting successful shape matching app placements as entered into Model 1 and Model 2.

| Model | Variable | B | SE B | Beta | *T* | *p* |
|---|---|---|---|---|---|---|
| 1 | Wood Puzzle success | 5.75 | 2.46 | 0.31 | 2.34 | 0.023* |
| 2 | Age (months) | 0.67 | 0.53 | 0.18 | 1.29 | 0.203 |
| | Wood puzzle success | 3.87 | 1.96 | 0.21 | 1.97 | 0.054 |
| | Total MEFS | 0.828 | 0.23 | 0.49 | 3.54 | 0.001** |

*p < 0.05*. p < 0.01**.*

**TABLE 4 |** Hierarchical regression analysis for the variables predicting recognition of the storybook app content as entered into Model 1 and Model 2.

| Model | Variable | B | SE B | Beta | *t* | *p* |
|---|---|---|---|---|---|---|
| 1 | Book format | 0.77 | 0.33 | 0.25 | 2.32 | 0.024* |
| | Age (months) | 0.09 | 0.03 | 0.38 | 2.65 | 0.011* |
| | MEFS | 0.04 | 0.02 | 0.36 | 2.58 | 0.013* |
| 2 | Book format | 0.75 | 0.33 | 0.25 | 2.29 | 0.026* |
| | Age (months) | 0.09 | 0.04 | 0.37 | 2.57 | 0.013* |
| | MEFS | 0.04 | 0.02 | 0.39 | 2.14 | 0.037* |
| | Book × MEFS | −0.01 | 0.02 | −0.03 | −0.24 | 0.821 |

*p < 0.05*.*

## DISCUSSION

Consistent with data from many countries around the world, almost 90% of the 2- and 3-year-olds in this study reported having previously used a tablet device. As the software developed for these devices is designed to be compelling, engaging, and can be matched to the skills and interest of the individual child, they have the potential to support and even enhance learning when used with appropriate content and adult oversight. Given the many empirical questions that remain to be answered about this possibility, the purpose of the current study was to address three basic questions: First, can toddlers operate a touchscreen device purposefully to attain a goal? Second, can they acquire operating skills and learn content from age-appropriate apps? Third, do individual differences in their executive functions predict success in using, and learning from the apps? Accordingly, a group of 2-year-old toddlers was compared with a group of 3-year-olds as they used an Apple iPad 3 to interact with two commercially available apps with different task and cognitive requirements–a shape matching puzzle and an e-storybook. Although the limited literature on how toddlers actually use tablet devices made the study exploratory, the expectation based on their attention to, and learning from traditional television and video content was that in the supportive presence of an adult, they would engage with both of the apps purposefully and acquire new skills and content, but that the maturity of their executive functioning would predict their success. The 3-year-olds were included as a standard against which to compare the toddlers' performance. As children over 3 years have largely resolved the transfer deficit, have more mature executive and cognitive functions and better fine motor control, they were expected to outperform the toddlers on all measures.

Concerning the first research question, most of the toddlers were able to use both of the apps purposefully, although their performance was below ceiling on both, with 70.64% successful placements out of 47 shapes on Day 3 and 53.0% correct recognitions out of five questions on the e-storybook. All had the basic search/look, tap, drag/slide, and drag-and-drop gestures in their repertoire and used them on at least some of the nine shape matching puzzles and on the e-storybook. Of these, drag-and-drop was the most challenging and accounted for numerous motor skill errors on the shape matching app as children tried to navigate the pieces to the intended location. The most effective strategy was to use a forefinger to lightly drag the shape directly toward the corresponding location and then drop it. Less effective strategies included using a thumb, several fingers, or the whole hand to move the piece. Others were pressing too firmly on the shape to be moved which slowed it down, tapping the piece repeatedly, trying to grasp it as if to pick it up, or using a forefinger to initiate movement but then “swiping” or “flinging” the piece toward its location. Most older children adopted the forefinger strategy soon after being instructed to do so. Their most frequent error was to drop a shape before reaching the target location, causing it to drift back to its starting point. The younger children more often used the less effective gestures and manual interactions even when instructed otherwise.

Comparable gestural, manual, and navigational skills have been reported in the few other studies that included toddlers (Aziz et al., 2014; Ahearne et al., 2015; Hourcade et al., 2015; Nacher and Jaen, 2015; Samarakoon et al., 2019). Some included the more difficult gestures for toddlers to execute such as drag-and-drop, but also free rotate and pinch and stretch to resize. Typically, 2- and even some 3-year-olds struggled with these with only about 30–60% achieving success. As the shape matching and e-book apps in the current study were selected to be both age appropriate and educational, they did not require these more difficult gestures beyond drag-and-drop. An important point to be taken from this is that when designing apps for toddlers, it is critical to incorporate only those gestures that they can readily produce to control the app and master the task. One contribution of the results reported here is the identification of a suite of touch gestures that can be used in any app to enhance learning, without including more difficult gestures that might drain toddlers' cognitive resources and diminish task performance.

Concerning the second research question, even the youngest children showed more precise manual interactions with practice, increasing their reliance on single-finger use with less use of the full hand and/or multiple fingers. This was apparent in their improved navigational skill in moving the pieces about the screen over the 3 days. Coincident with this, toddlers improved their shape matching outcomes across the three learning opportunities, even when their prior experience with shape puzzles was controlled. They increased their successful first placements by 15.89% and decreased the number of first concept and motor skill errors by 41.27 and 53.94%, respectively. The reduction in concept errors was notable as it indicated that children improved their shape identification and visuospatial matching along with motor and navigation skill over the same period. They also took 39.68% less time to complete the shape matching puzzles and received 56.49% fewer prompts. Their growing proficiency was also evident in their increased success/time ratios by 41.56%; making more successful placements in less time. These abilities are generally consistent with observational and survey data in which toddlers' have been rated as showing at least a “moderate” level of skill on the basic touch gestures, that with advances in fine motor control and experience, became better articulated and deployed (Aziz et al., 2014; Ahearne et al., 2015; Cristia and Seidl, 2015; Hourcade et al., 2015; Bedford et al., 2016). The older children also improved significantly on all measures across the 3 days, though not so markedly as the toddlers. They showed increased success and efficiency by 9.1 and 41.15%, respectively; and decreases in concept and motor errors, prompts, and completion times of 23.69, 42.19, 62.17, and 33.68%, respectively. Interestingly, apart from the motor skill measure, there were no interactions of age and trials. Both age groups improved at the same rate across trials and practice or experience did not differentially affect toddlers and the older children. The interpretation of the interaction with motor skills is unclear.

In contrast, the e-storybook task made less demand on children's fine motor or navigational skill than did the shape matching task. Although they did have to search to find the features and tap to activate them and to move through the e-book, these are the earliest and simplest gestures to appear in toddlers' repertoire (Aziz et al., 2014; Hourcade et al., 2015). Children had little difficulty with this as they explored and activated the features of interest about 28 times in the 7.39-min reading. The most important finding was that toddlers recognized more of the story content from the e-storybook than from the matched paper book. They were also more attentive (i.e., showed fewer distracted looks off task) during the e-book, though it took significantly longer to finish than did the paper book. This additional time might have been related to children's engagement with the e-book features. It might also have provided children with more time to process the story details and enabled better content recognition. As there are few studies comparing toddlers' learning from e-books and paper books, especially those with commercially available content, these results should be interpreted with caution pending replication (but see Strouse and Ganea, 2017a,b). Stories with a more traditional narrative structure, with more numerous or story irrelevant features, dialogic adult scaffolding, or those in which different or additional measures of retention are included (e.g., recall, story retelling or sequencing) might provide different results (Reich et al., 2016). Indeed, studies comparing book formats in older preschoolers have shown mixed results (Bus et al., 2015). Although a common finding is that they are more engaged in e-books, there is little evidence that they are consistently superior to traditional paper books for learning (Parish-Morris et al., 2013; Richter and Courage, 2017; O'Toole and Kannass, 2018). What the results reported here do indicate is that toddlers are very attentive to e-book stories and can engage with the app affordances as they listen to, and retain at least some of the story information.

Concerning the third research question, the results showed that children's executive functions as assessed by the MEFS were a significant predictor of their success on the respective outcome measures of the shape matching and storybook apps. This is consistent with existing studies in which executive functioning has been shown to predict aspects of emergent literacy, math performance, spatial knowledge, and school achievement from measures in children as young as 2 years (Verdine et al., 2014b; De Franchis et al., 2017; Mulder et al., 2017; Purpura et al., 2017). In any learning context, children with stronger executive functions would predictably have more working memory capacity to attend to several streams of information at once, to focus and shift attention to the important elements of the task, and to inhibit distraction from extraneous sources (Blair and Razza, 2007; Fisch, 2017). As using touchscreen devices can be effortful (e.g., Zack et al., 2013; Fisch, 2017; Russo-Johnson et al., 2017), a child with stronger executive functions might have a performance advantage when using these devices to achieve a goal. Considering the shape matching app, children had to coordinate the motor skills required to navigate the pieces around the screen while keeping in mind the goal of finding the corresponding locations and then dropping the pieces. Similarly, using the interactive features of the e-book required children to switch attention away from the narration to search for and activate the feature with a tap and then reengage with the narration.

Finally, it is important to note that the children engaged in both of the app activities in the presence of an adult who guided their performance and kept their attention focused on the task. This scaffolding has been critical to toddlers' successful learning from traditional, non-interactive screen media (see Barr, 2019) and is likely also the case for interactive devices (Samarakoon et al., 2019). Though not tested in the current study, Walter-Laager et al. (2016) found that 23- to 31-month-old toddlers who used a word-learning app scaffolded by an adult, had a larger vocabulary gain than those who used the app alone. Interestingly, some apps and e-books now contain built-in software features designed to simulate adult scaffolding (Bus et al., 2015). These include definitions, prompts, feedback, dialogic questions, pointing, and non-social contingent instructions (e.g., a "ghost" demonstration). Although some have been effective for older preschoolers (Takacs et al., 2014; Kwok et al., 2016; Strouse and Ganea, 2016), there is evidence that they are not as effective for toddlers as is having social contingency provided in person, especially if the problem is complex and likely to tax their cognitive resources (Moser et al., 2015; Zimmerman et al., 2017; Antrilli and Wang, 2018). A related concern is the broader issue of the impact of reduced or altered parent-child interactions when joint play or learning activities are in electronic format (Wooldridge and Shapka, 2012; Parish-Morris et al., 2013; Zosh et al., 2015; Verdine et al., 2016; Munzer et al., 2019). This will be a question for future research as more apps are designed for solitary play and learning (Takacs et al., 2014; Kucirkova and Zuckerman, 2017).

### Limitations to the Study

Although the results of the research cautiously support the appropriate use of well-designed apps for toddlers, there were several limitations to the study. First, the children comprised a convenience sample who happened to be from well-educated families in which most parents had at least one university degree. Whether the findings would generalize to children from a different demographic remains unclear. Second, the study took place in the children's childcare centers where they participated in the activities with an unfamiliar adult. Although they were attentive and cooperative, they rarely engaged the adult in conversation. As parent-child conversation supports learning during traditional shared reading and shape skill activities at home, the more formal research context did not reflect a typical learning interaction. Third, the sole measure of retention for the storybook activity was a picture recognition test. Although a recognition score can be inflated, it may be a more sensitive reflection of toddlers' retention than the more rigorous, standard measure of recall that would likely underestimate performance in children whose language production is immature. Finally, the story reading activity in both formats took place only once. Repeated opportunities such as children likely experience at home might have been more informative than a single trial.

## CONCLUSION

This study was among the first to show that children as young as 2-years of age were enthusiastic and attentive to an interactive touchscreen device and could learn to operate it purposefully to achieve a goal or to enhance a story. Importantly, the study also showed that those with more mature executive functions were particularly skilled using the apps as were a comparison group of 3-year-olds. The results add to a growing literature on the cognitive contents and skills (e.g., visuospatial, narrative, navigational) that toddlers can acquire from commercially available apps such as those they might have access to at home. This is important as the choice and availability of apps for toddlers that have educational content based on the science of learning (Hirsh-Pasek et al., 2015; Dore et al., 2019) will only increase. Some questions for future research include: (1) the logistics of app design that is age-appropriate and optimized for simple and intuitive use by toddlers as they explore the cognitive contents embedded in the material, (2) the nature of scaffolding that will best support and focus the user's attention while fostering the learning independence that is inherent in a well-designed app, and (3) the transfer of skills and content learned in electronic formats to real-world examples. Finally, although apps will unlikely replace traditional shape skill toys or paper storybooks any time soon, the evidence to date suggests that they might prove to be a valuable addition to the toolbox of activities including, children's spatial understanding and story comprehension more broadly. As such, they will continue to provide an alternative way to motivate, entertain, and instruct young children that will complement the traditional formats and could have implications for app design and policy development.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Committee on Ethics in Human

Research. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

## AUTHOR CONTRIBUTIONS

MC designed and supervised the study and data analysis and wrote the manuscript. LF, CW, and MS assisted in planning the study, recruited and tested participants, and organized the data. All authors contributed to the article and approved the submitted version.

## FUNDING

This research was supported by a grant from the Natural Sciences and Engineering Research Council of Canada (418206) to MC.

## REFERENCES


Adolph, K. E., and Franchak, J. M. (2017). The development of motor behavior. *Wiley Interdiscipl. Rev. Cogn. Sci.* 8, 1–2. doi: 10.1016/j.infbeh.2006.11.005

Ahearne, C., Dilworth, S., Rollings, R., Livingstone, V., and Murray, D. (2015). Touch-screen technology usage in toddlers. *Arch. Dis. Child.* 101, 181–183. doi: 10.1136/archdischild-2015-309278

Alade, F., Lauricella, A. R., Beaudoin-Ryan, L., and Wartella, E. (2016). Measuring with murray: touchscreen technology and preschoolers STEM learning. *Comp. Hum. Behav.* 62, 433–441. doi: 10.1016/j.chb.2016.03.080

Antrilli, N. K., and Wang, S. (2018). Toddlers on touchscreens: immediate effects of gaming and physical activity on cognitive flexibility of 2.5-year-olds in the US. *J. Child. Media* 12, 496–513.

Aziz, N., Sin, N., Batmaz, F., Stone, R., and Chung, P. (2014). Selection of touch gestures for children's applications: repeated experiment to increase reliability. *Int. J. Adv. Comp. Sci. Appl.* 5, 97–102.

Barr, R. (2019). Growing up in the digital age: early learning and family media ecology. *Curr. Direct. Psychol. Sci.* 28, 341–346. doi: 10.1177/0963721419838245

Barr, R., and Linebarger, D. N. (2017). *Media Exposure During Infancy and Early Childhood: The Effects of Content and Context on Learning and Development*. Switzerland: Springer.

Bedford, R., Saez, de Urbain, Cheung, C., Karmiloff-Smith, A., and Smith, T. (2016). Toddlers' fine motor milestone achievement is associated with early touchscreen scrolling. *Front. Psychol.* 7:1108. doi: 10.3389/fpsyg.2016.01108

Bell, M. A., and Cuevas, K. (2016). "Psychobiology of executive function in early development," in *Executive Function in Preschool-Aged Children: Integrating Measurement, Neurodevelopment, and Translational Research*, eds J. A. Griffin, P. McCardle, and L. S. Freund (Washington, DC: American Psychological Association), 157–179. doi: 10.1037/14797-008

Berkowitz, T., Schaeffer, M. W., Maloney, E. A., Peterson, L., Gregor, C., Lavine, S., et al. (2015). Math at home adds up to achievement in school. *Science* 350, 196–198. doi: 10.1126/science.aac7427

Blair, C., and Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Dev.* 78, 647–663. doi: 10.1111/j.1467-8624.2007.01019.x

Blumberg, F. C., and Brooks, P. J. (2017). *Cognitive Development in Digital Contexts*. London: Elsevier.

Brakke, K., and Pacheco, M. M. (2019). The development of bimanual coordination across toddlerhood. *Monogr. Soc. Res. Child Dev.* 84, 7–147. doi: 10.1111/mono.12405

Bus, A., Takacs, Z., and Kegel, C. (2015). Affordances and limitations of electronic storybooks for young children's emergent literacy. *Dev. Rev.* 35, 79–97. doi: 10.1016/j.dr.2014.12.004

Carlson, S. M. (2017). *Minnesota Executive Function Scale: Technical Report*, v. 2. St. Paul, MN: Reflection Sciences, Inc.

Carlson, S. M., and Zelazo, P. D. (2014). *Minnesota Executive Function Scale: Test Manual*. St. Paul, MN: Reflection Sciences, Inc.

Chang, H. Y., Park, E.-J., Yoo, H.-J., Lee, J. W., and Yunmi, S. (2018). Electronic media exposure and use among toddlers. *Psychiatry Invest.* 15, 568–573. doi: 10.30773/pi.2017.11.30.2

Chassiakos, Y. R., Radesky, J., Christakis, D., Moreno, M., and Cross, C. (2016). Children and adolescents and digital media. *Pediatrics* 138:e20162593.

Cheung, C. H., Bedford, R., Sayez, De Urabain, I. R., Karmiloff-Smith, A., and Smith, T. J. (2017). Touchscreen use in infants and toddlers is associated with reduced sleep and delayed sleep onset. *Sci. Rep.* 7:46104.

Chindamo, S., Buja, A., DeBattisti, E., Terranro, A., Marini, E., et al. (2019). Sleep and new media usage in toddlers. *Eur. J. Pediatr.* 178, 483–490. doi: 10.1007/s00431-019-03318-7

Choi, K., and Kirkorian, H. L. (2016). Touch or watch to learn? Toddlers' object retrieval using contingent and noncontingent video. *Psychol. Sci.* 27, 726–736. doi: 10.1177/0956797616636110

Choi, K., Kirkorian, H. L., and Pempek, T. A. (2017). Understanding the transfer deficit: contextual mismatch, Proactive interference, and working memory affect toddlers' video-based transfer. *Child Dev.* 89, 1378–1393. doi: 10.1111/cdev.12810

Cristia, A., and Seidl, A. (2015). Parental reports on touchscreen use in early childhood. *PLoS One* 10:e0128338. doi: 10.1371/journal.pone.0128338

De Franchis, V., Usai, M. C., Viterbori, P., and Traverso, L. (2017). Preschool executive functioning and literacy achievement in grades 1 and 3 of primary school: a longitudinal study. *Learn. Indiv. Differ.* 54, 184–195. doi: 10.1016/j.lindif.2017.01.026

Diamond, A. (2013). Executive functions. *Annu. Rev. Psychol.* 64, 135–168.

Dore, R. A., Shirilla, M., Hopkins, E., Collins, M., Scott, M., Schatz, J., et al. (2019). Education in the app store: using a mobile game to support U.S. preschoolers' vocabulary learning. *J. Child. Media* 13, 452–471. doi: 10.1080/17482798.2019.1650788

Fisch, S. M. (2017). "Cognitive development in digital contexts," in *Bridging Theory and Practice: Applying Cognitive and Educational Theory to the Design of Educational Media*, eds F. C. Blumberg and P. J. Brooks (Cambridge, MA: Elsevier), 217–234. doi: 10.1016/b978-0-12-809481-5.00011-0

Herodotou, C. (2017). Young children and tablets: a systematic review of effects on learning and development. *J. Comp. Assist. Learn.* 43, 1–9. doi: 10.1111/jcal.12220

Hirsh-Pasek, K., Zosh, J. M., Golinkoff, R. M., Gray, J. H., Robb, M. B., and Kaufman, J. (2015). Putting education in educational apps: Lessons from the science of learning. *Psychol. Sci.* 16, 3–34. doi: 10.1177/1529100615569721

Hourcade, J. P., Mascher, S. L., Wu, D., and Pantoja, L. (2015). "Look, my baby is using an iPad! An analysis of youtube videos of infants and toddlers using tablets," in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, Seoul Korea, 1915–1924.

Huber, B., Meyer, D., and Kaufman. J. (2019). Young children's contingent interactions with a touchscreen influence their memory for spatial and narrative content. *Media Psychol.* 23, 552–578. doi: 10.1080/15213269.2019.1611451

Huber, B., Tarasuik, J., Antoniou, M. N., Garrett, C., Bowe, S. J., and Kaufman, J. (2016). Young children transfer learning from a touchscreen device. *Comp. Hum. Behav.* 56, 56–64. doi: 10.1016/j.chb.2015.11.010

Johansson, M., Marciszko, C., Brocki, K., and Bohlin, G. (2015). Individual differences in early executive functions: a longitudinal study from 12 to 36 months. *Infant Child Dev.* 24, 533–549. doi: 10.1002/icd.1952

Kabali, H. K., Irigoyen, M. M., Nunez-Davis, R., Budacki, J. G., Mohanty, S. H., Leister, K. P., et al. (2015). Exposure and use of mobile media devices by young children. *Pediatrics* 136, 1044–1050. doi: 10.1542/peds.2015-2151

Kirkorian, H. L. (2018). When and how do interactive digital media help children connect what they see on and off the screen? *Child Dev. Perspect.* 12, 210–214. doi: 10.1111/cdep.12290

Kirkorian, H. L., Choi, K., and Pempek, T. A. (2016). Toddlers' word learning from contingent and noncontingent video on touchscreens. *Child Dev.* 87, 405–413. doi: 10.1111/cdev.12508

Kucirkova, N. (2019). Children's reading with digital books: the past moving quickly to the future. *Child Dev. Perspect.* 13, 208–214. doi: 10.1111/cdep.12339

Kucirkova, N., and Zuckerman, B. (2017). A guiding framework for considering touchscreens in children under two. *Int. J. Child Comp. Interaction* 12, 46–49. doi: 10.1016/j.ijcci.2017.03.001

Kwok, K., Ghrear, S., Li, V., Haddock, T., Coleman, P., and Birch, S. A. (2016). Children can learn new facts equally well from interactive media versus face to face instruction. *Front. Psychol.* 7:1603. doi: 10.3389/fpsyg.2016.01603

Lauricella, A. R., Wartella, E., and Rideout, V. J. (2015). Young children's screen time: the complex role of parent and child factors. *J. Appl. Dev. Psychol.* 36, 11–17. doi: 10.1016/j.appdev.2014.12.001

Levine, L. E., Waite, B. M., Bowman, L. L., and Kachinsky, K. (2019). Mobile media use by infants and toddlers. *Comp. Hum. Behav.* 94, 92–99. doi: 10.1016/j.chb.2018.12.045

Lovato, S. B., and Waxman, S. R. (2016). Young children learning from touch screens: taking a wider view. *Front. Psychol.* 7:1078. doi: 10.3389/fpsyg.2016.01078

Lytle, S. R., Garcia-Sierra, A., and Kuhl, K. (2018). Two are better than one: infant language learning from video improves in the presence of peers. *Proc. Natl. Acad. Sci. U.S.A.* 115, 9859–9866. doi: 10.1073/pnas.1611621115

Madigan, S., Browne, D., Racine, N., Camille, M., and Tough, S. (2019). Association between screen time and children's performance on a developmental screening test. *JAMA Pediatr.* 173, 244–250. doi: 10.1001/jamapediatrics.2018.5056

McClure, E. R., Chentsova, Y. E., Barr, R. F., Holochwost, S. J., and Parrott, W. G. (2015). "Facetime doesn't count": video chat as an exception to media restrictions for infants and toddlers. *Int. J. Child Comp. Interaction* 6, 1–6. doi: 10.1016/j.ijcci.2016.02.002

McClure, E. R., Chentsova-Dutton, Y. E., Holochwost, S. J., Parrott, W. G., and Barr, R. F. (2018). Look at that! Video chat and joint visual attention development among babies and toddlers. *Child Dev.* 89, 27–36. doi: 10.1111/cdev.12833

Mol, S. E., and Bus, A. G. (2011). To read or not to read: a meta-analysis of print exposure from infancy to early adulthood. *Psychol. Bull.* 137, 267–296. doi: 10.1037/a0021890

Moser, A., Zimmerman, L., Dickerson, K., Grenell, A., Barr, R., and Gerhardstein, P. (2015). They can interact, but can they learn? Toddlers' transfer learning from touchscreens and television. *J. Exp. Child Psychol.* 137, 137–155. doi: 10.1016/j.jecp.2015.04.002

Mulder, H., Verhagen, J., Van der Ven, S. H. G., Slot, P. L., and Leseman, P. P. M. (2017). Early executive function at age two predicts emergent mathematics and literacy at age five. *Front. Psychol.* 12:1706. doi: 10.3389/fpsyg.2017.01706

Munzer, T. G., Miller, A. K., Weeks, H. M., Kaciroti, N., and Radesky, J. (2019). Differences in parent-toddler interaction with electronic versus paper books. *JAMA Pediatr.* 173, 1076–1083. doi: 10.1001/jamapediatrics.2019.3480

Myers, L. J., Lewitt, R. B., Gallo, R. E., and Maselli, N. M. (2017). Baby facetime: can toddlers learn from on-line video chat? *Dev. Sci.* 20:e12439.

Nacher, V., and Jaen, J. (2015). *Multi-Touch Technology in Early Childhood: Current Trends and Future Challenges*. New York, NY: ACM.

Nevski, E., and Siibak, A. (2016). The role of parents and parental mediation on 0- to 3-year-olds'digital play with smart devices: estonian parents' attitudes and practices. *Early Years* 36, 227–241. doi: 10.1080/09575146.2016.1161601

O'Connor, J., and Fotakopoulou, O. (2016). A threat to childhood innocence or the future of learning? Parents' perspectives on the use of touchscreen technology by 0-3-year-olds in the UK. *Contemp. Issues Early Child.* 17, 235–247. doi: 10.1177/1463949116647290

O'Toole, K. J., and Kannass, K. N. (2018). Emergent literacy in print and electronic sources: the influence of book type, narration source, and attention. *J. Exp. Child Psychol.* 173, 100–115. doi: 10.1016/j.jecp.2018.03.013

Parish-Morris, J., Mahajam, N., Hirsh-Pasek, K., Golinkoff, R. M., and Collins, M. F. (2013). Once upon a time: parent-child dialogue and storybook reading in the electronic era. *Mind Brain Educ.* 7, 200–210. doi: 10.1111/mbe.12028

Pila, S., Blackwell, C. K., Lauricella, A. R., and Wartella, E. (2019). *Technology in the Lives of Educators and Early Childhood Programs: 2018 Survey*. Evanston, IL: Center on Media and Human Development, Northwestern University.

Purpura, D. J., Schmitt, S. A., and Ganley, C. M. (2017). Foundations of mathematics and literacy: the role of executive functioning components. *J. Exp. Child Psychol.* 153, 15–34. doi: 10.1016/j.jecp.2016.08.010

Radesky, J., Schumacher, J., and Zuckerman, B. (2015). Mobile and interactive media use by young children: the good, the bad, and the unknown. *Pediatrics* 135, 1–3. doi: 10.1542/peds.2014-2251

Radesky, J. S., Peacock-Chambers, E., Zuckerman, B., and Silverstein, M. (2016). The use of mobile technology to calm upset children: associations with social-emotional development. *JAMA Pediatr.* 170, 197–199.

Reich, S. M., Yau, J. C., and Warschauer, M. (2016). Tablet-based books for young children: what does the research say? *Dev. Behav. Pediatr.* 37, 585–591. doi: 10.1097/dbp.0000000000000335

Richter, A. R., and Courage, M. L. (2017). Comparing electronic and paper storybooks for preschoolers: attention, engagement, and recall. *J. Appl. Dev. Psychol.* 48, 92–102. doi: 10.1016/j.appdev.2017.01.002

Rideout, V. J. (2017). *The Common Sense Census: Media Use by Kids Aged Zero to Eight*. San Francisco, CA: Common Sense Media.

Roseberry, S., Hirsh-Pasek, K., and Golinkoff, R. M. (2014). Skype me! Socially contingent interactions help toddlers learn language. *Child Dev.* 85, 956–970. doi: 10.1111/cdev.12166

Russo-Johnson, C., Troseth, G., Duncan, C., and Mesghia, A. (2017). All tapped out: touchscreen interactivity and young children's word learning. *Front. Psychol.* 8:578. doi: 10.3389/fpsyg.2017.00578

Saffer, D. (2009). *Designing Gestural Interfaces: Touchscreens and Interactive Devices*. Sebastopol, CA: O'Reilly Media, Inc.

Samarakoon, U., Usoof, H., and Halloluwa, T. (2019). What they can and cannot: a meta-analysis of research on touch and multi-touch gestures by two to seven-year-olds. *Int. J. Child Comp. Interaction* 22:100151. doi: 10.1016/j.ijcci.2019.100151

Shuler, C. (2012). *iLearn II: An Analysis if the Education Category of the iTunes App Store*. New York, NY: The Joan Ganz Cooney Centre at Sesame Workshop.

Souto, P. H., Santos, J. N., Leite, H. R., Hadders-Algra, M., Guedes, S., and Nobre, J. (2020). Tablet use in young children is associated with advanced fine motor skills. *J. Motor Behav.* 52, 196–203. doi: 10.1080/00222895.2019.1602505

Strouse, G. A., and Ganea, P. A. (2016). Are prompts provided by electronic books as effective for teaching a biological concept as those provided by adults? *Early Educ. Dev.* 27, 1190–1204. doi: 10.1080/10409289.2016.1210457

Strouse, G. A., and Ganea, P. A. (2017a). A print book preference: caregivers report higher child enjoyment and more adult-child interactions when reading print than electronic books. *Int. J. Child Comp. Interaction* 12, 8–15. doi: 10.1016/j.ijcci.2017.02.001

Strouse, G. A., and Ganea, P. A. (2017b). Toddlers' word learning and transfer from electronic and print books. *J. Exp. Child Psychol.* 156, 129–142. doi: 10.1016/j.jecp.2016.12.001

Takacs, Z. K., Swart, E. K., and Bus, A. G. (2014). Can the computer replace the adult for storybook reading? A meta-analysis on the effects of multimedia stories as compared to sharing print stories with an adult. *Front. Psychol.* 5:1366. doi: 10.3389/fpsyg.2014.01366

Takacs, Z. K., Swart, E. K., and Bus, A. G. (2015). Benefits and pitfalls of multimedia and interactive features in technology-enhanced storybooks: a meta-analysis. *Rev. Educ. Res.* 85, 698–739. doi: 10.3102/0034654314566989

Taylor, G., Monaghan, P., and Westermann, G. (2018). Investigating the association between children' screen media exposure and vocabulary size in the UK. *J. Child. Media* 12, 51–65. doi: 10.1080/17482798.2017.1365737

Troseth, G. L., Strouse, G. A., Verdine, B. N., and Saylor, M. M. (2018). Let's chat: on-screen social responsiveness is not sufficient to support toddlers' word learning from video. *Front. Psychol.* 9:2195. doi: 10.3389/fpsyg.2018.02195

van den Heuvel, M., Ma, J., Borkhoff, C. M., Korosheygi, C., Dai, D., Parkin, P., et al. (2019). Mobile media device use is associated with expressive language delay in 18-month-old children. *Dev. Behav. Pediatr.* 40, 99–104. doi: 10.1097/dbp.0000000000000630

Verdine, B. N., Golinkoff, R. M., Hirsh-Pasek, K., and Newcombe, N. S. (2014a). Finding the missing piece: blocks, puzzles, and shapes fuel school readiness. *Trends Neurosci. Educ.* 3, 7–13. doi: 10.1016/j.tine.2014.02.005

Verdine, B. N., Irwin, C. M., Golinkoff, R. M., and Hirsh-Pasek, K. (2014b). Contributions of executive function and spatial skills to preschool mathematics achievement. *J. Exp. Child Psychol.* 126, 37–51. doi: 10.1016/j.jecp.2014.02.012

Verdine, B. N., Lucca, K. R., Golinkoff, R. M., Hirsh-Pasek, K., and Newcombe, N. S. (2016). The shape of things: the origins of young children's knowledge of the names and properties of geometric forms. *J. Cogn. Dev.* 17, 142–161. doi: 10.1080/15248372.2015.1016610

Villamore, C., Willis, D., and Wroblewski, L. (2010). *Touch Gesture Reference Guide*. Available online at: http://www.lukew.com/touch/

Walter-Laager, C., Brandenberg, K., Tinguely, L., Schwarz, J., Pfiffner, M. R., and Moschner, B. (2016). Media-assisted language learning for young children: effects of a word-learning app on the vocabulary acquisition of two-year-olds. *Br. J. Educ. Technol.* 48, 1063–1072.

Wholwend, K. E. (2015). One screen, many fingers: young children's collaborative literacy play with digital puppetry apps and touchscreen technologies. *Theory Pract.* 54, 154–162. doi: 10.1080/00405841.2015.1010837

Wooldridge, M. B., and Shapka, J. (2012). Playing with technology: mother-toddler interaction scores lower during play with electronic toys. *J. Appl. Dev. Psychol.* 33, 211–218. doi: 10.1016/j.appdev.2012.05.005

Zack, E., and Barr, R. (2016). The role of interactional quality in learning from touchscreens during infancy: context matters. *Front. Psychol.* 7:1264. doi: 10.3389/fpsyg.2016.01264

Zack, E., Gerhardstein, P., Meltzoff, A. N., and Barr, R. (2013). 15-month-olds' transfer of learning between touch screen and real-world, displays: language cues and cognitive loads. *Scand. J. Psychol.* 54, 20–25. doi: 10.1111/sjop.12001

Zelazo, P. D. (2006). The dimensional change card sort (DCS): a method of assessing executive functioning in children. *Nat. Protoc.* 1, 297–301. doi: 10.1038/nprot.2006.46

Zimmerman, L., Moser, A., Lee, H., Gerhardstein, P., and Barr, R. (2017). The ghost in the touchscreen: social scaffolds promote learning by toddlers. *Child Dev.* 88, 2013–2025. doi: 10.1111/cdev.12683

Zosh, J. M., Verdine, B. N., Filipowicz, A., Golinkoff, R. M., Hirsh-Pasek, K., and Newcombe, N. S. (2015). Talking shape: parental language with electronic versus traditional shape sorters. *Mind Brain Educ.* 9, 136–144. doi: 10.1111/mbe.12082

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

ORIGINAL RESEARCH
published: 02 December 2020
doi: 10.3389/fpsyg.2020.593482

# Narrative Potential of Picture-Book Apps: A Media- and Interaction-Oriented Study

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Digital literature is playing an increasingly important role in children's everyday lives and opening up new paths for family literacy and early childhood education. However, despite positive effects of electronic books and picture-book apps on vocabulary learning, early writing, or phonological awareness, research findings on early narrative skills are ambiguous. Particularly, there still is a research gap regarding how app materiality affects children's story understanding. Thus, based on the ViSAR model for picture-book app analysis and data stemming from 12 digital reading dyads containing German monolingual 2- to 3-year-olds and their caregivers this study assessed the narrative potential of a commercial picture-book app and how this is used in interaction. Results of the media analysis showed that the app provides a high number of narrative animations. These animations could be used interactively to engage the child in the story. However, results of the interaction analysis showed that adult readers do not exploit this potential due to their strong concentration on operative prompts and instructions. Furthermore, an explorative analysis of the relation between adults' utterances and children's story comprehension provided preliminary indicators regarding how the length of reading duration and the number of utterances might relate to children's understanding of the story. Findings and methodological limitations of the study are discussed and combined didactically with practical recommendations on how to use narrative animations in interaction effectively.

**Keywords: picture-book apps, app analysis, digital shared reading, interaction analysis, early story comprehension**



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***Specialty section:***
*This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology*

***Received:*** *10 August 2020*
***Accepted:*** *30 October 2020*
***Published:*** *02 December 2020*

***Citation:***
*Müller-Brauers C, Miosga C, Fischer S, Maus A and Potthast I (2020) Narrative Potential of Picture-Book Apps: A Media- and Interaction-Oriented Study. Front. Psychol. 11:593482. doi: 10.3389/fpsyg.2020.593482*

## INTRODUCTION

Due to increasing media use across societies, even very young children's media experiences have changed fundamentally (Ofcom, 2018, 2019; Bitkom, 2019). From an early age, children begin to explore digital media and use them very intuitively (Neumann, 2014; Reid-Chassiakos et al., 2016; Neumann and Neumann, 2017). As a consequence, digital technologies are expanding children's early access to written language by establishing modified modes of communication in home literacy environments (McPake et al., 2013; Aliagas and Margallo, 2015). The international market is reacting to this trend with a wide range of apps targeted at children (Sari et al., 2019; Starke et al., 2020). Besides gaming and entertainment apps, there is an increasing number of educational apps, storybook apps, and electronic books addressing children's language and literacy development in preschool age (Sargeant, 2015; Sari et al., 2019). Due to their flexible usability, technical features, and easy applicability (Serafini et al., 2016), these have become increasingly popular with parents and are supplementing print-based literacy activities in children's everyday lives (Ehmig and Reuter, 2013; Neumann, 2014; Ólafsson et al., 2014; Kabali et al., 2015; Real and Correro, 2015; Kucirkova and Littleton, 2016; Chaudron et al., 2018). In contrast to print-based picture books, picture-book apps contain visual and audio animations (visual movements, images, or sounds) that can be controlled by the touchpad either with or without the help of a visual pointer—a so-called hotspot (Serafini et al., 2016). They can also include technical features such as gaming activities, navigation applications, videoclips, or recording functions (Sargeant, 2015; Aguilera et al., 2016; Serafini et al., 2016).

## Digital Stories and Early Literacy

Numerous international studies have shown that emergent literacy skills unfold in reciprocity with children's literature (Whitehurst et al., 1988; Sénéchal and LeFevre, 2001; Dickinson et al., 2012; Towson et al., 2017) because even very young children not only develop a natural interest in all various forms of picture books (Kümmerling-Meibauer and Meibauer, 2005), but also expand their linguistic knowledge and early literacy skills in dialogic reading situations (Justice and Ezell, 2000; Blewitt et al., 2009; Grolig et al., 2019; Clemens and Kegel, 2020). Children benefit from the multimodality[1] of parental reading styles. In dialogic reading (Whitehurst et al., 1988), adults not only act intuitively to (re-)establish attention or adapt their non-verbal and verbal behavior to the needs and interests of the child (Hargrave and Sénéchal, 2000). They also ensure comprehension by applying multimodal strategies of "communicative attunement" (Stern, 2000, pp. 138–139) and "sustained shared thinking" (Siraj-Blatchford, 2007, p. 17, 18) including questioning and prompts that highlight relevant verbal information (Hildebrandt et al., 2016) and help children to extract and process information on what is told and how the story evolves (Strouse et al., 2013; Hoffman and Paciga, 2014). When reading storybooks, adult readers also introduce children to motifs, figures, narrative themes (Kümmerling-Meibauer and Meibauer, 2015), and story schemes that they reproduce in their own retellings based on mental representations (Fox, 1993). Especially decontextualized talk significantly facilitates children's language skills (Rowe, 2012; Demir et al., 2015). Decontextualized talk comprises talk beyond the "here and now" of the immediate context such as explanation, pretending, or narrative talk (Rowe, 2012) about the past and future, absent objects, or abstract entities, or explanations of cause-and-effect relations (Curenton et al., 2008; Demir et al., 2015). Different approaches define this concept across a range of dimensions, so that different studies operationalize it in various ways (see Grimminger et al., 2019, for an overview). Moreover, reading digital stories to children also holds numerous potentials for the development of early literacy. Ihmeideh (2014) assessed the efficacy of electronic book reading during preschool age on early literacy domains such as print awareness, vocabulary, phonological awareness, and alphabetic knowledge. Results showed higher early literacy scores in the experimental group after electronic book intervention than in the control group that used traditional book material. Several studies have also reported positive effects of digital storybooks on early literacy skills and language development (Shamir and Korat, 2007; Shamir and Shlafer, 2011; Shamir and Baruch, 2012; Neumann, 2014; Neumann and Neumann, 2017; Strouse and Ganea, 2017; Zipke, 2017; Herodotou, 2018; Lee, 2020). However, there is still a lack of research on how the specific conditions in digital reading impact children's understanding of stories and how shared reading interaction and adults' responsive strategies during digital reading are affected by the digital device (Herodotou, 2018; Courage, 2019). In an intervention study, Shamir and Korat (2007) compared the impact of digital story reading in comparison to analog storybook reading on the early literacy skills of 128 children aged 5–6 years from low- and middle-SES backgrounds. Post-measurements showed no differences in children's story comprehension performances in the two conditions analog vs. digital. Smeets and Bus (2015) assessed the effects of different types of autonomously operated electronic books on vocabulary learning and story comprehension in preschool children aged 4–5 years: (a) static electronic books with an activated reading-aloud function and no visual or audio animations, (b) animated electronic books with a reading-aloud function and visual and audio animations, and (c) interactively animated electronic books with a reading-aloud function and integrated hotspots presenting unknown words after being activated. Whereas children's vocabulary benefited most from interactively animated electronic book reading, there were no clear positive effects on early story comprehension. Moreover, children's story comprehension did not differ between the conditions. Zhou and Yadav (2017) also reported no significant effect of multimedia or digital story reading on story comprehension in preschool age. In contrast, Korat (2009, 2010) found positive effects of digital storybook reading on story comprehension in preschool age based on a non-commercial electronic book story specially designed to optimize literacy learning for study purposes. In a study with 3- and 5-year-old children, Parish-Morris et al. (2013) reported a negative impact of app-related technical features on children's early story comprehension and parental language teaching strategies in shared reading situations. In other words, in the digital condition, Parish-Morris et al. (2013) quantified a lesser degree of dialogic reading strategies based on content-related utterances and prompts and a higher degree of instructive utterances addressing the child's behavior. Vice versa, in the analog reading situation and in a situation in which the technical features of the app were deactivated, they found a lesser degree of behavior-related talk and a higher amount of content-related talk. Krcmar and Cingel (2014) also found that when reading analog story books to their 2- to 5-year-olds, parents focused more on content aspects, got less distracted by technical features, and showed

[1] By "multimodality," we mean the combination of phonetic with mimic, gestural and other body-related components, and thus auditory and visual 'modalities' in face-to-face interaction (Steinseifer, 2011, p. 165).

more responsiveness and engagement by adjusting to children's questions or comments on the story compared to the digital condition. In a study with children aged 2–3 years, Miosga (2020) showed that under digital reading conditions, the presence of technical features has a negative influence on not only language teaching strategies but also children's abilities to understand the story. In comparison to the analog condition, in the digital condition, adults used more media-related and less content-related utterances and proved to be less emotionally attuning and cognitively activating when interacting with their children. Negative effects on story comprehension were also found when storybooks contained numerous gaming items and hotspots (Yokota and Teale, 2014). In contrast, a meta-analysis based on 29 experimental studies by Takacs et al. (2014) revealed that when listening to multimedia stories, young children benefit to a higher degree in terms of story comprehension compared to traditional print-based story reading settings that are not framed interactively by an adult, provided that electronic storybooks are not overloaded with technical features. Other studies also report a positive influence of digital reading on story and reading comprehension, but these studies targeted older children and used outdated technologies (e.g., Doty et al., 2001).

## The Role of the Medium

In sum, empirical evidence shows that digital reading enhances literacy learning in various ways. With respect to story comprehension, research findings are heterogeneous. Studies indicate that early story comprehension can be affected negatively by app materiality and the specific interactive conditions of digital reading, but reading digital stories can also foster children's narrative and linguistic skills (Verhallen et al., 2006). Note that, interactivity in digital reading situations is not identical to that under analog book reading conditions. Thus, adult readers not only have to guide the reading situation dialogically, they also have to operate the technical features of the app in interplay with the narrative (Müller-Brauers et al., 2020). "Readers of digital picture books must work through the presentation of a fictional narrative using physical, cognitive, visual, emotional, and embodied strategies and capabilities, among others" (Serafini et al., 2016, p. 510). In this respect, the question arises, however, whether the technical features of an app (hotspots, video clips, background music) and the way animations are linked to the story also play a role in the process of story comprehension, and how they are interrelated to adult's interaction behavior and the way they involve children in the story.

Therefore, based on the research desiderata reported in Miosga's study (2020), we took a media- *and* interaction-oriented approach in this study to explore how adult caregivers use the technical features of a picture-book app to involve children in the story. In doing so, we have deliberately concentrated on a commercial app since research still lacks of studies assessing the impact of commercial picture-book apps and their application in interaction on children's early literacy development. Previous studies often used specially designed apps and electronic books (Takacs et al., 2014) or they focused on app analyses across different countries, age groups, specific educational areas (Sari et al., 2019) or according to technical features and game activities (Sargeant, 2015; Serafini et al., 2016).

We first performed a media analysis of a picture-book app in order to identify the narrative potential of the medium. We based our analysis on the ViSAR model for picture-book app analysis, which we have applied in previous works (Müller-Brauers et al., 2020; Miosga et al., in press) and which we present in the methods section. The ViSAR model not only provides a theoretical basis to determine and compare app qualities in terms of narrative learning. Applying it to the narrative potential of apps and their interactive use in shared reading situations might also provide a promising approach in order to contribute new findings to the state of research and to resolve contradictions in current research findings. Hence, secondly, we assessed how far caregivers used the narrative potential of the app interactively during reading by investigating how often and in which mode adult readers referred to narrative animations verbally.

Hence, our analyses focused on the following research questions (RQs):

RQ 1. What kind of animations does the picture-book app provide? And how many animations can be identified as narrative animations?

RQ 2. How often (a) and in which content mode (b) do adult readers refer verbally to narrative animations in digital shared reading and do they exploit the narrative potential of the app?

To generate new research questions in the field of digital reading, we also conducted an explorative analysis focusing on the role of narrative animations and their interactive processing by the adult reader in children's early story comprehension by including exemplary data from children's story comprehension scores obtained after reading. We assumed that a high number of narrative animations linked to the story line would engage the child in the narrative more probably and therefore foster story comprehension (Korat, 2010; Sargeant, 2013, p. 32; Kao et al., 2016) because narrative skills benefit from joint engagement (Miosga, 2020) and thematic involvement (Pesco and Gagné, 2017; Grolig et al., 2019). Findings can provide a starting point for future research to assess what role the adult readers' verbal references play to specific app animations in children's early story comprehension.

# METHODS

## Materials

The first research question in the study addressed the picture-book app "7 grummelige Grömmels und ein kleines Schwein" ("7 grumpy Grömmels and a little pig," abbreviated to Grömmels below) by Wewer (2012). The app addresses children aged 3–4 years and was honored with a reward by the Stiftung Lesen and Leipziger Buchmesse (2013). As stated above, we intentionally selected a commercial app because previous studies often used specially designed apps and electronic books (Takacs et al., 2014). The app contains a reading function, sound effects (that can be activated or deactivated), a recording function, a coloring picture, and numerous hotspots in the form of green icons that constantly flash according to a programmed interval. Navigating animations for turning pages consist of small arrow symbols.

The story, which is also available in book format, is about family and friendship. On a dark night, a pig arrives at a house where terrible monsters live—the hairy and grumpy Grömmels. The next morning, the seven Grömmels are not pleased when they notice their cheeky guest and threaten to eat it. By being kind and curious, however, the pig can save the day repeatedly and bring out the best in the Grömmels, so that they no longer wish to eat it.

## App Analysis (RQ 1)

To address RQ 1, the app's animations were coded according to parameters suggested in the ViSAR model (Müller-Brauers et al., 2020). To obtain valid results, coding was controlled independently by a team of three researchers (for the coding scheme, see **Supplementary Material**). Furthermore, ambiguous cases were discussed in a team of four researchers. The ViSAR model, shown in **Figure 1**, integrates four interconnected levels of picture-book app analysis: visual, animative, reader, and speaker.

For validation purposes, we applied the model in previous work to different apps (Müller-Brauers et al., 2020; Miosga et al., in press) and the model was also tested in student's master's theses (e.g., von Wingerden, 2020) and presented and discussed on different conferences (Miosga and Müller-Brauers, 2019, 2020). In the course of the validation process, we shaped the difference between audio animations and the read aloud function by integrating the reader level. We also inserted the reader level to stress the impact of interaction in digital shared reading situations. To distinguish the model from exclusively media analysis, we also developed the ViSA-model, which does not contain the reader level (see Müller-Brauers et al., 2020).

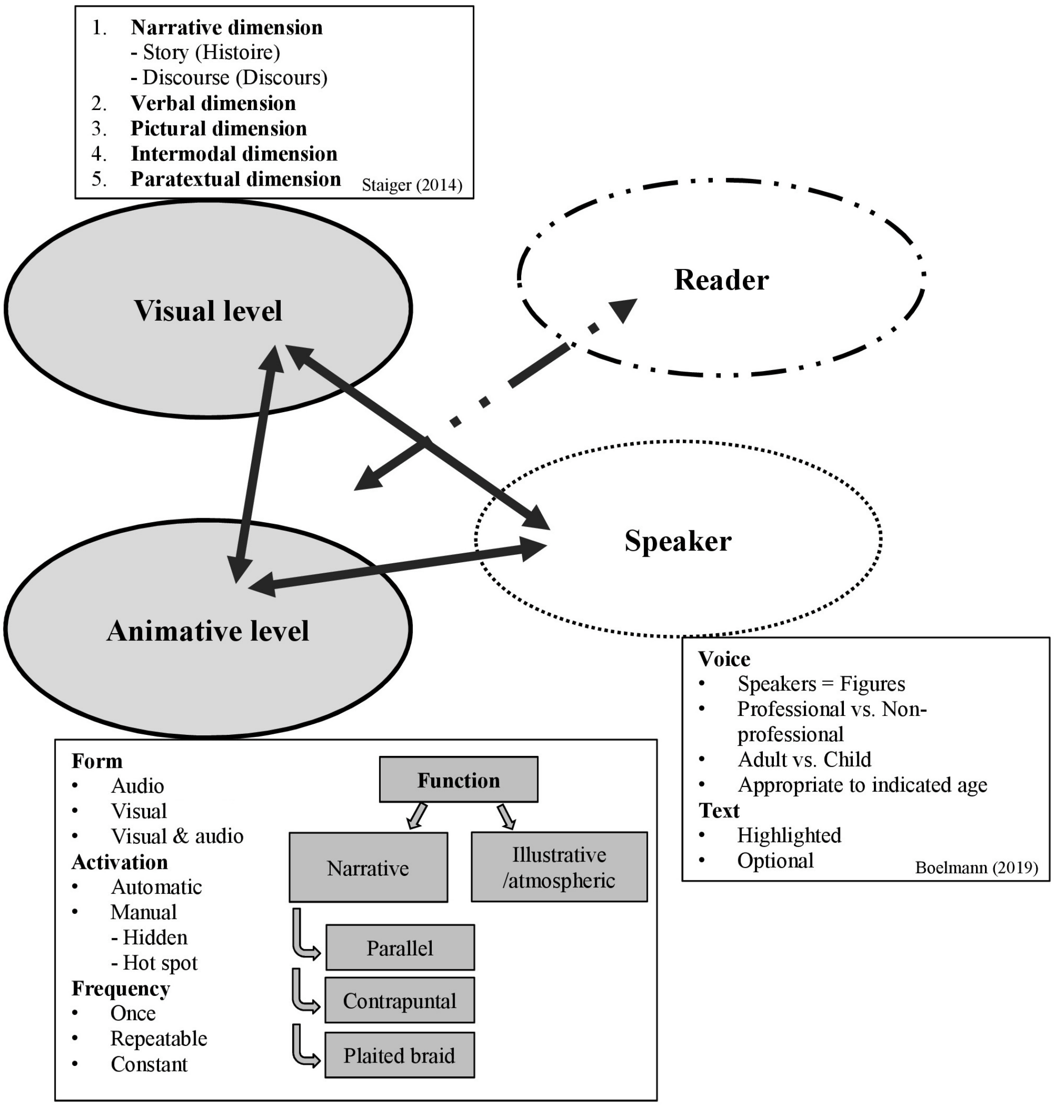


**FIGURE 1 |** The ViSAR model for picture-book app analysis (Müller-Brauers et al., 2020, p. 174).

The *visual level* of the ViSAR-model refers to Staiger's (2014, pp. 14–21) approach to a multimodal understanding of picture book analyses that integrates different analytical dimensions. The narrative dimension, for example, examines the function of the content and structure of the narrative: what is told in the story (plot, theme, space, figures, narrated time, etc.; see Kurwinkel, 2017) and how the story structure is unfolded (narrative perspective, figure speech, tense, and time sequences). The intermodal dimension highlights the interplay and interconnectedness of the verbal (text) and visual (images) code of picture books (Thiele, 2000). In the verbal dimension, analysis concentrates on the language input provided by the text in terms of text coherence, wording, syntax, linguistic style, and so forth[2].

The second level, the *animative level*, focuses on analyzing the animations included in the app. Parameters include the form of animation (audio, visual, visual + audio), its activation, and the frequency in which the animation occurs:

- *Form:* visual (e.g., movements), audio (e.g., noises), visual + audio
- *Activation:* automatic (e.g., background music) or manual (on request after being clicked on) with manual animations being either hidden or controlled by hotspots
- *Frequency:* once, repeatable, or constant

The animative level also highlights the function that different animations can serve in terms of their potential for story comprehension. In reference to text–image relations (Thiele, 2000; Nikolajeva and Scott, 2006), the model distinguishes between three different subcategories:

(1) *Parallel* (identical correlation of text and animated images/sounds). For example, the text describes a situation in which children are playing outside. Symmetrically, the animation displays identical actions or sounds when being activated.
(2) *Contrapuntal* (inconsistent relation between text and animated images/sounds). For example, the text refers to a given scene in which children are playing outside until sunset. Is the sunset animated once, the animation is classified as parallel. If the animated sun rises again when reactivated, the animation is categorized as contrapuntal because this animation breaks the timeline and leads to a contradictory relation to the text (Müller-Brauers et al., 2020).
(3) *Plaited braid* (complementary relation between text and animated images/sounds). Here, text and animated images/sounds present different but complementary information. Accordingly, one part of the relevant information is provided by the text, the other part by the visual or audio animation generating a meaningful context. For example, the text provides the information that the protagonist of the story had a lot of fun on that day, while the scene and the animations present the protagonist swimming, dancing, singing, and eating cake.

Animations can also be *illustrative* and thereby have an exclusively illustrative/atmospheric function (animating space visually: e.g., flying insects in trees; or evoking emotions auditorily: e.g., birds twittering in the background) and not be attached to the narrative dimension. In addition to illustrative and narrative animations, picture-book apps can also contain *navigating* animations that serve operative functions. Because these are not content-related, they are not addressed explicitly in the ViSAR model. However, by adding navigation applications, three types of animations can be accordingly distinguished: narrative, illustrative, and navigating animations.

The third level, the *reader level*, stresses the role of interaction in digital reading by pointing to the verbal and non-verbal behavior of the adult, caregiver, or any reading person in integrating the visual and animative level in the reading process. Our analysis focuses particularly on how the reader makes use of narrative animations to engage the child in the story, thereby possibly promoting the child's story comprehension[3]. The detailed coding scheme can be found in the **Supplementary Material**.

## Interaction Analysis (RQ 2)

The aim of the interaction analysis was twofold: When analyzing adult–child dyads ($n = 12$), we first aimed to determine how far the caregiver made use of the narrative potential of the app by referring to narrative animations verbally during reading. Therefore, we first assessed how often the caregiver referred to the different types of animations or hotspots (i.e., narrative or illustrative animations or hotspots), and how often she talked with the child about navigating the app[4].

Secondly, we focused on the mode of verbal references. This means, we assessed on which content level the adult reader referred verbally to an animation. We included the mode of verbal references because the adult reader can elaborate in a narrative manner not only on narrative animations but also on illustrative and navigating animations. Inversely, adults can comment on all animation types in an operative mode, thus focusing on handling aspects of the animations. The codes *narrative* and *illustrative* were derived theoretically from the ViSAR model (Müller-Brauers et al., 2020), *navigating* from empirical evidence (e.g. Sargeant, 2015; Serafini et al., 2016; Miosga, 2020).

### Participants

We analyzed data from a subsample of Miosga's (2020) participants containing 10 adults (5 mothers, 2 fathers, and 3 educational professionals) and 12 children (mean age: 36.33

[2]The visual design, color, picture space, typography, and pictorial composition (Staiger, 2014) frame the pictorial dimension of the analysis. Finally, the paratextual and material dimension highlights the material constitution of a picture book. These are the book format, cover and endpapers, type of paper, and so forth.

[3]The fourth level of the ViSAR model encompasses the *speaker* included in an app as part of the read-aloud function (Boelmann, 2019, p. 257). The speaker transfers the written text and therefore the narrative into oral language. Thereby, the speaker adopts the role of a narrator or reader to the child interacting with the app. For our analysis, the speaker is irrelevant. Therefore, we do not pursue this aspect further.

[4]Animations activated by a hotspot are not discriminated from other animations in the interaction analysis. Hence, in the following reports on the interaction analysis, we refer only to the term animation.

months, range: 24–43 months, $SD = 6.6$ months). Participants were recruited via a questionnaire on digital media use in home environments and early childhood education in the greater Hanover area of North Germany. Parental consent was obtained for all participants[5]. Participants were monolingual German speakers with normal hearing and language abilities. Adult participants reported being familiar with digital media use and experienced in traditional as well as digital shared reading. Twelve adult–child dyads read the Grömmels app that provides a wide range of visual and audio animations. Interactions were videotaped for transcription and coding.

## Coding

The adults' utterances were coded with the annotation tool ELAN (release 5.5, Max-Planck-Institute of Nijmegen). An utterance was defined as each phrase uttered by the adult or the child, not including reading the text (Miosga, 2020).

### Quantity of Adults' Verbal References to Animations (RQ 2a)

Based on the ViSAR model, we coded adults' utterances according to verbal references to functional animation types (*narrative* vs. *illustrative*) and *navigating* animations (e.g., arrow icons to turn pages) provided by the picture-book app.

The utterances to narrative and illustrative animations were coded for each individual page of the app. The coding scheme included exactly one category for all narrative and one category for all illustrative animations for each page, respectively, even if a page presented more than one animation of each type. We did not further distinguish the different narrative animations (or illustrative animations, respectively) on each individual page. Thus, we captured narrative animations on 22 pages and illustrative animations on 13 pages because every page presented narrative animations, but only 13 pages also presented illustrative animations. Unclear or general references (e.g., "you can always click the green buttons when you see them") as well as references to buttons for turning pages (navigating animations) were assessed in total (i.e., not distinguished between pages).

### Modes of Verbal References to Animations (RQ 2b)

In this analysis, the mode of adults' verbal references defined as the mode of reference (*narrative*, *illustrative*, *operative*) to the different animations (*narrative* vs. *illustrative* vs. *navigating*) was identified within an analytical process. *Operative* refers in this analysis to the navigating functions of the app in the adults' comments. This variable assesses, thus, communicative references to navigating functions of the app. In an iterative process we observed that mixed categories also occurred, i.e., that adults referred to, for example, a narrative animation, but the reference was about operating aspects. For reasons of accuracy, we differentiated these categories in the coding process in, for example, narrative and operative-narrative categories. In this way, the following six categories were identified:

(1) *Narrative:* The adult referred to a narrative animation narratively (e.g., "the pig is reading a book, isn't it?")
(2) *Illustrative:* The adult referred to an illustrative animation illustratively (e.g., "look, what is crawling on the wall?")
(3) *Operative-narrative:* The adult referred mainly operatively to a narrative animation, that means, for instance, including a story character (e.g., "can you tickle the pig")
(4) *Operative-illustrative:* The adult referred to an illustrative animation mainly operatively including an illustrative element (e.g., "will the dog reappear when you touch the sausage here?")
(5) *Narrative-navigating:* The adult referred narratively to an animation that serves navigating purposes (e.g., "shall we look at how to go on with the story?" when activating the button for turning pages)
(6) *Operative:* The adult referred entirely operatively to an animation regardless of its function (narrative, illustrative, navigating) (e.g., "press the green button")

The detailed coding scheme can be found in the **Supplementary Material**.

## Story Comprehension

We also used data from the subsample of Miosga's study (2020) to assess children's story comprehension. The study had used a within-subject design to compare children's story comprehension under different media conditions. The data has been transcribed, anonymized, and processed in accordance with data protection guidelines. All participating researchers are obliged to comply with these guidelines. Adult–child dyads were randomly assigned to read either the traditional (analog) or app version (digital) first. Children's story comprehension was investigated once after reading the app or the book with a semistructured conversation stimulus (see also Parish-Morris et al., 2013; Reich et al., 2019). In story comprehension assessment, no global test is available with a full item analysis so that each assessment has to be designed according to the specific story. We realized this communicative approach by adjusting the stimulus and the questions to the content of the digital app used and to the age of the children. Doing so, children completed the story comprehension assessment after reading the app with the caregiver. In our study, we analyzed data from the digital media condition ($n = 6$).

Adults used questions to assess children's factual information extraction during reading by highlighting the main protagonists of the story or the motives for action: *Who is taking part in the story? Who lives in the house? What is the pig doing in the Grömmels' house? Why does the Grömmel want to eat the pig? Why is the pig allowed to stay with the Grömmels? Who are the Grömmels afraid of?* Children's answers were noted, recorded, and analyzed in terms of the proportion of correctly answered, incorrectly answered, and unanswered questions. Examples of correct answers given by the children are: "Who lives in the house?" *The Grömmels, the pig and the dog, Mommy Grömmel and children Grömmel, Dad, Mom, Baby and the pig.* Examples of incorrect answers given by the children are: "Why does the Grömmel want to eat the pig?" *Because he loves him very much,*

[5] All subjects gave written informed consent in accordance with the Declaration of Helsinki.

*because he likes the piggy*. The coding scheme with further coding examples and descriptive statistics of the story comprehension categories is detailed in the **Supplementary Material**.

# RESULTS

## App Analysis

The Grömmels picture-book app contains a total of 87 animations: 64 % are visual + audio; 18 %, exclusively visual; and 17 %, exclusively audio (all percentages rounded off). This means that 82 % of the total number of animations integrate sounds; 55 % are repeatable; 31 % run constantly when the noise function is switched on; and 14 % can be activated only once. In terms of activation, the majority of 64 % of animations are hotspots; 33 % start automatically; and only 2 % are hidden manually. Hotspots consist of a visual pointer projected in the form of a green icon that automatically reappears according to a technically predefined interval. We found that 79 % of the hotspots are visual + audio; 18 %, audio; and 3 %, visual. Hence, 96 % integrate sounds. About two thirds (61 %) of the hotspots have a narrative function; and more than one third (39 %), an illustrative and atmospheric function. This is equivalent to findings on the function of the animations: 62 % are narrative and 38 % illustrative. The group of narrative animations contains predominantly animations that function as a "parallelism" to the text (59 %). That means, they highlight identical information such as "One night a little pig walked into a house" (animation: door opens and a little pig enters) or "It switched the light on" (animation: the light turns on). Only 2 % of the narrative animations evoke a complementary relation to the text (plaited braid)—for example, "The Grömmel was very scared" (animation: the Grömmel family stand wide-eyed in the semidarkness of the background and tremble with fear). No animations in this picture-book app were coded as contrapuntal. A large number of animations (38 %) have illustrative and atmospheric functions (such as a dog wagging its tail or a fly circling around while making a loud buzzing noise).

### Discussion of App Analysis

As a first interpretative step and reconsidering the theoretical background, we therefore conclude that the Grömmels picture-book app offers a high potential for early story comprehension because it includes a large number of various forms of narrative animations: 61 % of the animations have a narrative function; and at 59 %, almost all function as a parallelism. These animations have a high potential to support early story comprehension. In contrast, 39 % of the animations carry illustrative and atmospheric functions. These animations can distract from the storyline and may even be more likely to inhibit story comprehension. Similarly, the hotspots offer ambiguous potential: The app analysis shows that around two thirds of the animations are hotspots that appear temporarily, sequentially, and automatically. On the one hand, hotspots can support story comprehension if they appear at the right time and correspond to the narrative progress. On the other hand, they can distract from the storyline if they appear in an irregular manner. Additionally, the high number of animations that play with an auditory component (82 %) and have an illustrative function that mostly does not accompany the storyline can potentially distract from that storyline (Müller-Brauers et al., 2020; see also Parish-Morris et al., 2013; Smeets and Bus, 2013; Takacs et al., 2014; Yokota and Teale, 2014; Knopf, 2018).

However, there are also limits to our app analysis: The results of the app analysis based on the ViSAR model were verified by an independent researcher within the scope of an inter-reliability test who inspected 25 % of the animations. The level of agreement was 79 %. Maximum consensus was found in the frequency and activation categories. Most deviations were in the function category for the subcategories plaited braid and illustrative. The overall agreement on hotspots was slightly higher at 88 %. The frequency and total number categories showed the greatest consistency, whereas most deviations were found among functions—once more in the subcategories plaited braid and illustrative.

Ambiguous cases occurred especially for narrative parallel, plaited braid, and illustrative animations. Some animations could be interpreted as both plaited braid in the sense of referring to the Grömmels living in the house and illustrative in the sense of an atmospheric background supporting the scene. We finally classified these animations as illustrative because they tend to distract the reader from the narrative strand. Note, however, that counting animations on the basis of categories from the picture book analysis remains an interpretative process (Thiele, 2000).

In sum, we see that the app provides potential in terms of merits, but some demerits were demonstrated. The actual realization of this potential, however, needs to be illuminated by the following step.

## Interaction Analysis

Our second research question focused on (a) how far caregivers make use of the different animations in the app and (b) the mode of caregivers' verbal references to these animations. Our aim was to examine how adult readers exploit the narrative potential of the app. We therefore assessed how often caregivers addressed the different types of animations (*narrative*, *illustrative* and *navigating*) and in which ways they addressed them with regards to content. The numbers of utterances in each category were classified according to the coding schemes.

### a) Quantity of Adults' Verbal References to Animations

This analysis initially determined the number of adult utterances on all narrative and illustrative animations per individual page, and then summed these up to a whole. Results showed that there were about twice as many utterances to narrative animations as to illustrative animations (see **Tables 1**, **2**). The percentage ratio of solely narrative and illustrative animations without the other categories was about 70 % narrative to 29 % illustrative (see **Table 1**).

Expressed as a percentage of all utterances within the digital reading situation (narrative, illustrative, navigating, unclear/general), on average, about 55 % of adults' utterances were to narrative animations and 23 % to illustrative

**TABLE 1 |** Adult utterances to animation types ($n = 12$).

| Category | No. of utterances | | | No. of utterances/min | | |
|---|---|---|---|---|---|---|
| | *Md* | Min | Max | *Md* | Min | Max |
| Cumulative narrative | 45.00 | 7 | 75 | 3.12 | 0.62 | 6.21 |
| Cumulative illustrative | 18.00 | 3 | 35 | 1.45 | 0.34 | 3.56 |
| Cumulative narrative and illustrative | 55.00 | 14 | 104 | 4.39 | 1.24 | 9.77 |
| Navigating | 12.00 | 0 | 35 | 0.87 | 0.00 | 2.87 |
| Unclear/general | 1.00 | 0 | 8 | 0.10 | 0.00 | 0.63 |
| Total (narrative, illustrative, navigating, unclear/general) | 74.00 | 22 | 122 | 5.26 | 2.51 | 12.31 |
| Reading duration (min.) | 12.54 | 8.75 | 17.68 | | | |

**TABLE 2 |** Adult utterances (raw values) to animation types per page ($n = 12$).

| Page no./Type of animation | *Md* | Min | Max |
|---|---|---|---|
| 1 Illustrative | 0.00 | 0 | 6 |
| Narrative | 0.50 | 0 | 5 |
| 2 Narrative | 2.50 | 0 | 7 |
| 3 Narrative | 2.50 | 0 | 8 |
| 4 Illustrative | 3.50 | 0 | 10 |
| Narrative | 0.00 | 0 | 2 |
| 5 Narrative | 3.00 | 0 | 6 |
| 6 Illustrative | 2.00 | 0 | 10 |
| Narrative | 1.00 | 0 | 5 |
| 7 Illustrative | 3.00 | 0 | 17 |
| Narrative | 1.00 | 0 | 5 |
| 8 Illustrative | 1.00 | 0 | 8 |
| Narrative | 2.00 | 0 | 15 |
| 9 Illustrative | 0.00 | 0 | 6 |
| Narrative | 1.50 | 0 | 8 |
| 10 Narrative | 2.50 | 0 | 7 |
| 11 Narrative | 0.50 | 0 | 3 |
| 12 Narrative | 4.00 | 0 | 12 |
| 13 Illustrative | 0.00 | 0 | 0 |
| Narrative | 1.50 | 0 | 8 |
| 14 Narrative | 0.00 | 0 | 3 |
| 15 Narrative | 2.00 | 0 | 5 |
| 16 Illustrative | 0.00 | 0 | 3 |
| Narrative | 1.50 | 0 | 6 |
| 17 Illustrative | 0.00 | 0 | 2 |
| Narrative | 1.00 | 0 | 4 |
| 18 Illustrative | 0.00 | 0 | 1 |
| Narrative | 2.00 | 0 | 7 |
| 19 Illustrative | 0.00 | 0 | 4 |
| Narrative | 0.00 | 0 | 3 |
| 20 Narrative | 0.50 | 0 | 5 |
| 21 Illustrative | 0.00 | 0 | 1 |
| Narrative | 1.50 | 0 | 4 |
| 22 Illustrative | 0.00 | 0 | 2 |
| Narrative | 0.00 | 0 | 10 |

animations (19 % to navigating animations and 3 % unclear/general references).

Moreover, caregivers showed high variability in utterances to the different animation types (narrative: 19 to 82 %, illustrative: 8 to 42 %, navigating: 0 to 59 %, unclear/general: 0 to 12 %).

**Table 1** presents the descriptive statistics. Because the duration of the digital reading situations differed between dyads, we also determined a ratio of each category in relation to total reading duration (utterances per min). Due to the small sample size and high variability, we report median and range as measures of central tendency.

The difference between the number of utterances to narrative or illustrative animations was also apparent *per page*. On some pages, adults related verbally to the animation types four times (a narrative animation on page 12), whereas on page 13, adults did not refer to any illustrative animation at all (see **Table 2**).

Some animations were elaborated more interactively than others: Most frequently, the illustrative animations on pages 4 and 7 were referred to as well as the narrative animations on pages 5 and 12 (all $Md > 3.00$).

Further analysis revealed that at the beginning of the digital reading situation (pages 1 to 11), the number of utterances to the app's narrative and illustrative animations was higher ($Md = 35.00$, range 9.0 to 84.0) than at the end of the story (pages 12 to 22, $Md = 18.00$, range 2.0 to 37.0). The amount of verbal references to narrative ($Md = 16.5$, range 5.0 to 49.0) and illustrative ($Md = 17.0$, range 2.0 to 35.0) animations on the first eleven pages of the app was comparable. On the following eleven pages, utterances to narrative animations stayed at an equivalent level ($Md = 18$, range 2.0 to 37.0), whereas the quantity of utterances to illustrative animations declined strongly ($Md = 0.0$, range 0.0 to 7.0).

## Discussion of the Quantity of Adults' References

The analysis of the quantity of adults' verbal references to animations revealed that adult readers referred to narrative as well as to illustrative animations in a digital shared reading situation, and the number of utterances to narrative animations was about twice as high as those to illustrative animations. The number of references to navigating animations, however, was also substantial, nearly reaching the percentage of utterances to illustrative animations.

Further, when examining the adults' references to the animations on individual pages, some animations seemed to be especially attracting, and narrative animations might have an advantage here as well. The overall most frequently commented on animation was a narrative one (sleeping scene on page 12), whereas the one animation that was never commented by any dyad was an illustrative one (page 13, a fly flying through the room).

Considering the course of the reading situation, it becomes clear that references to illustrative animations strongly decreased during reading, whereas narrative animations were referred to quite consistently throughout the reading process, resulting in an overall lower amount of utterances to animations in general in the second part of the story. This result might be impacted by the reading process itself, and suggests that at the beginning of the reading situation, adults and children are testing the new functions of the different narrative or illustrative hotspot buttons. The operating modes might be exploited in this way, and the dyads focus on the functions and supplementary features that are not provided by a book, because they are somehow "new" and more interesting at the beginning.

Additionally, caregivers might arrange the entry to the story more extensively than the later progress of the reading situation—perhaps because they are aware that their child's concentration starts to fade or because they want to end the reading session. Especially the illustrative animations might be left out at the end of the story to save time in favor of narrative animations and a desire to concentrate on completing the story's plot. Further or alternatively, the illustrative animations might be less noteworthy or striking at the end of the story.

However, this result mirrors the fact that some dyads did not finish reading the app—indicating that interest decreased over the course of the reading situation. In this context, it is even more remarkable that a sleeping scene later in the app (page 12) was the most frequently referred to animation. It is possible that the content of this page had a major impact on this result because the scene might be linked closely to children's everyday lives at this age. App design might appreciate this content aspect.

Taken together, these findings suggest that narrative animations played a significant role in a digital reading situation with the Grömmels app because they were commented on more frequently than illustrative animations throughout the whole process of the reading situation.

Viewed together with the analysis of the app according to the ViSAR model, these results suggest that the full narrative potential presented by the app materiality (i.e., the number of narrative compared to illustrative animations) is fulfilled only partly in a digital reading situation. Indeed, on an interactive level, the percentage ratio of utterances to narrative and illustrative animations was about 70 to 30 %, therefore actually exceeding the ratio of the app materiality of 61 to 39 % from a narrative perspective. But, taking the reading situation as a whole and considering all utterances in the dyads' dialogues, talk about narrative animations was below what the app's materiality provides (i.e., about 55 %). Utterances on illustrative animations were even lower at only 23 %. The proportion of navigating and general references was similar (22 %). In other words, to some extent, adults referred to narrative animations to a slightly lesser extent than the app's overall narrative animations would suggest.

However, in this analysis, we did not focus on the way adults referred to the animations—that means, we did not examine the verbal content of these utterances. We concentrated only on the number of utterances to the different types of animation that adults referred to without considering their content. The content was examined in the following analysis.

### b) Modes of Adults' Verbal References to Animations

Further analyses focused on the quality of verbal references by assessing the caregiver's mode of reference to the animations. We therefore determined the extent of narrative or illustrative elaborations on animations on the one hand and references to operative aspects of the app on the other hand in combination with the particular animation types based on the category system stated above (see **Supplementary Material**).

Descriptive statistics showed that the number of utterances in an operative mode of reference to navigating animations (operative) was highest compared to all other reference categories, and that this was apparent in raw values as well as in a ratio of each category to the individual reading duration of number of utterances per min. The range of utterances was high, indicating high variability in reading styles in the dyads. For descriptive statistics of raw values and a ratio of each category per duration of the reading situation, see **Table 3**.

Narrative utterances to narrative animations constituted 35 %, whereas illustrative utterances to illustrative animations represented 13 % of all utterances. Operative utterances to the animation types as a large category made up 37 %. Operative-narrative together with operative-illustrative and narrative-navigating constituted smaller categories at 7, 5, and 3 %, respectively (all values based on means and rounded off).

A Friedman test based on the ratio values indicated that across all categories, utterances differed significantly from each other, $\chi^2(5) = 44.41$, $p < 0.001$, $n = 12$. Pairwise comparisons with subsequent Wilcoxon tests revealed that operative did not differ significantly from narrative, but from all other categories (illustrative: $p = 0.019$, operative-narrative: $p = 0.002$, operative-illustrative: $p = 0.003$, narrative-navigating: $p = 0.002$). The category narrative also differed significantly from all other categories (all $p$s $= 0.002$). This revealed that the narrative mode of reference to narrative animations (narrative) was just as frequent as the operative category, but all other categories occurred significantly less often.

With regard to these categories, illustrative references to illustrative animations (illustrative) were used similarly frequently as operative references to narrative animations (operative-narrative, $p = 0.11$), but significantly more often than operative-illustrative and narrative-navigating (both $p$s $< 0.05$).

Adults used operative-narrative utterances significantly more often than operative-illustrative and narrative-navigating (both $p$s $< 0.05$). Operative references to illustrative animations (operative-illustrative) were less frequent, and the least frequent

**TABLE 3** | Mode of adult's references to animation types ($n = 12$).

| Category | No. of utterances | | | No. of utterances/min | | |
|---|---|---|---|---|---|---|
| | *Md* | Min | Max | *Md* | Min | Max |
| Narrative | 25.50 | 2 | 45 | 2.15 | 0.18 | 4.48 |
| Illustrative | 6.00 | 0 | 28 | 0.45 | 0.00 | 2.03 |
| Operative-narrative | 5.50 | 0 | 16 | 0.42 | 0.00 | 1.17 |
| Operative-illustrative | 3.00 | 0 | 11 | 0.24 | 0.00 | 0.79 |
| Narrative-navigating (turn page) | 0.50 | 0 | 13 | 0.05 | 0.00 | 1.16 |
| Operative | 30.50 | 1 | 61 | 2.21 | 0.11 | 4.33 |
| Utterances (total) | 74.00 | 22 | 122 | 5.26 | 2.51 | 12.31 |
| Reading duration (min.) | 12.54 | 8.75 | 17.68 | | | |

was referencing narrative in turning the pages (narrative-navigating). However, this comparison did not attain significance ($p = 0.11$).

Reliability was established by a second coder rating 25 % of the videos. Intercoder reliability was very good to perfect (Krippendorff's $\alpha$ ranged between $p = 0.83$ and $p = 1.00$ for all six categories).

## Discussion of the Modes of Adults' Verbal References

Adults showed different modes of referencing during shared reading of the Grömmels app when considering the content of utterances. The most frequent were exclusively operative utterances to narrative, illustrative, and navigating animation types and, to the same amount, narrative references to narrative animations. Together with the results of the analysis of animation types and the app analysis, we can conclude that the narrative potential of the app was not exploited fully in a shared reading situation with a child. Even though adults referred to a large amount of narrative animations and often did so in a narrative mode, nearly the same amount of utterances addressed operating the animations.

Analysis 2b adds an important aspect regarding the content of the adults' references to the first two analyses (app materiality and the number of references to animation types): Although the app presents about 60 % narrative animations, and talk about narrative animations is slightly less frequent within a reading situation (55 % of all utterances), Analysis 2b reveals that narrative talk about narrative animations represents only 35 % of the dialogue. Illustrative talk about illustrative animations still constitutes 13 %, whereas the majority of utterances are about operating aspects (categories operative-narrative, operative-illustrative, and operative) representing 50 % of all utterances.

Thus, in digital reading situations, a large part of the talk addresses the digital nature of the app—talk that does not occur within an analog shared book reading situation. Illustrative talk to illustrative animations also takes place to the same extent as operative talk to narrative animations that also had some narrative aspects or referred to the story's characters. Operating aspects of illustrative animations and narrative comments on navigating were comparatively low.

## Story Comprehension

In our explorative analysis focusing on children's story comprehension, we examined descriptively the children's answers (*correct*, *incorrect*, *no answer*) to the story comprehension questions in relation to the six coding categories of the mode of adults' utterances of the dyads and reading duration ($n = 6$).

The number of correctly answered questions was low overall (*correct answers: Md* = 1, range 0 to 5, *incorrect answers: Md* = 1, range 0 to 2, *no answer*: *Md* = 4, range 1 to 5). Therefore, we examined children's story comprehension and adults' verbal reference categories in a subsample of dyads in which adults used more narrative speech—thereby assuming that there would be a clearer relationship in these dyads. We performed a median split with the sample of the interaction analysis ($n = 12$) and identified this way six dyads with a higher ratio of the narrative category and analyzed the data of the dyads in which children had completed the story comprehension test ($Md > 2.15$, $n = 4$).

**Table 4** reports the number of children's correctly answered, incorrectly answered, and unanswered questions for every single dyad as well as the respective reading duration and the mode of adults' utterances sorted by reading duration. For this analysis, and against the background that especially narrative references might foster the children's story comprehension, we summed up all categories other than narrative to one single category ("other than narrative") for these four dyads.

A first analysis of the data suggested that children gave more incorrect answers on the comprehension of the story after longer digital reading situations as the number of incorrect responses was higher for those children experiencing a longer reading session (cf. **Table 4**).

With regard to the number of adults' overall utterances, the data shows that when the adults produced more utterances, the children's answers were less correct. This relationship is also mirrored in the number of no answers and the ratio of the quantity of all utterances per minute (utterances/min). The more utterances were produced in relation to the reading duration, the less children gave any answer.

The categories of the coding scheme suggest that the rate of narratives in relation to reading duration (narrative/min) might be related negatively to no answers, in the way that

**TABLE 4 |** Results on children's story comprehension, reading duration and adults' utterances per dyad ($n = 4$).

| Dyad | Reading duration (min) | Utterances | Utterances/ min | Narrative/ min | Other than narrative/min | Correct answer | Incorrect answer | No answer |
|---|---|---|---|---|---|---|---|---|
| 1 | 9.83 | 121 | 12.31 | 0.36 | 7.83 | 1 | 0 | 5 |
| 2 | 11.16 | 85 | 7.62 | 0.29 | 5.38 | 1 | 1 | 4 |
| 3 | 12.70 | 69 | 5.43 | 0.41 | 3.23 | 5 | 1 | 1 |
| 4 | 17.68 | 122 | 6.90 | 0.37 | 4.36 | 0 | 2 | 4 |

the more narrative utterances to narrative animations in the reading situation, the more children found an answer to the story comprehension questions (i.e., the lesser the number of "no answers"), although this observation is based on the behavior of a single dyad (no. 3). This child also showed the highest number of correct test responses. Conversely, a combined category of all five utterance types other than narrative might be related positively to no answers, in the way that the more utterances in the categories, the less children gave an answer. However, these descriptive results simply report data of four single app reading dyads, and have to be interpreted carefully as they sometimes rely on observations of a single dyad's behavior.

### Discussion of the Story Comprehension

Taking story comprehension into account, descriptive results in a subsample of dyads in which the adults used a high rate of narrative utterances to narrative animations in relation to reading duration show that a higher number of utterances goes along with a lesser quantity of correct answers. Furthermore, when adults produced a higher number of utterances in relation to the duration of the reading situation, children more often left answers out.

All categories other than narrative related equally to children's left-out answers. In contrast, one dyad's child showed the best story comprehension after experiencing the most narrative utterances per minute in a reading session. Potentially, this observation indicates that narrative references of the adult lead to less left out answers and even more correct answers. However, this fact is in line with previous research that has shown narrative references to foster story comprehension (Korat, 2010; Sargeant, 2013, p. 32; Kao et al., 2016). This might possibly point out that our sample of four dyads also mirrors reading behavior that has been found in larger samples. Reading duration negatively affected the number of correctly answered questions in the way that the longer the reading duration, the higher the amount of incorrect answers in the children. Taken together, these results might indicate that story comprehension was lower when (a) reading duration was longer and (b) when adults made more utterances except for narrative utterances. However, these observations can offer only first suggestions regarding story comprehension in digital reading and point to the relevance of further research assessing the role of adult readers' verbal references to animations in processing digital stories.

## GENERAL DISCUSSION AND PRACTICAL IMPLICATIONS

In this study, we aimed to investigate how adult caregivers use animations of picture-book apps to involve children in stories from a media- as well as an interaction-oriented perspective. We first conducted an analysis of the app used in our study to determine the quantity of narrative animations (Analysis 1). Secondly, based on a quantitative interaction analysis, we examined how often (Analysis 2a) and in which content-related mode (Analysis 2b) adult readers make use of narrative animations to exploit the narrative potential of the app. Additionally, in an explorative analysis and as a starting point for further research, we also included children's story comprehension scores after digital reading to generate assumptions on the role of adults' verbal references for children's early story comprehension for a small subsample.

By adopting a two-fold approach, we aimed to close a research gap and combine an analysis of the medium with an analysis of interaction in dyads with the medium. Results suggest a promising number of narrative animations in the app, but adults do not fully exploit this potential in shared reading. Furthermore, derived from our explorative analysis on story comprehension, there are preliminary indicators that a prolonged reading duration might play a role in processing digital stories.

## Discussion of the Analyses

With regard to Analysis 1, note that from a theoretical point of view, the Grömmels app is promising with respect to children's story comprehension because it provides numerous narrative animations that can be used in shared reading to engage the child in the narrative. But, despite the high number of narrative animations, the app also contains technical features that may have a negative effect on story engagement, attention, and cognitive and verbal processing by providing a high proportion of automatically activated and constantly running visual + audio animations that cannot be deactivated (e.g., permanent buzzing flies or sounds of eating). Furthermore, adding a qualitative level of analysis, 32 % of the animations consist of multisectional sounds or visual images that take place at the same time or in quick succession and may lead to cognitive overload (e.g., the door opens with a squeaking noise and the little pig sticks its head through the door and grunts a couple of times). By the term "multisectional," we refer to an animation consisting entirely of one or several subanimations that are interrelated regardless of whether they are linked by content, serve as complementary elements, or start simultaneously. Several visual + audio large-scale animations (9 %) operate all over the screen (e.g., the little pig sits on a ceiling lamp swinging from one side to the other) and several further animations (9 %) bear a risk of inducing auditory overload because they consist of multiple sound effects and background noises. Furthermore, the relatively high number of illustrative animations, hotspots, and animations played with an auditory component can potentially distract the reader.

Yet, a further descriptive level of analysis needs to be added to capture the app's functions in their entirety and to interpret its merits and demerits: the temporal appearance of the hotspots. During the reading process, it is notable that the hotspots appear arbitrarily in time and disorderly in terms of the story's progress. Therefore, the animations cannot be integrated into the narrative by the reader. Instead, a presentation of hotspots that corresponds to the story in terms of time and sequence would provide a beneficial context to the narrative.

With regard to Analyses 2 a and 2b, results from interaction analyses focusing on the type (Analysis 2a) and mode (Analysis 2b) of adults' verbal references show that adults refer most frequently to narrative animations, but not in a narrative way. This means that they do not use these animations primarily to engage the child in the story. Instead, they concentrate more on operating the animation. This also counts for illustrative and navigating animations, resulting in a predominance of operative references as the largest category with 49 %. A first analysis step (Analysis 2a) shows that adults refer twice as much to narrative as to illustrative animations, and percentages almost represent the ratio of the existing narrative to illustrative animations. But the content analysis in the second step (Analysis 2b) finally reveals that operating the app's animations is the most prominent mode of reference.

With regard to the story comprehension analysis, results provide first indicators that narrative references to narrative animations not necessarily guarantee that children are involved in the story, even though the small sample size restricts the generalization of these results to the population and limits interpreting the results in depth and reliability. We hope these results encourage future research for investigating this relationship thoroughly. There are also further limitations, such as we did not assess children's initial skill levels and include these in the analyses, although they have been shown to be relevant for story comprehension (Reese and Cox, 1999).

Moreover, the story comprehension assessment also requires productive language skills because children have to answer the questions. Thus, it may be considered to be quite demanding at this age, particularly as the characters' internal plans are relevant for half of the story comprehension questions. As Miosga (2020) has already pointed out, answers on factual information were superior to those on inference information.

At the same time, adults' concentration on the operative mode results in a high degree of operative talk leading to an extended reading duration that may affect children's story comprehension. Reading duration may have negatively affected the number of answered questions, suggesting that long reading sessions and a lot of operative input might raise the processing load. This suggestion is supported by an observation concerning the reading length: In the study by Miosga (2020) that compared analog and digital reading situations based on this app, reading duration differed significantly between both conditions; the digital reading session being around one third longer than the analog session.

Thus, we assume that the high amount of operative utterances combined with extended reading duration may have a negative effect on children's story comprehension, though, interpreting the results against the background of a small sample size that substantially limits drawing inferences and generalizations. The negative effect might potentially derive from a cognitive overload not only drawing children's attention away from the story and the thematic dimension of the reading, but also providing a less cognitively activating and content-related language input compared to analog book reading (Bus et al., 2015; Miosga, 2020). The high degree of operative talk may also affect the impact of dialogic reading routines that have proved to be advantageous for children's emergent literacy (Whitehurst and Lonigan, 1998). However, these analyses are considered only to be preliminary. Further analysis has to clarify whether these findings are replicable.

## Practical Implications and Outlook

The results of this study address several practice-related aspects: The app analysis suggests that in terms of story comprehension, the quality of an app results not only from the presence of numerous narrative animations but also from restricting the number of large-scale and multisectional animations that can carry cognitively overloading input and using a small, but targeted number of hotspots that correspond to the story in terms of time and sequence. The ViSAR model provides a theoretical basis that can be applied not only for study purposes but also in app design. Especially for developers of commercial apps, it might be interesting to know that "less can be more," and that the nature and temporal design of animations are of importance; or, in other words, that it is more about the "how" and "when" of the animations than about the quantity.

Building on previous practical insights into what constitutes a "good" app for emergent literacy skills, the ViSAR model can enrich the search for conducive features, and it complements existing quality criteria and recommendations (Smeets and Bus, 2013). In particular, visual animations coordinated with the text have proved useful for word learning (Takacs and Bus, 2016). Interactive functions such as hotspots are also superior to pure text reading for word learning (Smeets and Bus, 2013). But what applies to word learning does not necessarily apply to story comprehension. Takacs (2015, pp. 144–145) formulates guidelines for app developers, parents, and educators on digital children's books based on the empirical evidence available to date and refers particularly to the integration of interactive animations and their effects on story comprehension. Therefore, the use of animated illustrations and the inclusion of sound and musical elements to illustrate the story is recommended. However, animations should be congruent with the text in terms of both content and timing. Animations can serve as a means of drawing the child's attention to individual details of the illustrations. Our results confirm these guidelines and can contribute differentiated recommendations on which type of animations has narrative potential.

A high proportion of narrative animations can be seen as beneficial because they enable the reader to involve the child in the story when being used in a narrative mode. At the same time, a high number of illustrative animations, hotspots, and animations that are played with an auditory component can potentially distract the reader (see also Parish-Morris et al., 2013; Smeets and Bus, 2013; Yokota and Teale, 2014). Overall, we conclude that when designing and developing picture-book apps, the proportion of illustrative and auditory animations should be reduced, and they should be used only sparingly and in a well-dosed manner (see also Smeets and Bus, 2013). The proportion of narrative parallel animations, in contrast, should be increased. Such animations might facilitate story comprehension in younger children and children with (linguistic or perceptual) impairments (see also Smeets et al., 2014), whereas numerous unconnected animations such as hotspots that appear arbitrarily in time and without relation to the story's progress can distract them. The reader cannot integrate such animations into the narrative. Instead, hotspots that correspond to the story in terms of time and sequence would provide a beneficial context to the narrative.

Previous quality criteria for picture-book apps in terms of story comprehension have been developed on the basis of empirical studies using specially designed apps. There, positive effects of digital story book reading on story comprehension in preschool age are often based on a non-commercial electronic book story designed especially for study purposes and optimized in accordance with literacy learning principles (Korat, 2009, 2010). Our study complements these results by providing recommendations for widely used commercial apps that have not been optimized deliberately for literacy learning. With regard to promoting narrative skills such as storytelling and story comprehension, our detailed interaction analyses preliminarily suggest that a high number of narrative animations does not lead to their integration into shared reading in a narrative way. On the contrary, hotspots lead to a large amount of operative talk, and large-scale moving images may lead to cognitive overload and shut down. This may apply especially when commercial apps are used for reading because these are not programmed according to psychological, pedagogical, or developmental criteria. Provided that the animations are especially designed as "narrative" with respect to the story, adults may be better able to refer to them; but when using commercial apps, the animations may not be a suitable resource for adults' reading dialogues.

Most importantly, these findings have practical implications on how to use narrative animations in interaction effectively. Guidelines for parents, practitioners, and caregivers should include recommendations on how to use narrative animations or animations in the narrative mode. For example, adults should take care that they refer to narrative animations in terms of the story and that they comment on the content. Moreover, illustrative animations can provide an opportunity to adapt adult's utterances to the child's everyday life experiences as well; in this case also through joint engagement and content-related, decontextualized language input that fosters story comprehension. Adults support story comprehension when making sure to link dialogues on illustrative animation back to the story. In sum, quality criteria for apps should be differentiated according to the target perspective and the area of support. For this very reason, it is essential for the adult reference person to take a reflected approach to the animations.

Illustrations in picture storybooks are multifunctional and need to be interpreted (Schickedanz and Collins, 2012). This may also be applied to electronic features. Practitioners should consider the ways in which technology can help support children in specific areas. They should try out different interactive apps and experiment with the interactive features. Self-reflection on how these functions affect their reading of the text will lead to a more conscious approach. Electronic resources can thus deliver a potential benefit compared to analog reading. The present study contributes to research on the nature of these potentials.

However, our interaction studies are subject to some further limitations: First, the age range of the children was quite high, making our sample rather heterogeneous. Because parents attune to their children, their reading behavior is influenced by age (e.g., Barachetti and Lavelli, 2011; see also Strouse and Ganea, 2017). Moreover, children's story comprehension is better at an older age (e.g., Parish-Morris et al., 2013), and this might have impacted on our story comprehension results. The book and the app might also have been quite demanding and too long for some of the children in the age group tested here. Hence, it would be desirable to examine more homogeneous samples of slightly older children with this app.

Another limitation is inherent to the chosen method of quantitative content analysis because categories represent a selected choice and contain rather fixed boundaries compared to other methods. Moreover, we concentrated on examining talk referring to animations and hotspots in this study without further considering the talk outside these animations such as comments on the whole scenes or utterances about the story itself. Additionally, the content analysis distinguished only two broad categories: adults' narrative and operative utterances. It would be worth expanding these analyses and considering precisely the adults' verbal behavior in digital book reading. Miosga (2020) has already shown that the content of utterances differs between digital and analog book reading, and such analyses might be extended to other categories that have been identified as fostering language development such as decontextualized language.

Further research on the use of animations in interactive reading situations might not only consider both children and caregivers, but also include conversational analysis in order to display the mutual process of attunement and multimodal communication. As desiderata for literacy learning, we also recommend a further validation of the ViSAR model and the development of apps on the basis of the ViSAR model testing them systematically in the field. We strongly recommend examining both the digital medium and its application in interaction in order to further analyze the potential of digital picture-book apps and shared reading situations.

## DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because the data used in this article are processed under the informed consent, which excludes passing the data on. Requests to further information on the datasets should be directed to Christiane Miosga, christiane.miosga@ifs.uni-hannover.de.

## ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

CM-B, CM, and SF contributed to conception and design of the study. SF, CM-B, and AM performed the analyses and statistical analyses. SF, AM, IP, CM-B, and CM wrote the methods chapter of the manuscript and discussion of the manuscript. SF, AM, and IP wrote the results. All authors contributed to the section practical implication and outlook. All authors also contributed to manuscript revision, read, and approved the submitted version.

## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.593482/full#supplementary-material

## REFERENCES


Aguilera, E., Kachorsky, D., Gee, E., and Serafini, F. (2016). Expanding analytical perspectives on children's picturebook apps. *LR:TMP* 65, 421–435. doi: 10.1177/2381336916661516

Aliagas, C., and Margallo, A. M. (2015). "iPads, emergent readers and families," in *Digital Literature for Children: Texts, Readers and Educational Practices*, eds M. Manresa, N. Real (Brussels: Peter Lang), 155–172.

Barachetti, C., and Lavelli, M. (2011). Responsiveness of children with specific language impairment and maternal repairs during shared book reading. *IJLCD* 46, 579–591. doi: 10.1111/j.1460-6984.2011.00032.x

Bitkom (2019). Kinder und Jugendliche in der digitalen Welt. Available online at: https://www.bitkom.org/sites/default/files/2019-05/bitkom_pk-charts_kinder_und_jugendliche_2019.pdf (accessed August 05, 2020).

Blewitt, P., Rump, K. M., Shealy, S. E., and Cook, S. A. (2009). Shared book reading: when and how questions affect young children's word learning. *J. Educ. Psychol.* 101, 294–304. doi: 10.1037/a0013844

Boelmann, J. M. (2019). "Hörspiele," in *Handbuch Lehr- und Lernmittel für den Deutschunterricht. Bestandsaufnahmen, Analysen, didaktische Reflexionen*, eds T. von Brand, and F. Radvan (Hanover: Klett Kallmeyer), 249–261.

Bus, A. G., Takacs, Z. K., and Kegel, C. A. (2015). Affordances and limitations of electronic storybooks for young children's emergent literacy. *Dev. Rev*. 35, 79–97. doi: 10.1016/j.dr.2014.12.004

Chaudron, S., Di Gioia, R., and Gemo, M. (2018). *Young Children (0–8) and Digital Technology: A Qualitative Exploratory Study Across Seven Countries*. Publications Office of the European Union. doi: 10.2760/294383

Clemens, L. F., and Kegel, C. A. T. (2020). Unique contribution of shared book reading on adult-child language interaction. *J. Child Lang.* 11, 1–14. doi: 10.1017/S0305000920000331

Courage, M. L. (2019). "From print to digital: The medium is only part of the message," in *Reading in the Digital Age: Young Children's Experiences with E-books*, eds J. E. Kim, and B. Hassinger-Das (Cham: Springer), 23–43.

Curenton, S. M., Craig, M. J., and Flanigan, N. (2008). Use of decontextualized talk across story contexts: how oral storytelling and emergent reading can scaffold children's development. *Early Educ. Dev.* 19, 161–187. doi: 10.1080/10409280701839296

Demir, Ö. E., Rowe, M. L., Heller, G., Goldin-Meadow, S., and Levine, S. C. (2015). Vocabulary, syntax, and narrative development in typically developing children and children with early unilateral brain injury: early parental talk about the "there-and-then" matters. *Dev. Psychol.* 51, 161–175. doi: 10.1037/a0038476

Dickinson, D. K., Griffith, J. A., Golinkoff, R. M., and Hirsh-Pasek, K. (2012). How reading books fosters language development around the world. *Child Dev. Res.* doi: 10.1155/2012/602807

Doty, D. E., Popplewell, S. R., and Byers, G. O. (2001). Interactive CD-ROM storybooks and young readers' reading comprehension. *J. Res. Comput. Educ*. 33, 374–384. doi: 10.1080/08886504.2001.10782322

Ehmig, S. C., and Reuter, T. (2013). Vorlesen im Kinderalltag. Bedeutung des Vorlesens für die Entwicklung von Kindern und Jugendlichen und Vorlesepraxis in den Familien. Zusammenfassung und Einordnung zentraler Befunde der Vorlesestudien von Stiftung Lesen, DIE ZEIT und Deutsche Bahn 2007-2012. Retrieved from https://www.stiftunglesen.de/download.php?type=documentpdf&id=951 (accessed August 05, 2020).

Fox, C. (1993). *At the Very Edge of the Forest: The Influence of Literature on Storytelling by Children*. London: Cassell.

Grimminger, A., Rohlfing, K. J., Lüke, C., Liszkowski, U., and Ritterfeld, U. (2019). Decontextualized talk in caregivers' input to 12-month-old children during structured interaction. *J. Child Lang.* 47, 418–434. doi: 10.1017/S0305000919000710

Grolig, L., Cohrdes, C., Tiffin-Richards, S. P., and Schroeder, S. (2019). Effects of preschoolers' storybook exposure and literacy environments on lower level and higher level language skill. *Read. Writ.* 32, 1061–1084. doi: 10.1007/s11145-018-9901-2

Hargrave, A., and Sénéchal, M. (2000). A book reading intervention with preschool children who have limited vocabularies: the benefits of regular reading and dialogic reading. *Early Child. Res. Q.* 15, 75–90. doi: 10.1016/S0885-2006(99)00038-1

Herodotou, C. (2018). Young children and tablets: a systematic review of effects on learning and development. *J. Comp. Assist. Learn.* 34, 1–9. doi: 10.1111/jcal.12220

Hildebrandt, F., Scheidt, A., Hildebrandt, A., Hédervári-Heller, É., and Dreier, A. (2016). Sustained shared thinking als Interaktionsformat und das Sprachverhalten von Kindern. *Frühe Bildung* 5, 82–90. doi: 10.1026/2191-9186/a000256

Hoffman, J. L., and Paciga, K. A. (2014). Click, swipe, and read: sharing e-books with toddlers and preschoolers. *Early Child. Educ. J.* 42, 379–388. doi: 10.1007/s10643-013-0622-5

Ihmeideh, F. M. (2014). The effect of electronic books on enhancing emergent literacy skills of pre-school children. *Comput. Educ.* 79, 40–48. doi: 10.1016/j.compedu.2014.07.008

Justice, L. M., and Ezell, H. K. (2000). Enhancing children's print and word awareness through home-based parent intervention. *Am. J. Speech-Lang. Pathol.* 9, 257–269. doi: 10.1044/1058-0360.0903.257

Kabali, H. K., Irigoyen, M. M., Nunez-Davis, R., Budacki, J. G., Mohanty, S. H., Leister, K. P., et al. (2015). Exposure and use of mobile media devices by young children. *Pediatrics* 136, 1044–1050. doi: 10.1542/peds.2015-2151

Kao, G., Y.-M., Tsai, C.-C., Liu, C.-Y., and Yang, C.-H. (2016). The effects of high/low interactive electronic storybooks on elementary school students' reading motivation, story comprehension and chromatics concepts. *Comput. Educ.* 100, 56–70. doi: 10.1016/j.compedu.2016.04.013

Knopf, J. (2018). "Bilderbuch-Apps im Kindergarten und in der Primarstufe. Potential für das literarische Lernen?!," in *Digitalisierung und Bildung*, eds S. Ladel, J. Knopf, and A. Weinberger (Wiesbaden: Springer), 23–38. doi: 10.1007/978-3-658-18333-2_2

Korat, O. (2009). The effects of CD-ROM storybook reading on Israeli children's early literacy as a function of age group and repeated reading. *Educ. Inf. Technol.* 14, 39–53. doi: 10.1007/s10639-008-9063-y

Korat, O. (2010). Reading electronic books as a support for vocabulary, story comprehension and word reading in kindergarten and first grade. *Comput. Educ.* 55, 24–31. doi: 10.1016/j.compedu.2009.11.014

Krcmar, M., and Cingel, D. P. (2014). Parent–child joint reading in traditional and electronic formats. *Media Psychol.* 17, 262–281. doi: 10.1080/15213269.2013.840243

Kucirkova, N., and Littleton, K. (2016). The digital reading habits of children. A national survey of parents' perceptions of and practices in relation to children's reading for pleasure with print and digital books. Book Trust. Retrieved from: https://www.booktrust.org.uk/globalassets/resources/research/digital_reading_survey-final-report-8.2.16.pdf (accessed August 05, 2020).

Kümmerling-Meibauer, B., and Meibauer, J. (2005). First pictures, early concepts: early concept books. *Lion Unicorn* 29, 324–347. doi: 10.1353/uni.2005.0039

Kümmerling-Meibauer, B., and Meibauer, J. (2015). "Picturebooks and early literacy. How do picturebooks support early conceptual development?," in *Learning from picturebooks. Perspectives from child development and literacy studies*, eds B. Kümmerling-Meibauer, J. Meibauer, K. Nachtigäller, and K. R. Rohlfing (London: Routledge), 13–32.

Kurwinkel, T. (2017). *Bilderbuchanalyse. Narrativik – Ästhetik – Didaktik*. Stuttgart: UTB.

Lee, S. H. (2020). Learning vocabulary from e-book reading and recorded word explanation for low-income elementary students with and without reading difficulties. *Read. Writ.* 33, 691–717. doi: 10.1111/lang.12411

McPake, J., Plowman, L., and Stephen, C. (2013). Pre-school children creating and communicating with digital technologies in the home. *Br. J. Educ. Technol.* 44, 421–431. doi: 10.1111/j.1467-8535.2012.01323.x

Miosga, C. (2020). "Cognitively activating and emotionally attuning interactions: their relevance for language and literacy learning and teaching with digital media," in *International Perspectives on Digital Media and Early Literacy: The Impact of Digital Devices on Learning, Language Acquisition and Social Interaction*, eds K. J. Rohlfing, and C. Müller-Brauers (London: Routledge), 27–49.

Miosga, C., and Müller-Brauers, C. (2019). "Digitale Kinderliteratur im Kontext der kindlichen Literacy-Entwicklung – Potentiale und interaktive Herausforderungen," in *Presentation at the GAL-Conference*. Halle.

Miosga, C., and Müller-Brauers, C. (2020). "Vorlesen digitaler Kinderliteratur - konversationsbezogene Analysen. Presentation at the 2nd international workshop," in Kinder im Gespräch – Mit Kindern im Gespräch. Halle.

Miosga, C., Müller-Brauers, C., and Hahn, A. (in press). Mit Bilderbuch-Apps in Geschichten eintauchen — Ideen für den inklusiven Deutschunterricht. Praxis Grundschule 1, 28–33.

Müller-Brauers, C., Boelmann J. M., Miosga, C., and Potthast, I. (2020). "Digital children's literature in the interplay of visuality and animation - A model to analyze picture book apps and their potential for children's story comprehension," in *International Perspectives on Digital Media and Early Literacy: The Impact of Digital Devices on Learning, Language Acquisition and Social Interaction*, eds K. J. Rohlfing, and C. Müller-Brauers (London: Routledge), 161–179.

Neumann, M. M. (2014). An examination of touch screen tablets and emergent literacy in Australian pre-school children. *Aust. J. Educ.* 58, 109–122. doi: 10.1177/0004944114523368

Neumann, M. M., and Neumann, D. L. (2017). The use of touch-screen tablets at home and pre-school to foster emergent literacy. *J. Early Child. Lit.* 17, 203–220. doi: 10.1177/1468798415619773

Nikolajeva, M., and Scott, C. (2006). *How Picturebooks Work*. London: Routledge.

Ofcom (2018). Children and parents: Media use and attitudes report. Retrieved from: https://www.ofcom.org.uk/__data/assets/pdf_file/0024/134907/children-and-parents-media-use-and-attitudes-2018.pdf (accessed August 05, 2020).

Ofcom (2019). Children and parents: Media use and attitudes report. Retrieved from: https://www.ofcom.org.uk/__data/assets/pdf_file/0023/190616/children-media-use-attitudes-2019-report.pdf (accessed August 05, 2020).

Ólafsson, K., Livingstone, S., and Haddon, L. (2014). *Children's Use of Online Technologies in Europe. A Review of the European Evidence Base.* LSE, London: EU Kids Online. Retrieved from: http://eprints.lse.ac.uk/60221/1/EU_Kids_Online_Children%E2%80%99sUseofOnlineTechnologiesinEurope_ReviewofEuropeanEvidenceBase_Revised_2014.pdf (accessed August 05, 2020).

Parish-Morris, J., Mahajan, N., Hirsh-Pasek, K., Golinkoff, R. M., and Collins, M. F. (2013). Once upon a time: parent–child dialogue and storybook reading in the electronic era. *Mind Brain Educ.* 7, 200–211. doi: 10.1111/mbe.12028

Pesco, D., and Gagné, A. (2017). Scaffolding narrative skills: a meta-analysis of instruction in early childhood settings. *Early Educ. Dev.* 28, 773–793. doi: 10.1080/10409289.2015.1060800

Real, N., and Correro, C. (2015). "Digital literature in early childhood. Reading experiences in family and school contexts," in *Digital Literature for Children: Texts, Readers and Educational Practices*, eds M. Manres, and N. Real (Brussels: Peter Lang), 173–189.

Reese, E., and Cox, A. (1999). Quality of adult book reading affects children's emergent literacy. *Dev Psychol.* 35, 20–28. doi: 10.1037/0012-1649.35.1.20

Reich, S. M., Yau, J. C., Xu, Y., Muskat, T., Uvalle, J., and Cannata, D. (2019). Digital or print? A comparison of preschoolers' comprehension, vocabulary, and engagement from a print book and an e-book. *AERA Open* 5, 1–16. doi: 10.1177/2332858419878389

Reid-Chassiakos, Y., Radesky, J., Christakis, D., Moreno, M., and Cross, C. (2016). Children and adolescents and digital media. *Pediatrics* 138, 2016–2593. doi: 10.1542/peds.2016-2593

Rowe, M. L. (2012). A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Dev.* 83, 1762–1774. doi: 10.1111/j.1467-8624.2012.01805.x

Sargeant, B. (2013). Interactive storytelling: How picture book conventions inform multimedia book app narratives. *AJIIPS* 13, 29–35.

Sargeant, B. (2015). What is an ebook? What is a book app? And why should we care? An analysis of contemporary digital picture books. *Child. Lit. Educ.* 46, 454–466. doi: 10.1007/s10583-015-9243-5

Sari, B., Takacs, Z. K., and Bus, A. G. (2019). What are we downloading for our children? Best-selling children's apps in four European countries. *J. Early Child. Lit* 19, 515–532. doi: 10.1177/1468798417744057

Schickedanz, J. A., and Collins, M. F. (2012). For young children, pictures in storybooks are rarely worth a thousand words. *Read. Teach*. 65, 539–549. doi: 10.1002/TRTR.01080

Sénéchal, M., and LeFevre, J. (2001). "Storybook reading and parent teaching: Links to language and literacy development," in *New directions in child development: No. 92. The Role of Family Literacy Environments in Promoting Young Children's Emerging Literacy Skills*, eds P. R. Britto, and J. Brooks-Gunn (San Francisco, CA: Jossey-Bass), 39–52.

Serafini, F., Kachorsky, D., and Aguilera, E. (2016). Picture books in the digital age. *Read. Teach*. 69, 509–512. doi: 10.1002/trtr.1452

Shamir, A., and Baruch, D. (2012). Educational e-books: a support for vocabulary and early math for children at risk for learning disabilities. *Educ. Media Int.* 49, 33–47. doi: 10.1080/09523987.2012.662623

Shamir, A., and Korat, O. (2007). Developing an educational e-book for fostering kindergarten children's emergent literacy. *Comput. Sch.* 24, 125–143. doi: 10.1300/J025v24n01_09

Shamir, A., and Shlafer, I. (2011). E-books effectiveness in promoting phonological awareness and concept about print: a comparison between children at risk for learning disabilities and typically developing kindergarteners. *Comp. Educ.* 57, 1989–1997. doi: 10.1016/j.compedu.2011.05.001

Siraj-Blatchford, I. (2007). Creativity, communication and collaboration: The identification of pedagogic progress in sustained shared thinking. *Asia-Pacific J. Res. Early Childhood Educ.* 1, 3–23.

Smeets, D., and Bus, A. G. (2013). "Picture storybooks go digital: Pros and cons," in *Quality Reading Instruction in the Age of Common cAre Standards,* eds S. B. Neuman, and L. B. Gambrell (Newark, DE: International Reading Association), 176–189.

Smeets, D., and Bus, A. G. (2015). The interactive animated e-book as a word learning device for kindergartners. *Appl Psycholinguist.* 36, 899–920. doi: 10.1017/S0142716413000556

Smeets, D., van Dijken, M. J., and Bus, A. G. (2014). Using electronic storybooks to support word learning in children with severe language impairments. *JLD* 47, 435–449. doi: 10.1177/0022219412467069

Staiger, M. (2014). "Erzählen mit Bild-Schrifttext-Kombinationen. Ein fünfdimensionales Modell der Bilderbuchanalyse," in *BilderBücher. Vol 1 Theorie*, eds J. Knopf, and U. Abraham (Baltmannsweiler: Schneider), 12–23.

Starke, A., Leinweber, J., and Ritterfeld, U. (2020). "Designing apps to facilitate first and second language acquisition in children," in *International Perspectives on Digital Media and Early Literacy: The Impact of Digital Devices on Learning, Language Acquisition and Social Interaction*, eds K. J. Rohlfing, and C. Müller-Brauers (London: Routledge).

Steinseifer, M. (2011). "Die Typologisierung multimodaler Kommunikationsangebote. Am Beispiel der visuellen Aspekte seitenbasierter Dokumente," in *Textsorten, Handlungsmuster, Oberflächen. Linguistische Typologien der Kommunikation*, ed S. Habscheid (Berlin: Walter de Gruyter), 164–189.

Stern, D. N. (2000). *The Interpersonal World of the Infant: A View From Psychoanalysis and Development Psychology* (2nd ed. with new introduction). New York, NY: Basic Books.

Stiftung Lesen and Leipziger Buchmesse (2013). Leipziger Lesekompass. Fürs Lesen begeistern. 2-6 Jahre. Eine Orientierungshilfe im Buch- und Medienmarkt für Eltern, Erzieherinnen und Erzieher. Retrieved from: https://www.stiftunglesen.de/download.php?type=documentpdf&id=825 (accessed July 01, 2020).

Strouse, G. A., and Ganea, P. A. (2017). Parent–toddler behavior and language differ when reading electronic and print picture books. *Front. Psychol.* 8:677. doi: 10.3389/fpsyg.2017.00677

Strouse, G. A., O'Doherty, K., and Troseth, G. L. (2013). Effective coviewing: preschoolers' learning from video after a dialogic questioning intervention. *Dev. Psychol.* 49, 2368–2382. doi: 10.1037/a0032463

Takacs, Z. K. (2015). *On-Screen Children's Stories: The Good, the Bad and the Ugly.* [Dissertation]. Leiden: Leiden University.

Takacs, Z. K., and Bus, A. G. (2016). Benefits of motion in animated storybooks for children's visual attention and story comprehension. An eye-tracking study. *Front. Psychol* 7:1591. doi: 10.3389/fpsyg.2016.01591

Takacs, Z. K., Swart, E. K., and Bus, A. G. (2014). Can the computer replace the adult for storybook reading? A meta-analysis on the effects of multimedia stories as compared to sharing print stories with an adult. *Front. Psychol* 5:1366. doi: 10.3389/fpsyg.2014.01366

Thiele, J. (2000). "Das Bilderbuch," in *Das Bilderbuch: Ästhetik – Theorie – Analyse – Didaktik – Rezeption*, ed J. Thiele (Oldenburg: Isenseep), 70–98.

Towson, J., Fettig, A., Fleury, V., and Abarca, D. (2017). Dialogic reading in early childhood settings: a summary of the evidence base. *Topics Early Child Spec. Educ.* 37, 132–146. doi: 10.1177/027112141772487

Verhallen, M. J. A. J., Bus, A. G., and de Jong, M. T. (2006). The promise of multimedia stories for kindergarten children at risk. *J. Educ. Psychol.* 98, 410–419. doi: 10.1037/0022-0663.98.2.410

von Wingerden, T. (2020). *Bilderbuch vs. Bilderbuch-App - Zum Potenzial digitaler Kinderliteratur für das Geschichtenverständnis und den Erwerb narrativen Wissens* (master's thesis). Leibniz University Hannover, Hanover, Germany.

Wewer, I. (2012). 7 grummelige grömmels und ein kleines schwein [7 grumpy grömmels and a little pig]. Retrieved from the app "Tigerbooks." (accessed August 05, 2020).

Whitehurst, G. J., Falco, F. L., Lonigan, C. J., Fischel, J. E., DeBaryshe, B. D., Valdez-Menchaca, M. C., et al. (1988). Accelerating language development through picture book reading. *Dev Psychol.* 24, 552–559. doi: 10.1037/0012-1649.24.4.552

Whitehurst, G. J., and Lonigan, C. J. (1998). Child development and emergent literacy. *Child Dev*. 69, 848–872. doi: 10.1111/j.1467-8624.1998.tb06247.x

Yokota, J., and Teale, W. H. (2014). Picture books and the digital world: educators making informed choices. *Read. Teach.* 67, 577–585. doi: 10.1002/trtr.1262

Zhou, N., and Yadav, A. (2017). Effects of multimedia story reading and questioning on preschoolers' vocabulary learning, story comprehension and reading engagement. *Educ. Technol. Res. Dev*. 65, 1523–1545. doi: 10.1007/s11423-017-9533-2

Zipke, M. (2017). Preschoolers explore interactive storybook apps: the effect on word recognition and story comprehension. *Educ. Inf. Technol.* 22, 1695–1712. doi: 10.1007/s10639-016-9513-x

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 12 November 2020
doi: 10.3389/fpsyg.2020.570652

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# What Happens Before Book Reading Starts? an Analysis of Teacher–Child Behaviours With Print and Digital Books

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A body of research documents teacher–child reading behaviors in educational settings. Few will disagree that the potential for word and narrative comprehension increases when children's prior knowledge is activated and when children's focus is fully on the reading session. Despite this, little is known about the potential for establishment of joint attention and activation of prior knowledge in an early childhood education and care setting and how early childhood educators prepare young children to participate in shared book reading sessions before formal reading starts. Based on video data of teachers (*N* = 12) and small groups of children (*N* = 72) reading picture books and picture book apps in kindergarten, we sought to shed light on what behaviors occur *before* reading starts. The analyses were conducted in two phases. The first phase was based on 48 videotaped readings and followed a descriptive quantitative approach to investigate early childhood teachers' time use before the reading session, with readings of both print books and picture book apps. The second phase was based on two app readings in which the pre-reading phases stood out for their long duration. A qualitative analytical approach was applied to describe the teacher–child behavior, establishment of joint attention, and activation of prior knowledge during the two specific pre-reading events. Even though the sample is small, we find clear examples of pre-reading strategies specific to app readings. In this study, we discuss teachers' strategies to promote joint attention and activation of prior knowledge in new ways and how teachers exploit the pre-reading phase, for instance taking advantage of the books paratext, while adapting to the medium. Nevertheless, there remains a knowledge gap concerning app readings with short or no pre-reading phases.

**Keywords: picture book apps, print picture books, joint attention, prior knowledge activation, early childhood education and care, shared reading, paratext**

OPEN ACCESS

**Edited by:**
*Mikael Heimann, Linköping University, Sweden*

**Reviewed by:**
*Andrea Paula Goldin, Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina*
*Stacey Campbell, Queensland University of Technology, Australia*

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**Specialty section:**
*This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology*

***Received:*** *08 June 2020*
***Accepted:*** *19 October 2020*
***Published:*** *12 November 2020*

**Citation:**
*Hoel T, Stangeland EB and Schulz-Heidorf K (2020) What Happens Before Book Reading Starts? an Analysis of Teacher–Child Behaviours With Print and Digital Books. Front. Psychol. 11:570652. doi: 10.3389/fpsyg.2020.570652*

## INTRODUCTION

Shared reading with young children in early childhood education and care (ECEC) settings[1] involves children and teachers directing their attention toward the forthcoming activity and the book to be shared. Shared reading is in this study understood as verbal alternations between the mediator of the story and the children in order to encourage the children to participate in extended

[1] ECEC institutions for children aged 1–5 years are called kindergartens in Norway.

discourses, contributing to the children's early literacy and language development (Dickinson and Morse, 2019). The pre-reading time period offers valuable opportunities to support children's comprehension during the shared reading sessions. Activating children's prior knowledge and helping them connect their reading to their background knowledge (Keene and Zimmermann, 1997) is an effective way to improve children's understanding of the text being read. The parallel processes of having to create a mental representation of information contained in the text and decoding the language units might constitute a cognitive load (Bishop, 2014). Given that activation of prior knowledge reduces some of the cognitive load on the working memory for storyline processing and even language learning, the pre-reading phase is of great significance from a language stimulation perspective.

Further, joint attention, where children's and teachers' mutual engagement is coordinated with their common focus on the book (Tomasello et al., 2005), can serve as a scaffold for children's engagement in the reading activity. Communication and coordination in preparing and participating in shared efforts involves making adjustments among the participants, "stretching their common understanding to fit new perspectives in the shared endeavor" (Rogoff, 1997, p. 272). Establishing a frame of joint attention from the start can help teachers re-establish joint attention and draw the children back to the story when they become distracted during the shared reading.

In this way, a teacher's task prior to the reading session is to create engagement for both participation in the reading activity and for the story itself. Despite this understanding of the key roles of joint attention and prior knowledge, very few studies have explored what happens *before* the reading with groups of children in ECEC settings begins. In this regard, it is of interest to determine whether kindergarten teachers spend time on pre-reading activities at all. In addition, if they do spend time on pre-reading activities, what do they actually do within this time period?

While print books are traditionally used in shared reading, the digital medium is becoming increasingly applicable. A body of research has shown that shared reading of both print picture books and picture book apps enhances comprehension (van den Broek et al., 2017) and vocabulary growth (Mol et al., 2008, 2009; Mol and Bus, 2011). This positive effect can be attributed to the talk that surrounds the storybook reading (Pesco and Gagné, 2017). The effects of the content of teachers' talk and what pre-reading strategies teachers use have yet to be explored.

In this study, we are interested in what happens before shared reading starts, and our main research questions are as follows:

– How much time is spent on establishing joint attention and activating prior knowledge before reading print picture books and picture book apps?
– How does establishing joint attention and activating prior knowledge manifest in two examples of app readings characterized by the longest pre-reading phase durations in the sample?

The present study contributes to the field in three main ways. First, by using video observations of ECEC reading sessions of print picture books and picture book apps, we illuminate whether kindergarten teachers promote joint attention and activate prior knowledge before shared reading with groups of 4- and 5-year-olds. Second, by exploring what actually happens before reading starts in two selected reading events, this study gives special consideration to the practical implications of activating children's prior knowledge and establishing a frame of joint attention. Third, the present study fills the gap in the understanding of adult–child behaviors before a shared reading session. With this triple focus, we want to ascertain the possibilities and limitations of print picture books and picture book apps, which could contribute to understanding of the qualitative markers of optimal design for children's print and digital books.

## STUDY BACKGROUND

Prior to shared reading, teachers have the opportunity to provide texts and media in ways that promote and secure children's participation in the session. In a typical Norwegian ECEC setting, before the reading session, children and teachers come together to calm down and focus on the book. They may explore the front and back cover, discuss details of the illustrations or what the title of the book might mean, or if they have read the book earlier, retell parts of the story for each other (Hoel et al., 2011). In this vein, the study background is based on two well-established psychological variables, namely, *joint attention* and *prior knowledge*. In addition, the study draws on literary studies that do not empirically investigate children's engagement with books but describe in detail the relevant or accessible parts of the book for pre-reading conversations and explorations, that is, the paratext.

### Joint Attention

When children and teachers share their associations and reflections surrounding the story to be read, they pay attention to each other and to the utterances related to the book. Tomasello (2003) refers to this coordination of attention to each other and a third event (or object) as *joint attention*. Joint attention was found to correlate with children's word learning and is therefore considered to play a critical role in vocabulary development (Carpenter et al., 1998). However, in the context of shared reading, establishing a frame of joint attention prior to the reading activity can also play a crucial role in maintaining children's attention and can, through this already established engagement, help them come back to the story when the reading is disrupted. In this way, establishing a frame of engagement and joint attention serve as a scaffold for children's attention and therefore their story comprehension.

A prominent part of the teacher's scaffolding (Wood et al., 1976) is thus to encourage joint attention among learners. This scaffolding strategy, known as *recruitment*, revolves around getting children interested and engaged in the learning activity and creating a common ground for shared reading. The teacher may contribute to the children's expectations of the joint activity by expressing his or her own expectations. Another pre-reading scaffolding strategy is to refine the children's area of attention, described as a *reduction in degrees of freedom* (Wood et al., 1976). With the reduction in degrees of freedom technique, teachers design a reading situation that allows the children to be active participants while the teacher stays in control, for instance, by removing potential distractors. The teacher can ensure that all children are able to see the book or the screen well, that toys are cleared away, and that inappropriate behaviors do not disrupt the session. This scaffolding strategy must also be understood in relation to the medium one reads from, as reading from a touch screen in an early education setting is different from reading print books (Hoel and Tønnessen, 2019). Reading from a touch screen in kindergarten also differs from screen reading practices established in homes, where reading in dyads is the most common practice (Tønnessen, 2016).

## Prior Knowledge

According to Rogoff (1997, p. 272), individuals transform their understanding of and responsibility for activities, such as shared reading, through participation, where they make contributions either in actions or in "stretching to understand the actions or ideas of others." To contribute to the children's comprehension of the text, the teacher can help them activate prior knowledge. Prior knowledge involves insights that the individual children already have when they encounter a text. Within reading research, the importance of utilizing readers' prior knowledge and experiences, also called pre-understanding, is well documented (Bråten, 2007; Roe, 2008). With prior knowledge, the children can connect the new and unfamiliar elements that they encounter in the text with what they already know. In communicating these insights before reading starts, all participants stretch their understanding, thus increasing their understanding and expectations of a text before it is read.

Children's prior knowledge can be prompted with questions, which are widely used in interactions between educators and children. In her research in Norwegian kindergartens, Bae (2004) distinguishes between closed questions, which signal the expectation of a given answer, and open questions, where the children can answer more freely. Questioning statements of the open type are equivalent to appreciative communication, which invites reflection and common wonder, while closed questions are assumed to undermine independent reflection (Bae, 2004, p. 87). Questions such as "What do you see in the picture?," "Does this remind you of anything?," "What can this title mean?," and "What do you think this book is about?" may be used to retrieve the children's prior knowledge. In parallel, prompting questions might enhance children's interest in the book as well as their expectations for the activity, which are vital parts of the actual reading experience.

## The Role of Paratext

The term "paratext" describes all textual elements that come with a text and that influence how the text is interpreted. Examples of such textual elements may be the front page and colophon. Before reading starts, readers will relate to a book's paratext to a greater or lesser extent (Genette, 1997). The central text is surrounded by other textual resources, operating at different levels, in both external and proximate relation to the main text. The paratext acts as a link between the institutional framework of the text and the text itself. At the same time, the paratext serves as a series of entries that the reader can use to establish joint attention and prior knowledge before the reading starts and to interpret the text. The paratext has verbal and visual functions; it prepares, presents, and contains information about the content of the book. The paratext thereby forms part of the book's meaning potential and can condition and even change the reader's reception of a text.

Genette (1997) further distinguishes between peritext and epitext, where the former involves the textual elements that have a clear connection to the main text without being an explicit part of it and the latter refers to those parts of the paratext that are clearly separated from the main text itself; thus, the paratext can either be an addition to the story or an integrated part of the story.

Opening a picture book app may have some similarities, yet some features differ from those of a print book. Picture book apps are available within digital media; therefore, the first step is to turn on the tablet and choose the right app. In some apps, the opening page mimics the front cover of the print book, with the title, name of author/illustrator, and illustration; some apps add sound (i.e., an opening tune); and some add movement or interactivity. The app's paratext also includes menus with options and information for the book app, and in some apps, the opening page is an introduction to how to turn pages, turn the sound on and off, etc.

Zhao and Unsworth (2017) see the app as a semiotic artifact, drawing a distinction between the technological features that form an integral part of the text's meaning-making (intratextual interactivity) and those that help make the app work but that are not part of the narrative's meaning-making, such as peritexts and navigation menus (extratextual interactivity). With print picture books, the children's meaning-making springs from verbal text and illustrations together. With picture book apps, other semiotic resources, such as sound and animations, may also be subject to exploration, display esthetic qualities (Schwebs, 2014), and add to prior knowledge and rich dialogs.

In this study, we are interested in what happens before shared reading starts, and our main research questions are as follows: How much time is spent on establishing joint attention and activating prior knowledge before shared reading of print picture books and picture book apps? How does establishing joint attention and activating prior knowledge manifest in two specific examples of app readings characterized by the longest pre-reading phase durations in the sample? Based on empirical material with videos of teachers and small groups of children reading print picture books and picture book apps in ECEC settings, we aimed to ascertain what happens prior to the start of a reading session.

# MATERIALS AND METHODS

Data from the project "Books and apps: Developing an evaluation tool for e-books targeted towards children" (VEBB)

(Mangen et al., 2019) were used. In the overall project, the teacher's educational aim is to facilitate language learning by providing challenging content that requires the use of language to be explored and shared (Grøver, 2018), and both print picture books and picture book apps are the basis for dialog-based shared reading (Mol et al., 2008; Burger, 2015).

## Participants

The VEBB project involved 12 kindergarten teachers in six kindergartens. All 12 kindergarten teachers have a bachelor's degree in early childhood education. Each teacher carried out four reading sessions, reading two titles in both the print book version and the app version with the same groups of up to six children ($M$ = 57.2 months, SD = 7.9), for a total of 72 children.

The study was approved by *The Norwegian Social Science Data Service*, a third-party ethical supervisory agency in Norway. All participants were informed about voluntary participation and the opportunity to withdraw during the study. Each child's parents gave written informed consent for their child to participate. In addition, the children gave verbal informed consent to participate. Neither the children nor the kindergarten teachers can be identified in our work. To preserve the children's anonymity in the videotapes and still allow for their recognition between films, they were given number tags ranging from 1 to 6 to place on their jumpers.

## Preparing and Videotaping Reading Events

In preparation for the study, the teachers participated in a workshop on shared dialog-based reading of print and on-screen books. In this workshop joint attention, prior knowledge and the function of books paratext were highlighted. Following this, for the next 6 months, they had access to both types of media for practice.

The teachers were in charge of putting together reading groups that take into account the children's interests, mastery of language, and group interaction, as well as the physical conditions to optimize the children's engagement and participation (Hoel and Tønnessen, 2019). The teachers were free to design and conduct each reading. Children who were not present on the day of the filmed reading were not replaced. The reading events were videotaped by the kindergarten teachers themselves over the course of 3 weeks. In the videotaped readings, each teacher read two titles in their print and app versions, making the total number of filmed sessions 48. The reading order of the print and app versions was reversed for the readings of the second title to secure balance in the overall design.

## Coding the Videos

The video data were entered into the INTERACT video analysis program (Mangold, 2010, Lab Suite Version, Program Version 16.4.0.56), a video coding and analysis software for observational studies that can be used as an interface for both quantitative and qualitative coding. A coding scheme was developed, adapting categories from previous studies of children's engagement with picture book apps (Roskos et al., 2012; Merchant, 2015) and adjusting them to cater to the focus on the purpose of the study. Four coders took part in the coding. Intercoder agreement was checked, with four films being independently coded by two coders each, and intercoder reliability was found to be acceptable: kappa reached a level of $\kappa = 0.71$ for the frequency codes and $\kappa = 0.60$ for the duration codes (Mangen et al., 2019).

There are two main categories of codes: duration codes, which record how long a phenomenon lasts, and frequency codes, which record the number of instances. All frequency codes are linked to either the children or the teacher to identify the active party. For the quantitative analysis in this article, the applicable code is the duration code labeled *Pre-understanding*, characterized in the coding scheme as the "time spent on establishing shared focus before the reading starts: concerning expectations and background knowledge related to the story, the medium and/or the participation" (Mangen et al., 2019, p. 94). For the qualitative analysis in this article, video recordings of the specific time interval prior to the reading activity (coinciding with the duration code) were transcribed using the CHAT (Codes for the Human Analysis of Transcripts) standardized transcription system (MacWhinney Brian, 1991) for a selection of videos. For the purposes of this article, parts of these transcripts have also been translated from Norwegian to English.

## From Quantitative to Qualitative Analysis

The analysis was conducted in two phases. In the first phase, we used qualitative coding of video data in quantitative analyses to reveal how much time the kindergarten teachers actually spent on establishing joint attention and activating prior knowledge before the reading started. The data were imported into SPSS 21 for descriptive frequency analyses. The duration time in each film was analyzed, both in print picture books and in picture book apps. Based on the descriptive analyses, two reading sessions stood out for their long duration (3 min 6 s and 3 min 7 s), and these sessions were selected for further inspection in the second phase.

The second phase was an exploration of what happened before the reading session in these two specific picture book app reading events. By analyzing teacher–child pre-reading behavior for the two specific sessions, we identified strategies for establishing joint attention and prior knowledge in picture book app readings. The distinctive strategies were formulated (**Table 1**) both theoretically, based on the literature (Cresswell,

**TABLE 1 |** Strategies for joint attention and prior knowledge.

| Pre-reading | Strategies | Description |
|---|---|---|
| Joint attention | Recruitment | Engaging; expressions of curiosity; humor |
| | Maintaining attention | Elaboration; questions; corrections |
| | Reduction in freedom | Organization; corrections; rules |
| | Retrieval of attention | Questions; distractions; touching |
| Prior knowledge | Open and closed questions | On the literary elements; on the medium; on reading experiences |
| | Confirmation | Of the children's associations |

2007) and based on the data through a combination of inductive and deductive analytic approaches (Riessman, 2008).

In the result and discussion part, we give brief descriptions of the two selected reading events as well as rich descriptions of the paratext of the two picture book apps. We present the results continuously in the discussion and use excerpts from the transcripts to exemplify.

## The Story Titles

The following four titles, all available in both print and app format, were selected for use in the video observation study: Jansson (1952/2017), *The Book about Moomin, Mymble and Little My [Hvordan gikk det?]* (available in English); Stai (2008), *Yesper and Noper [Jakob og Neikob]* (available in English); Aisato (2014), *A Fish for Luna [En fisk til Luna]* (not available in English); and Charlotte Bråthen and Markhus (2013): *The Seed [Frøet]* (not available in English). The selection of the titles was based on the following selection criteria: the titles are available in Norwegian, in print and app format; there is ample potential in the story and the text for rich dialogs; the apps display a variety of interactive options; the books and apps are of high linguistic and esthetic quality; the theme/topic/content in the stories is relevant for both boys and girls and age-appropriate (age 4–5 years); and the books and apps display a diverse verbal language from simple words and sentences to more complex language in which the wording might generate curiosity and invite readers to explore vocabulary, metaphors, etc. (Mangen et al., 2019).

# RESULTS AND DISCUSSION

In the following, we will present our analysis and continuously follow up with discussions. We will start by addressing the quantitative material in order to answer the first research question: How much time is spent on establishing joint attention and activating prior knowledge before reading print picture books and picture book apps?

**Table 2** presents the distribution of the pre-reading time in all reading sessions in our material. Based on all the videotaped reading sessions, the frequency analysis shows that on average, the pre-reading phase represents 5.4% of each reading session ($M$ = 76 s, SD = 89.84). As expressed by the standard deviation, the pre-reading time varies greatly between each reading session.

**TABLE 2 |** Pre-reading phase duration time for digital and print picture books.

| | Reading session | Pre-reading phase | | |
|---|---|---|---|---|
| | Total duration time (mean duration time) | Total duration time (mean duration time) | Mean duration time in % | SD |
| All reading sessions (48) | 18 h 47 min ($M$ = 39 min) | 1 h 25 s ($M$ = 1 min 16 s) | 5.4% | 89.84 |
| App readings (24) | 9 h 6 min 25 s ($M$ = 22 min 46 s) | 53 min 35 s ($M$ = 55 s) | 4.0% | 55.24 |
| Print readings (24) | 9 h 40 min 30 s ($M$ = 24 min 11 s) | 38 min 35 s ($M$ = 1 min 36 s) | 6.6% | 111.92 |

The longest sequences are found for the print book readings (**Figure 1**). For example, in one reading of the print version of *The Book about Moomin, Mymble and Little My* (Jansson, 2017), the pre-reading time is 7.5 min. In other reading sessions, the teacher starts the reading immediately, without any pre-reading phase.

The results also show that the absence or very short duration of the pre-reading phase was slightly more frequent for the app readings than for the print book readings (see **Figure 1**). In addition to the teachers' pre-reading strategies, this could point to that the medium—print or digital—might have influence on how much time is spent on establishing joint attention and activating prior knowledge before reading starts. However, this should be tested in a bigger sample.

When the medium is a picture book app, on average, 4% of the whole reading session is spent on pre-reading (**Table 2**). When the medium is a print picture book, 6.6% is spent on pre-reading. However, the variation in pre-reading time during the app readings (SD = 55.24) is noticeably smaller than that during the print book readings (SD = 111.92). This might point to that the digital medium imposes certain frames that make the teachers' strategies for establishing joint attention and activate prior knowledge relatively homogeneous. Does this imply that teachers struggle with establishing joint attention and prior knowledge when preparing to read the picture book app, or does the digital book, with its medium specific epi- and peritextual features, provide poor conditions for establishing joint attention and prior knowledge? This leads us to phase 2 of the analyses. Inspired by the results showing that the pre-reading phase in app readings is relatively short, we explored to a greater extent what happens before reading using the recordings of the two longest app readings in the sample.

In phase 2, we explore what happened before reading started in two specific app reading events, and the research question is as follows: How does establishing joint attention and activating prior knowledge manifest in two examples of app readings characterized by the longest pre-reading phase durations in the sample?

Going back to **Figure 1**, two of the app readings stand out in regard to the duration of the pre-reading phase; a longer duration theoretically presents a greater opportunity than a shorter duration of this phase for pre-reading activities. The picture book app *The Book about Moomin, Mymble and Little My* (Jansson, 2017) was read in one of these sessions. *Yesper and Noper* (Stai, 2008) was read in the other. One is a first reading and the other a second reading, and the teacher is the same in both readings.

## Before Reading the Picture Book App *The Book About Moomin, Mymble and Little My*

In video observation 612appMU1, a kindergarten teacher and six children (two boys and four girls) prepare to read the picture book app *The Book about Moomin, Mymble and Little My* (Jansson, 2017). The children sit on low chairs in a semicircle, and the teacher sits in front of them on a stool with wheels. On their sweaters, the children have stickers with numbers from 1 to 6.

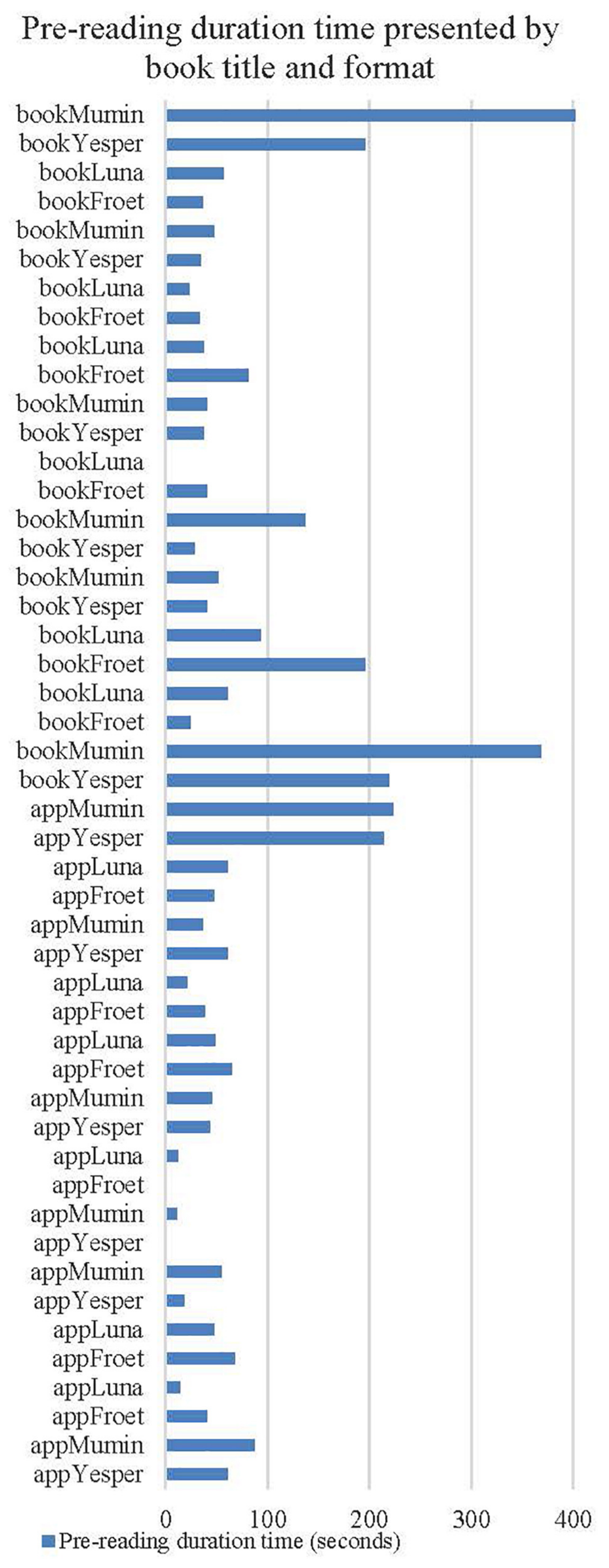


**FIGURE 1 |** Pre-reading duration time in each reading session presented by book format and title.

The teacher holds the tablet facing the children. She stretches it forward when they ask to see and to study the details in the illustrations, and she gives them the opportunity to tap/touch the screen. The teacher's strategy, the "show strategy" (Hoel and Tønnessen, 2019), is characterized by the teacher facing the children—not the screen—so that she meets the children's gaze, sees where they are turning their attention, and controls the children's access to the screen. The children have read neither the print nor the app version of the book earlier, although the classic Moomin universe may be familiar to some of them.

## Paratext in the Picture Book App *The Book About Moomin, Mymble and Little My*

The opening page in the app displays the name of the author, book title, and manufacturers (**Figure 2**). There is an illustration of two trolls opening a lid on the left side of the screen. Below the lid, two of the book's characters, Mymble and Moomin, are portrayed. When the page is open, there are ongoing bird chirps. The page contains two banners on the right side, where the readers can choose between "Read by myself" and "Read to me." After the reader has chosen, page two appears.

On page 2 (**Figure 3**), the readers are addressed with the text: "Hi! Here are the reading instructions," and below the written text, there is a full body illustration of the main characters Mymble, Moomin, and Little My. On the right side of the screen, there are three instructions presented as written text and small animations of a hand that performs a movement: "Turn page from the edge to change sides," "Press to see exciting animations," and "Rotate to control the objects on the screen."

In the analysis, we looked at the dialog and interaction between the teacher, the children, and the medium that takes place in the minutes from the teacher turns on the camera until the story starts, after approximately 4 min.

## Establishing Joint Attention

To get the children interested in the shared reading activity, the teacher starts by creating a common starting point before the app is opened. While the children are studying the digital bookshelf on the tablet, where they can see thumbnail images of the different available picture book apps, the teacher encourages them to focus their attention in search of a specific book: "Let's find a book that we have not read earlier." Thus, the teacher is recruiting (Wood et al., 1976) the children to take part in the shared search activity. She also asks questions to engage the children urging them to study the front cover illustrations:

T: Which one of these is Moomin?
C: [points]
C: The white one.
T: Do you know who this is? [points]
C: It's the girlfriend.
T: Are they boyfriend and girlfriend, do you think?
C: Yes/No.
T: Yes, they might be, I don't know.


**FIGURE 2 |** Opening page of the app *The Book about Moomin, Mymble and Little My.* Screenshot reproduced with permission from Aschehoug and Rights and brands.

Even though the questions are formulated in a closed way (Bae, 2004) ("Which one of these is Moomin?," "Do you know who this is?"), they have a practical function in helping the children attune their attention to the story that they are about to read. The questions also create engagement inasmuch as the children actively engage with the paratext both by answering questions and tapping the screen.

This short sequence helps build expectations of who and what the story might be about: Are Mymble and Moomin girlfriend and boyfriend? The teacher, who has prepared for the shared reading and knows the book well, lets the children explore and establish their own prior knowledge, thus establishing joint attention in the whole group.

During the minutes prior to the reading activity, one of the participants in the group applies the strategy of "refining the area of attention" (Wood et al., 1976), and this is not the teacher. The child with sticker number 1 on her sweater finds an opportunity to promote her candidacy to be the first to tap the screen.

> C: Can we do it like this: That number one [points to the sticker on her jumper] can turn the page first, and then the one with number two can do it afterwards and then . . . [goes on to number 6]
> T: So we do it one at a time?
> T: Is it OK if I decide who will turn the pages?

The organization of taking turns has been highlighted by the introduction of various forms of technology in kindergartens (Arnott, 2018). To control the activity, the teacher decides who is allowed to press hot spots and when, thus reducing the children's degrees of freedom (Wood et al., 1976). Kindergarten teachers find that this regulation contributes to joint attention on the story and that it makes it easier for the children to follow the narrative (Hoel and Jernes, 2020). However, in this situation, it is not the teacher who seeks to take control of the situation but one of the children. The teacher confirms the child's input ("one at a time") before asking the children if it is okay that she, the teacher, be the one who decides.

Rather than using a reduction in degrees of freedom to establish joint attention, the teacher accentuates new interactive affordances of the picture book app presented as part of the extratextual interactivity (Zhao and Unsworth, 2017) to refine the area of attention (Wood et al., 1976).

> T: Here it says, "Rotate to control elements on the screen".
> T: That means that we can do like this with it [demonstrates rotation with the tablet].
> T: That will be kind of fun.
> C: Yes.

By announcing her own expectations ("fun"), the teacher contributes to building the children's positive expectations of interactive opportunities, which is a fundamental part of establishing joint attention toward the picture book app.

Interestingly, the pre-reading phase in this example starts on the tablet book shelf, at a moment when the book is

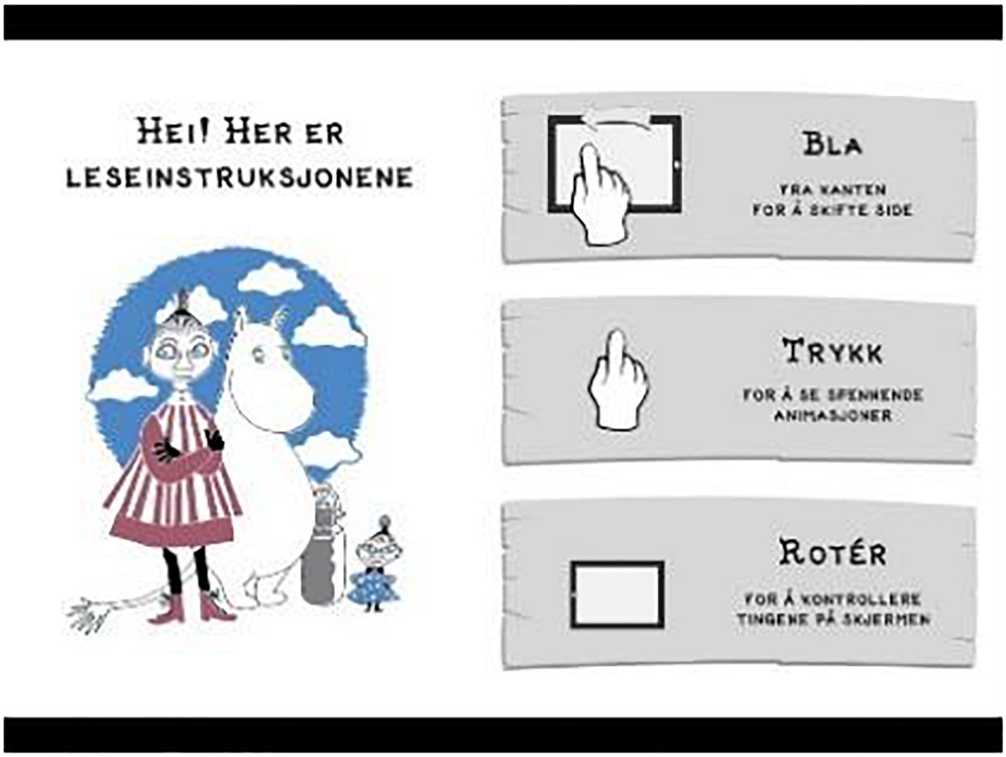


**FIGURE 3 |** Second page of the app *The Book about Moomin, Mymble and Little My.* Screenshot reproduced with permission from Aschehoug and Rights and brands.

just a small picture among others. The kindergarten teacher involves the children in searching for the book and, in doing so, takes advantage of the unique potential and features of the app medium. With this, the teacher initiates a frame of joint attention. This teacher is not steamrollered by the medium; on the contrary, she insists on implementing pre-reading, even though the paratext of this specific app does not invite to traditional pre-reading activities.

## Activating Prior Knowledge

During the 4 min before reading starts, the teacher contributes to the children's comprehension of the text by helping them activate their prior knowledge. With prior knowledge, the children can connect the new and unfamiliar elements that they encounter in the text with what they already know. Even though the picture book app is new to the children, the teacher tries to link the book to children's assumed experiences with the classic Moomin universe.

T: Do you know who Moomin is?
C: No.
C: I've seen her on TV.
T: Can you see Moomin anywhere? [stretches forward and shows tablet]
C: It's her with the black hair.
T: Can you tap on Moomin?
V: [The child taps at the app. The character is not Moomin.]

The teacher also activates the children's prior knowledge on how to read a picture book app using the menu in the apps' paratext.

T: When we turn pages in this book we do like this [demonstrates movement with hand].
T: And then it says "Tap to see exciting animations".
T: Does anyone know what an animation is?
C: Yes.
T: What is an animation?
C: [hesitates]
T: It's movements in a way.
C: Yes, like this? [stands up and wiggles].
T: Do you remember the other books we have read, the ones where we sometimes can tap. Like in the Billy Goats. What happens when we tap on the goat's butt?
C: Like this [stands up and pretends to flatulate, laughs].
T: That is a kind of animation.
T: In this book, there are also animations that we can tap. But I will tell you when you can tap.

The children are experienced readers of picture book apps with interactive features. By activating children's prior knowledge of the medium, the teacher also establishes an arena for using terminology related to digitization ("animation"), thus contributing to expanding the children's vocabulary within a frame of shared attention where the children are attentive to each other and to the digital book (Tomasello et al., 2005).


**FIGURE 4 |** Opening page of the app *Yesper and Noper.* Screenshot reproduced with permissions from Kari Stai and Det Norske Samlaget.

The first excerpt shows the teacher relying on the children's supposed knowledge of the Moomin universe, a strategy of activating prior knowledge from print book reading. As the children are not familiar with the literary universe, this strategy fails. In the second excerpt, she turns her attention toward the digital features of the app paratext presenting extratextual interactivity, and by this, exploiting the potential to activate prior knowledge within this specific pre-reading.

## Before Reading the Picture Book App *Yesper and Noper*

In video observation 612appJA4, the kindergarten teacher and four children[2] (one boy and three girls) prepare to read the picture book app *Yesper and Noper* (Stai, 2008). The setup is the same as in the first reading session, and the teacher implements the "show strategy" (Hoel and Tønnessen, 2019). In preparation for the shared reading, the teacher has taken advantage of recording opportunities in the app, and she has created her own soundtrack for the book. The discussion starts with the screensaver image on the iPad: a picture of the teacher, who has dressed up as a professor, and the children argue over whether it is the teacher. Then, they talk about their number tags, and they start adding numbers. "Have you started school yet?" the teacher teases. The children have read the print version of the book earlier.

## Paratext in the Picture Book App *Yesper and Noper*

In the app version of *Yesper and Noper*, a catchy melody with verbal text explaining who Yesper and Noper are starts immediately. As in the print version of the book, the opening page of the app displays the name of the author, the book title, and a full-page illustration of the characters Yesper and Noper (**Figure 4**). Interactivity is added to the illustration: On Yesper's hat is written "Press me!" and on Noper's hat "Not me!" When these hot spots are tapped, the characters say either "Yes" or "No." The menu opens when the publisher's logo at the bottom of the page is tapped. The choices in the menu are "Sound effects" (yes/no), "Show written text" (yes/no), "Read to me" (yes/own recording/no), and "Play the latest sound recording." In the bottom right corner, it says, "Here you can turn the page." Page 2 in the menu gives an overview of the pages in the app, instructions for recording and playing the reader's own sound, and a memory game based on illustrations from the book.

As in the analysis of the first event, we looked at the dialog and interaction taking place prior to the reading activity.

## Establishing Joint Attention

The screensaver image on the tablet captures the children's attention immediately, and to recruit (Wood et al., 1976) the children to the shared reading activity, the teacher uses the children's knowledge of the book as a common starting point, saying: "This time I have a book that you have seen before [shows the screen], and what is it called?" "Yesper and Noper!," the children reply. The teacher's thorough planning, creating a soundtrack for the book, adds enthusiasm and helps to anchor the children's attention and dedication.

> T: We will do it like this. You can choose if you want to hear the voice that is on the iPad [touches the Yesper character and activates the soundtrack].
> App: Press me [with the voice of the kindergarten teacher].
> C (all): [Smile and laugh as their eyes move between the screen and the teacher].
> C (5): He said "Press me", "Press me".
> T: [touches the Noper character and activates the soundtrack]
> App: Not me [with the voice of the kindergarten teacher].
> C (5): "Not me", "Not me" [mimics the voice in the app].
> C (all): [Laugh].
> T: Have you heard that voice before?
> C (several): Yes/No.
> C (6): It's you!
> T: Are you absolutely sure?
> C (all): Yes [smiling].
> C (6): Put that voice back on.

As in the reading of the Moomin app, the interactive and intratextual hot spots attract the children's attention. They are eager to take turns tapping. Instead of making strict rules and denying the children access, the teacher allows the children to tap the screen one at a time, thus reducing the children's degrees of freedom (Wood et al., 1976).

> T: Would you like to try pressing it? [extends the tablet toward child 5].
> C (5): [Taps on Yesper and smiles, then taps on Noper; the other children watch closely].
> C (5): No [mimics the voice in the app].
> C (5): I see both.
> T: [Extends the tablet toward child 6].
> C (6): [Taps quickly, first on Yesper, then on Noper].
> C (5): [Laughs out loud].

[2]The children with number tags 1 and 3 are not present during this reading event.

T: [Extends the tablet toward child 4].
(4): [Taps repeatedly, and the publisher's logo appears on the screen].
C (4): Hey.
T: Oi, what happened now? 'Loading', it says.
C (4): It was because I pressed so many times.
T: Do you think that's why?
C (5): It was I who did it many times.
T: Yes, now we can read a completely blank book.
C (all): [Laugh and smile]

Even as the children take advantage of their opportunity to rapidly tap the hot spots and the app starts reloading, the teacher keeps calm and turns the situation into a joke where she reminds the children of the purpose of the picture book app, namely, reading.

Before the reading starts, the children also build their expectations for the digital affordances, which the new medium adds to the story. In this reading of *Yesper and Noper*, the new element is the teacher's own soundtrack.

T: Should we listen to the voice on the iPad then?
C (all): Yes
T: There are two different voices on the iPad.
C (6): You!
T: Yes, and then there is another lady.
C (all): You, you [point at the teacher].
T: Would you like to hear how the second lady is first?
C (all): No, you.
C (6): You first.
C (all): You first.
T: OK.

This is an example of joint attention, where the children unite their interest and show that they greatly appreciate the teacher's preparation.

Similar to in the Moomin reading, the pre-reading in this example starts before the children have seen the book. However, the paratext of the Yesper and Noper app differs from that of the Moomin app in that it invites readers to engage in the literary universe before the story starts also *via* intratextual interactivity (Zhao and Unsworth, 2017). One might say that pre-reading is implemented in the paratext of this app, still on the premises of the medium, with built-in hot spots and sound. The teacher actively uses these digital features to initiate a frame of joint attention.

## Activating Prior Knowledge

The teacher contributes to the children's comprehension of the text by helping them activate their prior knowledge. The children have read the book earlier: they know the story and the characters. Nevertheless, by describing what they see in the paratext such as the opening illustration, they are reminded of the contrasts between the characters (colors, clothes, temper, and mood) and thus of the main plot of the story.

T: Yes, is there any other difference between them?
C (6): [Leaning forward and pointing] There is sun and rain.
C (4): [Leaning forward and pointing] And he's angry, and he's happy.
T: Yes.
C (2): [Stands up, takes a few steps toward the board and points] He has blue here, and he has red here.
T: Yes, it's true.
C (6): And he has a hat, and he has cap.
T: Mmhmm [affirms].
C (5): And Yesper has sun, and Noper has. . . [looking for the word] rain!
T: Why do you think so?
C (2): And then Yesper has red ears, and then Noper has blue eyes, no, blue ears [laughs].
T: Mmhmm [affirms].
T: Why do you think there is a sun over Yesper and rain over Noper?
C (6) [pointing]: He's glad, and he's angry.
C (2): Angry [confirms].
C (5): [Makes an angry facial expression, clenches his hands and grins].

Even though the children know the story, they express their appreciation of this recall process. They focus on details in the illustrations, put forward hypotheses, and are active and co-creative based on their experience horizon (Rogoff, 1997). In this way, the children's prior knowledge forms the basis for a deeper understanding of the text. In the children's investigation of the details in the illustration, they are attentive, and they use verbal as well as body language to communicate observations and interpretations of observations.

The strategy to activate prior knowledge bears a resemblance to the pre-reading phase in traditional print book readings. The children establish and widen the literary universe by elaborating on the contrasting illustrations of Yesper and Noper, driven by questions as well as confirmations from the teacher. This activation of prior knowledge is directly linked to the characters and the text. In this case, the teacher's questions do not activate prior knowledge related to the medium and the digital affordances within the paratext, for example, the soundtrack and the intratextual hot spots: "Why does Yesper say 'Yes' and Noper say 'No'?" This might be seen as a missed opportunity.

# CONCLUSION AND IMPLICATIONS FOR PRACTICE

In this study, we sought to explore what happens in the minutes before shared reading starts by asking: How much time is spent on establishing joint attention and activating prior knowledge before reading print picture books and picture book apps? In addition: How does establishing joint attention and activating prior knowledge manifest in two examples of app readings characterized by the longest pre-reading phase durations in the sample?

Our results show that there is great variation in kindergarten teachers' practice with regard to the time spent on pre-reading, and based on qualitative inspection, it is slightly more common with short pre-reading phases for picture book app readings than for print book readings (**Figure 1** and **Table 2**). The wide-ranging variation between the different readings is clearly an expression of the different teachers' pre-reading strategies; however, held together by the benefits that pre-reading provides (Bråten, 2007; Roe, 2008), it is also an expression of great differences in children's opportunities for language learning and text comprehension. This finding implies a need for knowledge in the field of practice in regard to providing equal learning opportunities for all children in kindergarten.

Short time spent on pre-reading in story times with app readings might indicate that the app medium does not invite joint attention and activation of prior knowledge to the same degree as do print books. However, the results might indicate that we need to look for new ways to invite joint attention and activation of prior knowledge starting with the possibilities that the medium provides. The two examples that we present in this article, which might be considered best-practice examples due to the strategies employed by the teacher, highlight the great potential for pre-reading found within the paratext of the picture book apps. In these examples, traditional and unorthodox methods are employed.

In the two pre-reading recordings, we found clear manifestations of activating prior knowledge and joint attention. The design of the paratext differs between each story; however, within the relatively short time before reading starts, it seems to promote teacher behavior that is associated with establishing joint attention. The menus are important in creating and forming the children's expectations on the shared reading and the picture book app. In the Moomin app, these instructions and extratextual interactivity are not part of the narrative's meaning-making, yet they play an important part in what happens prior to the reading activity because the teacher recognizes this potential and insists on making room for elaborating the digital affordances. In the Yesper and Noper app, the reading instruction "Play own sound" adds to the frame of joint attention and expectations of the text.

In our examples, the teacher goes beyond the picture book apps and exploits the potential of the medium itself for joint attention and activation of prior knowledge. The digital bookshelf and even the screen saver represent possibilities. Thus, the digital medium provides a unique potential to start pre-reading in new ways, unknown from print book reading. To recognize this potential affords the teacher a frame for establishing joint attention and activating prior knowledge, even though the medium does not invite this specific action.

With regard to the activation of prior knowledge, the teacher's strategies are traditional, especially in the example of Yesper and Noper, where the paratext serves as an invitation to highlight the illustrations of the main characters both to recruit the children's joint attention and to activate prior knowledge. In the Moomin app, the children guess and speculate, yet this strategy fails because they have no prior knowledge of the Moomin universe. The teacher's new and creative strategy is provided by the paratext: the menu giving instructions on how to read the app. Even if the menu might be considered to be an instruction for the reader physically holding the device, this teacher chooses to use this as an opening for activating prior knowledge and connecting new and familiar elements within the digital medium. Finding creative ways to exploit the possibilities of the paratext might mark the difference between the teachers who spend time on pre-reading in app readings and those who do not.

## STUDY LIMITATIONS

Based on our material, we find clear examples of pre-reading strategies specific to app readings. As the sample is small, more research is needed to deepen knowledge of pre-reading in ECEC institutions in general and with reference to digital books specifically. In our article, we have focused on best-practice examples of pre-reading events. Nevertheless, a knowledge gap remains concerning app readings with short or no pre-reading phases. As digital books present new ways of reading, our study contributes to addressing the great need for knowledge on how to promote joint attention and activation of prior knowledge in these new ways of reading.

## DATA AVAILABILITY STATEMENT

The qualitative data and transcripts of the specific video data that support the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Norwegian Centre for Research Data. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

TH participated in design of the overall study, collecting and coding of data. TH and ES conceived the original idea for this manuscript. ES and KS-H performed the quantitative analysis. TH and ES analyzed the qualitative data and interpreted results. TH and ES wrote the manuscript. All authors contributed to the article and approved the submitted version.

## FUNDING

The VEBB project is funded by The Research Council of Norway, educational science research programme "FINNUT", Grant number 260356.

## REFERENCES


Aisato, L. (2014). *En fisk til Luna*. Oslo: Gyldendal.

Arnott, L. (2018). Children's negotiation tactics and socio-emotional self-regulation in child-led play experiences: the influence of the preschool pedagogic culture. *Early Child Dev. Care* 188, 951–965. doi: 10.1080/03004430.2018.1443919

Bae, B. (2004). *Dialoger Mellom Førskolelærer Og Barn - En Beskrivende og Fortolkende Studie*. UiO: Avhandling til graden Dr. Philos, Det utdanningsvitenskapelige fakultetet, Institutt for spesialpedagogikk.

Bishop, D. V. M. (2014). *Uncommon Understanding: Development and Disorders of Language Comprehension in Children*. London: Psychology Press.

Bråten, I. (ed.) (2007). *Leseforståelse: Lesing I Kunnskapssamfunnet-Teori Og Praksis*. Oslo: Cappelen akademisk forlag.

Bråthen, C., and Markhus, R. (2013). *Frøet*. Oslo: Gyldendal.

Burger, K. (2015). Effective early childhood care and education: successful approaches and didactic strategies for fostering child development. *Eur. Early Childhood Educ. Res. J.* 23, 743–760. doi: 10.1080/1350293x.2014.882076

Carpenter, M., Nagell, K., Tomasello, M., Butterworth, G., and Moore, C. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monogr. Soc. Res. Child Dev*. 63, 1–174. doi: 10.1515/9783110802047-fm

Cresswell, J. W. (2007). *Qualitative Inquiry & Research Design (Vol. 2)*. California: Sage Publications.

Dickinson, D. K., and Morse, A. B. (2019). *Connecting Through Talk. Nurturing Children's Development with Language*. Baltimore: Brookes.

Genette, G. (1997). *Paratexts: Thresholds of Interpretation*, Vol. 20. Cambridge, MA: Cambridge University Press.

Grøver, V. (2018). *Å lære språk i barnehagen [Learning language in kindergarten]*. Oslo: Cappelen Damm akademiske.

Hoel, T., Wagner, Å. K. H., and Oxborough, G. H. O. (2011). Lesefrø: språkstimulering gjennom leseaktiviteter i barnehagen. [Language stimulation through reading activities in kindergarten]. *Cappelen Damm Akademisk*.

Hoel, T., and Tønnessen, E. S. (2019). Organizing shared digital reading in groups: optimizing the affordances of text and medium. *AERA Open* 5, 1–14. doi: 10.1177/2332858419883822

Hoel, T., and Jernes, M. (2020). Samtalebasert lesing av bildebok-apper: barnehagelærer versus hotspoter [Dialogue based reading of picture book apps: kindergarten teacher versus hotspots]. *Norsk Pedagogisk Tidsskrift* 104, 121–133. doi: 10.18261/issn.1504-2987-2020-02-04

Jansson, T. (2017). *Hvordan gikk det? (orig. Hur gick det sen?)*. Oslo: Cappelen Damm.

Keene, E. O., and Zimmermann, S. (1997). *Mosaic of Thought: Teaching Comprehension in a Reader's Workshop*. Oslo: Cappelen Damm akademiske.

MacWhinney Brian (1991). *The Childes Project: Tools for Analyzing Talk*. Oslo: MacWhinney Brian.

Mangen, A., Hoel, T., Jernes, M., and Moser, T. (2019). Shared, dialogue-based reading with books vs tablets in early childhood education and care: protocol for a mixed-methods intervention study. *Int. J. Educ. Res.* 97, 88–98. doi: 10.1016/j.ijer.2019.07.002

Mangold (2010). *INTERACT quicstart manual V2.4. Online*. Arnstorf: Mangold International GmbH.

Merchant, G. (2015). Keep taking the tablets: iPads, story apps and early literacy. *Austral. J. Lang. Literacy* 38, 3–11.

Mol, S. E., and Bus, A. G. (2011). To read or not to read: a meta-analysis of print exposure from infancy to early adulthood. *Psychol. Bull.* 137, 267–296. doi: 10.1037/a0021890

Mol, S. E., Bus, A. G., and de Jong, M. T. (2009). Interactive book reading in early education: a tool to stimulate print knowledge as well as oral language. *Rev. Educ. Res.* 79, 979–1007. doi: 10.3102/0034654309332561

Mol, S. E., Bus, A. G., de Jong, M. T., and Smeets, D. J. H. (2008). Added value of dialogic parent–child book readings: a meta-analysis. *Early Educ. Dev.* 19, 7–26. doi: 10.1080/10409280701838603

Pesco, D., and Gagné, A. (2017). Scaffolding narrative skills: a meta-analysis of instruction in early childhood settings. *Early Educ. Dev.* 28, 773–793. doi: 10.1080/10409289.2015.1060800

Riessman, C. K. (2008). *Narrative Methods for the Human Sciences*. Los Angeles: Sage Publications.

Roe, A. (2008). *Lesedidaktikk: etter den første leseopplæringen*. Oslo: Universitetsforlaget.

Rogoff, B. (1997). Evaluating development in the process of participation: theory, methods, and practice building on each other. *Change Dev.* 13, 265–285.

Roskos, K., Burstein, K., and You, B.-K. (2012). A typology for observing children's engagement with eBooks at preschool. *J. Interact. Online Learn.* 11, 47–66.

Schwebs, T. (2014). Affordances of an app. A reading of the fantastic flying books of mr. morris lessmore. *Nordic J. ChildLit Aesth.* 5:24169. doi: 10.3402/blft.v5.24169

Stai, K. (2008). *Jakob & Neikob*. Oslo: Samlaget.

Tomasello, M. (2003). *Constructing a Language. A Usage-Based Theory of Language Acquisition*. Cambridge, MA: Harvard university press.

Tomasello, M., Carpenter, M., Call, J., Behne, T., and Moll, H. (2005). Understanding and sharing intentions: the origins of cultural cognition. *Behav. Brain Sci.* 28, 675–691. doi: 10.1017/s0140525x05000129

Tønnessen, E. S. (2016). "Bildebokresepsjon på skjerm; nye erfaringer av det litterære," in *Litteratur inter artes. Nordisk litteratur i samspill med andre kunstarter*, eds U. Langas and K. Sanders (Kristiansand: Portal forlag), 345–366.

van den Broek, P., Kendeou, P., Lousberg, S., and Visser, G. (2017). Preparing for reading comprehension: fostering text comprehension skills in preschool and early elementary school children. *Int. Electron. J. Element. Educ.* 4, 259–268.

Wood, D., Bruner, J., and Ross, G. (1976). The role of tutoring in problemsolving. *J. Child Psychol. Psychiatry* 17, 89–100.

Zhao, S., and Unsworth, L. (2017). "Touch design and narrative interpretation: a social semiotic approach to picture book apps," in *Apps, Technology and Younger Learners*, eds N. Kucirckova and G. Falloon (New York: Routledge), 89–101.


**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 16 October 2020
doi: 10.3389/fpsyg.2020.569891

# Children's Narrative Elaboration After Reading a Storybook Versus Viewing a Video

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Previous studies have found that narrative input conveyed through different media influences the structure and content of children's narrative retellings. Visual, televised narratives appear to elicit richer and more detailed narratives than traditional, orally transmitted storybook media. To extend this prior work and drawing from research on narrative elaboration, the current study's main goal was to identify the core plot component differences (the *who*, *what*, *where*, *when*, *why*, and *how* of a story) between children's retellings of televised versus traditional storybook narratives. However, because children also differ individually in their IQ, we further incorporated this variable into our analysis of children's narrative retellings. For our purpose, a novel coding schema was developed, following and extending the existing narrative elaboration approaches. Participants were 46 typically developing children aged 4–5 years from Germany. The current study incorporated two narrative input conditions to which children were randomly assigned: in the video condition, children watched a non-verbal, visually conveyed, televised story from a DVD; and in the book condition, children read the story with an adult and experienced an orally conveyed version in the form of a book with minimal accompanying pictures. In both conditions, the same story was conveyed. After including IQ as a covariate in our analyses, results show that the children from the video condition gave significantly more elaborated retellings, particularly across the *who*, *what*, and *where* (sub-)components. Differences between the conditions in the component *when*, *how* and *why* did not reach statistical significance. Our findings indicate that different media types entail differential cognitive processing demands of a story, resulting in type-specific memories and narratives. The effect of different medial conditions was significant and persisted when individual differences in cognitive development were considered. Consequences for children's development, education, and interaction with and within today's digital world are discussed.

**Keywords: narrative skill development, narrative retelling, narrative elaboration, digital media, non-verbal IQ**



***Edited by:***
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***Specialty section:***
*This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology*

***Received:*** *05 June 2020*
***Accepted:*** *14 September 2020*
***Published:*** *16 October 2020*

***Citation:***
*Crawshaw CE, Kern F, Mertens U and Rohlfing KJ (2020) Children's Narrative Elaboration After Reading a Storybook Versus Viewing a Video. Front. Psychol. 11:569891. doi: 10.3389/fpsyg.2020.569891*

## INTRODUCTION AND PRIOR WORK

The literature on children's development of narrative skills is both vast in volume and broad in focus. In this paper, preschool children's narrative elaborations are investigated in relation to medial input and their cognitive development. This focus takes into account the structural and social contexts underlying the components of a narrative, considering and drawing from wide-ranging research traditions with diverse theoretical underpinnings.

## Narrative Structure and Narrative Elaboration

A story's plot components occur within a structural narrative context. In oral narratives, past events are retold and evaluated from the speaker's perspective, structured into chronological and causal sequences of sub-events and reproduced with linguistic and multimodal resources (Burdelski and Evaldsson, 2019; Heller, 2019; Makdissi et al., 2019; Takagi, 2019). For this purpose, storytellers need to leave the here and now of an interaction (Bühler, 1934/2011) and create a fictional world in which the narrated events occur, allowing them to narrate events about persons displaced from the here (space) and now (time), packaging these concepts accessibly for their listeners (Heller, 2019; Nicolopoulou, 2019; Takada and Kawashima, 2019). In doing so, they establish a situation of "joint imagination" in which the hearer is also a key contributor to the storytelling process (Heller, 2019, p. 168). Many studies have shown that narrative structure and content is not the product of the speaker alone but co-constructed and jointly achieved in the process of storytelling (e.g. Mandelbaum, 2012). While the ability to create a story with consideration of what the hearer knows and can imagine is crucial to tell a good story, here we focus on the components that a story comprises. These represent various types of information about a narrative event, which the teller can package and structure into an elaborated and entertaining story for their listener. According to Mandler and Johnson (1977, p. 111), narrative components can be summarised into a "story schema," i.e. an idealised representation of a typical story. In this sense, structure is a transferrable aspect of narratives and while it is crucial to the production of narratives, so too is the unique story and plot content delivered within the structural elements. Children start with limited linguistic means with which they can express the elements but over time the "expressive options" increase and "come to fulfil more specific and differentiated functions" (Veneziano and Nicolopoulou, 2019, p. 3). In this way, *narrative elaboration* involves the integration of structure and content within the process of telling a story and effectively communicating its events.

Linguistic research has now shown that narratives feature components produced systematically and in a specific order during the process of storytelling (see Veneziano and Nicolopoulou, 2019 for a recent summary). These include: (a) an orientation providing "relevant setting information" (Polanyi, 1985, p. 191) about the situation and the people involved, thus locating the event told in space and time, (b) a complication action, and (c) an evaluation section that can include personal, emotional and evaluative comments. Finally, (d) a coda takes the setting back to the present. The complicating action constitutes the point of the story (Polanyi, 1985), or its "high-point" (Peterson and McCabe, 1983, p. 37), and bears important functions for the "reportability" or "tellability" (Norrick, 2004, p. 86) of a story. This is supported by the referential and temporal "connectivity" of a story (Veneziano and Nicolopoulou, 2019). Labov and Waletzky (1967, p. 34–35) proposed that evaluation tends to cluster around emotional "high points" (during the complicating action component). Evaluation is important for achieving tellability and usually necessitates inferencing, because it provides explanations of why events occur, in particular the actions of characters in the story, and involves reference to feelings, thoughts and intentions (Eaton et al., 1999). Inferencing can, however, also be required for non-evaluative story-sequencing and linguistic details (e.g. anaphoric pronouns). Conversely, sequencing could also be viewed as implicitly supporting inferencing, functioning as a precursor to more explicitly expressed causality and consequences.

In the area of language acquisition, Saywitz and Snyder (1996) developed the *Narrative Elaboration* (NE) procedure to elicit and promote children's recall of narrative events (framed in our work as plot components), particularly for use within forensic environments. The design of this procedure was also based on work on story grammars as well as work on script theories and event knowledge (Flavell, 1970; Stein and Glenn, 1978; Nelson, 1986), separating out a narrative into "logically salient" categories in order to help children conceptualise the parts of a story and guide their event recall (Saywitz and Snyder, 1996, p. 1348; Saywitz et al., 1996). These categories represented various plot components and consisted of: participants, setting, actions, conversation/affective state, corresponding to questions about the *who*, *what*, *where*, *when*, *how*, and *why* of a story (Saywitz et al., 1996; Camparo et al., 2001; Brown and Pipe, 2003a). Various studies (Saywitz et al., 1996; Camparo et al., 2001; Brown and Pipe, 2003a,b) have since examined the effectiveness of this elicitation technique on the accuracy of children's free and cued event recall.

A story's components, corresponding to details concerning the *who*, *what*, *where*, *when*, *why*, and *how* of its events (Saywitz and Snyder, 1996; Saywitz et al., 1996), can be perceived as the "content" of a story, but these elements are also focused on and feature within the different structural elements to varying extents. The *who*, *where* and *when* represent setting information (Norbury and Bishop, 2003) and thus in conjunction with the *what* could be seen as representing aspects of orientation (who did what, as well as where and when they did it). The *how* could feature both as a visually more descriptive element (how something looked or was done) as well as a method for providing affective information and details about the characters (how they felt), straddling the elements of orientation, complicating action or high point, and informing the evaluation of the story. The *why*, then, represents the evaluative and goal-oriented elements of the story. It draws on sequencing to provide information about causality and consequences, incorporates affective stance, and thus does important work in establishing a story's reportability. In the sense that a speaker creates a fictional world to tell a story (s.a.), the *who* also relates to bodily displacement, the *where* to spatial displacement, and its *when* to temporal displacement. In studying the emerging elaboration of children's narratives, it is thus difficult to decouple the aspect of a complete narrative structure being provided from the elaboration itself. Both aspects are often intertwined in the literature.

## Narrative Development

Combining plot components to form a whole story draws on various abilities. Becoming able to knit narrative content into an accessible structure is driven by children's linguistic and cognitive development as well as influenced by social and situational factors. This development occurs over a protracted period from the production of early, simplistic narratives at 2 years of age to far more complex narratives at 10 years of age, continuing to mature even into their adolescence (Stadler and Ward, 2005; Quasthoff et al., 2017; Heller, 2019; Theobald, 2019). When constructing a story, young children struggle to effectively incorporate important details about the *who*, *what*, *where*, *when*, *why*, and *how* of a story (Saywitz and Snyder, 1996; Saywitz et al., 1996). The reason for this appears to be manifold: It may be due to limited event knowledge or understanding of causal and temporal relations and still-developing linguistic (i.e., grammatical and lexical) skills (Colletta et al., 2010; Hamilton et al., 2020). In this respect, the ability to express temporal and causal sequencing in a more differentiated way depends on the complexity of linguistic means available to the speaker (Veneziano and Nicolopoulou, 2019). The reasons for children's struggle with incorporating important details can also be related to limited discursive and sociocognitive skills which enable them to effectively orient their listener and adjust the narrative to their informational needs (Saywitz and Snyder, 1996; Saywitz et al., 1996; Genereux and McKeough, 2007; Colletta et al., 2010; Melzi et al., 2011; Pavias et al., 2016; Dore et al., 2018; Hamilton et al., 2020).

Whereas the above literature demonstrates the linguistic variability in the acquisition of narrative structure and content, the explanations of this variability are also associated with cognitive and social influences. Little is known about the influence of IQ on narrative skills and elaboration. Children will naturally approach the telling of a narrative pre-furnished with varying individual assets or levels of ability and some researchers have touched upon this idea in their work with children with learning disabilities (Humphries et al., 2004; Stetter and Hughes, 2010; Shamir et al., 2018). In order to retell a story, a child must make inferences about and remember information about the original story's plot. To linguistically construe an event (Nicolopoulou, 2019), a child must retain or conceive of relevant vocabulary and grammatical structures that appeared in or pertain to the original story (Humphries et al., 2004; Shamir et al., 2018) without relying on implicitly shared knowledge. Because of this challenge, studies report that children's early narratives are initially heavily dependent on scaffolding activities from more competent speakers before they develop strategies for recalling and providing more elaborate details about a story as well as producing a coherent and contextualised discourse unit without adult support (Saywitz and Snyder, 1996; Saywitz et al., 1996; Kern and Quasthoff, 2005; Haden et al., 2009; Melzi et al., 2011; Quasthoff et al., 2017; Theobald, 2019). They also rely on scaffolding before they become able to establish reportability for their audience (Kern and Quasthoff, 2005). Families are thus seen as the primary context within which children's storytelling skills emerge and evolve (Hyvärinen, 2008; Heller, 2019; Takada and Kawashima, 2019; Takagi, 2019).

Because of the variability of the linguistic structure and content that is associated with these influences, methodologically, it is a challenge to assess children's narrative performance properly. Prior works have taken differing yet overlapping approaches to the delineation and classification of children's narratives. Following Labov (1972) and McCabe and Peterson (1991) devised the method of high point analysis in order to examine children's narrative macrostructure across a developmental continuum, identifying seven progressive steps of narrative structure (also: Peterson and McCabe, 1983). Building from Stein and Glenn's (1979) work on story grammar, Stadler and Ward (2005) took a similar approach in developing their model for narrative development which included the following levels: labelling, listing, connecting, sequencing, and narrating. Their approach lacked this socially interactive concept of a "high point" but, as discussed above, sequencing is also an important aspect of tellability and supports inferencing. Taking a somewhat different approach by extending the concept of plot components derived from the (1967) work of Labov and Waletzky (1967), Kemper (1984) proposed that children first acquire an inventory of diverse plot components, then the rules for coordinating them, and finally the rules for embedding these components recursively, with stories conforming to grammatical principles governing structural components and their organisation. More recently, Makdissi et al., 2019, p. 51) introduced a narrative recall coding scale that offers a hierarchy starting from naming objects, recollection of isolated actions and developing further to temporal, causal structuring and finally explanations. However, these studies all focused on children's narrative content primarily within the context of structure, and while structure is an important aspect, the varying content and the unique plot components that children choose to incorporate within a transferrable structural schema can also contribute to our understanding of their narrative development. This is an area that should be further addressed in the literature.

Another aspect challenging the methodology in assessing children's narrative performance is linked to the material that is supposed to elicit children's narration. McCabe and Rollins (1994) drew attention to the manifold issues involved in eliciting narratives from children. Studies comparing narrative retellings (e.g. of fictional stories and personal experiences) to narrative generation from picture stimuli have shown that elicited narratives based on pictures taken out of context barely reach the quality of situated personal narratives, and that retold narratives appear to be longer and more detailed with more frequently complete episodes (Liles et al., 1989; Merritt and Liles, 1989). This has consequences for the validity and generalisability of research findings. Differences in children's performance might also result from the interactive process of constructing a narrative for and with an audience. This is relevant to children's experience of both real-life and experimental settings. Certain types of stimuli such as televised media or storybooks appear to be much more effective at stimulating and scaffolding children's production of narratives, although it is as yet still unknown which forms of media generate comparatively greater outcomes. In accordance with our aim to explore the influence of different media on narrative elaboration, we present further related research in the following section.

## Media Effects on Narrative Elaboration

Given that children today are growing up in a digital world, it is important to address questions concerning the impact digital media might have on cultural traditions such as storytelling and how children engage with them. In particular, the ways in which the content and structure of different input medias or experiences might bias or influence narrators' strategies. This might include which narrative details they form stronger mental representations of or consider most pragmatically salient or appropriate for retelling to their listeners. Differential opportunities to access print media exist across the socio-economic spectrum but the majority of households in developed countries have access to televisions and televised narratives (Linebarger and Piotrowski, 2009; McPake et al., 2013). The benefits of television in comparison to traditional media had previously been obscured, but more recently it has been shown that televised narratives (among other digital media or enhancements) can actually have positive impacts on children's development in different ways (Krendl and Watkins, 1983; McPake et al., 2013; Sarı et al., 2019). Yet, few studies have examined its impact on children's narrative development and production, let alone in comparison to traditional static or storybook media, and those that have done so tend to focus on either cognitive processing (e.g. Krendl and Watkins, 1983), story comprehension (e.g. Beentjes and van der Voort, 1991a,b; Podszebka et al., 1998; Linebarger and Piotrowski, 2009) or word learning (e.g. Podszebka et al., 1998; Diehm et al., 2020).

The use of video narratives in experiments has been observed to lead to the production of richer and more detailed narratives: Processing and encoding them may be cognitively easier for children, given that they tend to fall back onto reporting information presented in the visual format (Beck and Clarke-Stewart, 1998; Eaton et al., 1999; Linebarger and Piotrowski, 2009; Diehm et al., 2020). In a (1983) study by Krendl and Watkins, results indicated that viewers engaged in an active and differential processing of televised information, consequently acquiring a stronger mental encoding, a more sophisticated understanding, and better recall of the material. They argued that people have a lesser degree of control over the pace of its presentation in contrast to book reading and thus may activate different cognitive methods for processing the information conveyed, potentially at different levels of meaning. In addition to this, viewers of all ages need to continually revise their hypotheses about a televised narrative's implicit plot and sub-plots, and this uncertainty may result in increased levels of attention and cognitive effort (Krendl and Watkins, 1983). A better comprehension of the original material would certainly support children's ability to successfully retell a story and if children employ different strategies when processing narrative input, this could shape their retellings. From the findings of their (1998) study with 66 5-years-old, Beck and Clarke-Stewart also proposed that television could be especially effective at presenting stories (facilitating greater narrative elaboration) because (a) it is enjoyable and maintains children's attention, (b) information is often redundant (allowing for children to be momentarily distracted but still acquire the story's gist), (c) the dual presentation (visual and verbal) of information has a beneficial effect on memory, and (d) audiovisuals can depict affective content more transparently, making it easier to perceive and remember (also: Linebarger and Piotrowski, 2009).

Linebarger and Piotrowski (2009) investigated the effects of viewing different types of televised programmes (expository frameworks, embedded narrative, and traditional narrative, as well as a no viewing condition) on story knowledge and narrative skills in 311 at-risk pre-schoolers, and found that story knowledge scores (the ability to sequence story events and then tell stories around these events) and narrative skills (narrative involvement, retelling, explicit comprehension, and implicit comprehension) were higher in children assigned to either narrative condition. Sarı et al. (2019) investigated the impact of digital enhancements of storybooks on narrative comprehension and word learning. These types of digitally enhanced e-books could be seen as a bridge between traditional print and modern televised media. Their study with 99 children between 4 and 6 years of age covered four experimental conditions: Static illustrations with/without music or sounds, and animated illustrations with/without music or sounds. They found that visual enhancements and film-like story presentation benefited story comprehension. These findings are in line with the previous work, indicating that, overall, televised narratives boost story comprehension in comparison to traditional oral narratives, perhaps as a result of visual information being easier to process than verbal or language-based input.

Despite the ubiquity of television narratives in the everyday lives of many people today, very few studies have been conducted that actually compare the retellings of storybook and video narratives and even fewer have done so with very young children. In a study with four classes of children in the eighth grade ($N$ = 70), Podszebka et al. (1998) found that children who read a book version of a story better acquired target vocabulary, while those who viewed a video version better comprehended it. Diehm et al. (2020) recently investigated the effect of the presentation format of a story (static picture book versus animated video) on the language content of preschool children's narrative retellings), finding that typically developing children demonstrated a higher quantity and quality of language within a story retelling setting after viewing an animated video than after viewing images from the same video presented in a static picture book format. The findings of both Podszebka et al. (1998) and Diehm et al. (2020) also suggest that the content of children's narratives may be differentially affected by the medium of input to which they are exposed. With regard to story content, Beentjes and van der Voort (1991a; 1991b) conducted two studies comparing children's written retellings of a printed story versus its video version, the first with 88 children in grades 4–6 and the second with 127 children aged 10–12. They found that the children in the video condition included more scenes (narrative events) in their essays and had fewer errors, while the children in the printed book condition were better at specifically referencing characters and using descriptive details in their retellings (Beentjes and van der Voort, 1991a). They further found that recall of the video and storybook narratives varied with age: the younger children's recall of the film was more complete than that of the book, although this effect dropped off in the older children (Beentjes and van der Voort, 1991b). Podszebka et al. and Beentjes and van der Voort's findings support the previously discussed hypotheses of Krendl and Watkins (1983); Beck and Clarke-Stewart (1998), Eaton et al. (1999), and Linebarger and Piotrowski (2009) that televised narratives are more strongly mentally encoded, leading to more detailed retellings.

Taken together, the above research appears to demonstrate that children better encode and recall original story input after watching a televised narrative in contrast to a traditional storybook format, leading to narrative retellings which are more elaborate and detailed. However, this prior work has not focused on the specific ways in which children's retold narratives differ in terms of story and plot components after viewing a video versus reading a book. The study we report here has attempted to address this gap in the research by exploring how specific plot components of a retold story may be affected by the two conditions. For this purpose, a coding system had to be developed in order to identify core aspects of story content that are linked to and reflect narrative structure.

## THE CURRENT STUDY

Our study worked from a psycholinguistic perspective to examine narrative content and elaboration grounded in language-based categories. Our aims were threefold: The first aim was to develop a functionally operational coding system fit for the purpose of analysing narrative content and elaboration. The second aim was to use this coding system to investigate whether the focus of children's elaborative narrative content differed between their retellings of two narrative input conditions: a verbal narrative conveyed to the children from an illustrated storybook by a caregiver at home and a non-verbally conveyed narrative in the form of an animated video with sound effects that the children watched at home. Building on the previous research demonstrating that televised narratives are better encoded and thus lead to more detailed retellings, it was hypothesised that the children viewing the video version of the story would produce more elaborated retellings than those who had experienced the traditional storybook version. For the third aim of our study, we followed the literature documenting the influence of cognitive development on narrative retelling success and incorporated children's scores on a non-verbal intelligence test (IQ) as a covariate within our analyses to address the lack of its inclusion in prior studies.

### Method

The focus of this particular study is on the narrative retelling setting of a wider study on children's linguistic and gestural development which involved multiple settings (Rohlfing et al., in prep).

### Ethics

The ethical considerations for all procedures, measures, and assessment of participants were evaluated and granted approval by the ethical committee of the Bielefeld University (EUB 2014-111). Parents of the children participating gave informed consent and the children were given the opportunity to withdraw from the experimental interaction at any time.

**TABLE 1 |** Details of the data collected and participant numbers per condition.

| Collected data | Condition | |
|---|---|---|
| | Video | Storybook |
| §4.1 Dimension Analyses | 21 (10 male and 11 female) | 25 (17 male and 8 female) |
| §4.2 Medial Condition Analyses | 16 (9 male and 7 female) | 23 (16 male and 7 female) |

### Participants

A sample of 55 children between the ages of 4–5 years old were recruited for the wider study. Of these 55 participants, 9 had to be excluded such that the narrative retelling data from 46 participants (27 male and 19 female) could be used for our analyses. Of the 9 excluded from the analyses, 6 children experienced the wrong story at home, 2 children used the book or DVD-cover when retelling the story and 1 caregiver already knew the story. The ages of these 46 children in months at point of testing ranged between 45 and 61 months ($M$ = 50; $SD$ = 3.4). Data concerning the children's IQ scores was collected in a follow-up session which 7 participants did not attend, such that it could only be collected in 39 of these 46 cases (see **Table 1** for a summary).

### Stimuli

In the book condition, we used a published German translation of a Czechian children's storybook titled "The mole and the green star" (Doskočilová et al., 1998/2013). This book is commercially available as is the DVD version used in the video condition. This material has the same pictures: Moving pictures for the video condition and selected static pictures for the book condition. In the story, the mole protagonist wakes up from hibernation, begins spring-cleaning his burrow and finds a green gemstone in the process. The mole believes that this is a green star that has fallen from the sky and spends the rest of the book trying to put it back in the sky with help from his friends, including the moon who finally helps him achieve his goal. The plot of the book came from a non-verbally presented cartoon (Miler, 1969), and we used this cartoon in the video condition. The book and video were almost identical in underlying plot with very minor differences in scene emphasis or focus as a result of the mode of presentation.

### Measures

#### IQ

We assessed the children's IQ using the measure SON-R (Tellegen et al., 2007), which creates a generalised composite measure of children's intellectual abilities from two sub-tests: SON-H covering spatial thinking skills, and SON-D corresponding to abstract thinking skills.

#### Narrative Condition

The recruited children were randomly assigned to either of two narrative input conditions: the traditional illustrated storybook

**TABLE 2 |** Comparison of narrative elaboration categories and coding schema components.

| Saywitz and colleagues' categories | Extension for this study |
|---|---|
| Characters | *Who*—characters named directly or indirectly in the story |
| Setting/Location | *Where and When* |
| | • *Where* (representing the spatial element) |
| | • *When* (representing the temporal element) |
| Actions | *What*—for this component we coded verbs (linguistically encoded actions/states) |
| Affective States | *How*—extended to code for adjectives as well as adverbs of manner and degree |
| Consequences | *Why*—causal connectives and purpose/goal-oriented elements |

format or the non-verbal animated cartoon-video format. A strength of this study lies in that both narratives depicted the same underlying events, as they both told the story of "The mole and the green star" (Miler, 1969; Doskočilová et al., 1998/2013), allowing for direct comparison of the content of the children's narrative retellings between the two conditions.

### Data Collection

Each child's narrative retelling was audio- and video-recorded, transcribed, and coded using ELAN (2019). The child retold the narrative to a caregiver who had not been present during the original presentation of the narrative input. The setting was designed to promote a natural narrative retelling interaction between the child and caregiver, and for this reason, neither the child nor the caregiver were instructed to behave or speak in any specific way during the exchange.

## CODING

To compare children's narratives across two conditions, a novel coding system was developed. It took a qualitative content analysis approach (following Schreier, 2012) extending Saywitz and colleagues' work on the narrative elaboration technique/procedure of cued event recall (Saywitz and Snyder, 1996; Saywitz et al., 1996). The extension of Saywitz and colleagues' narrative elaboration categories (participants, setting, actions, conversation/affective states, and consequences) pertains to the underlying question cues about the *who*, *what*, *where*, *when*, *why*, and *how* of the story (see **Table 2**). Importantly, the categories also reflect narrative structure, as they routinely occur in the various structural parts of a narrative (s.a., section "Introduction and Prior Work").

As can be seen in **Table 2**, six categories (who, what, where, when, why, how) formed our main components for the core and elaborative information of children's narrative retellings. These were then segregated into three dimensions, loosely following syntactic structure. The main reason behind this was the assumption that syntactic components of a clause match major narrative components on a sentence level, and emerging syntactic complexity reflects increasing narrative complexity, although of course a story is also influenced by wider pragmatic aspects and is more than just the sum of its parts. However, by including linguistic categories that are relevant on a text level as well (such as nouns vs. pronouns, and temporal adverbs), we hope to catch aspects of narrative complexity above the sentence level as well.

Our dimensions included: Dimension 1 (*who*, *what*) reflecting the basic necessary linguistic properties of a sentence required to orient the listener (predicate: Subject and verb); Dimension 2 (*where*, *when*, *how*) representing the inclusion of (slightly more optional) temporal, spatial, and descriptive information; and finally Dimension 3 (*why*) incorporating causality, the most complex element of the stories (see also Makdissi et al., 2019). Following Kemper's (1984) model of narrative competence, Dimensions 1 and 2 represent the content and diverse plot components of children's narratives which are first acquired and elaborated on before children can progress to relating them and creating the causal structure of a story within Dimension 3. "Dimension 1" information has to be included in any sentence in order for it to make grammatical sense and thus would naturally feature most prominently and at the basic level in children's retellings. These items would also be grounded in more obvious visual content like a character's appearance and the actions they took. "Dimension 1" components therefore would not be as "elaborated" as the inclusion of more optional elements such as the "Dimension 2" components that would require further reflection on or extra processing of the scenes such as temporal and spatial information or how a character actually performed an action. Finally, the most elaborate element of a narrative pertains to the inferential complexity of causality conveyed by "Dimension 3" components.

Throughout the trial-and-error revision process of the coding schema (following Schreier, 2012), we further created a number of more finely grained subcomponents within each main dimension (see **Table 3**). Note that the selection of the components on the sublevel was derived from/adjusted to the data and thus reflects children's use of linguistic means to refer to the six main components:

Four further categories of children's talk: Meta-talk, Associative Talk, Sound Effects and Reported Speech, were created for assigning the remaining communicative resources used by the children and for observational purposes. "Meta-talk" (Schiffrin, 1980, p. 200) referred to any talk or conversation about the process of telling the narrative, e.g. with whom and when they experienced it, or instances of stepping out of the narrative to say something directed at the listener, such as out-of-story comments or signals to their listener for attention or help with constructing the narrative (e.g. yes/no, "hmmm," "what else. . .," "I can't remember any more," etc.). "Associative Talk" (Ornstein et al., 2004, p. 382) referred to only the talk from the child that oriented the listener to details in the story using the child's or shared previous experiences or information (i.e., "the star was green, like that jumper of yours, Mama."). Any instances where the children quoted dialogue from the characters (e.g. "The hare said: 'We'll help you"'.) were coded as Reported Speech, and any instances of onomatopoeia or sound effects (e.g. "Tsching-tsching!" for a shovel hitting a boulder) were coded

**TABLE 3 |** Full details of narrative elaboration coding schema.

| Narrative elaboration coding schema | Linguistic means | Example |
|---|---|---|
| **Component of *Who*** | | |
| • Who.1—direct naming of actors, agents or participants | → nouns plus articles | → e.g. "the mole" |
| • Who.2—indirect references to actors/agents/participants | → gendered pronouns and articles | → e.g. "he", "the (masc.)" |
| **Component of *What*** | | |
| • *What.1*—all general actions including their relevant inanimate objects | → general verbs | → e.g. "is", "went" |
| • *What.2*—actions that highlight the manner of an event | → verbs of manner | → e.g. *hüpfen, leuchten* ("hop", "glow") |
| • *What.3*—actions that highlight a spatial transition or location | → verbs with an additionally encoded spatial element | → e.g. *hin* + *setzen* ("to place within") |
| **Component of *Where*** | | |
| • *Where.1*—spatial axis locations | → spatial prepositions/adverbs | → e.g. "above", "inside" |
| • *Where.2*—explicit mentioning of specific story settings/locations | → nouns referring to locations | → e.g. "the pond", "the nest" |
| **Component of *When*** | | |
| • *When.1*—temporal sequencing | → temporal prepositions/adverbs | → e.g. "and then", "before", "after" |
| • *When.2*—explicit mentioning of specific temporal locations or points in time | → (adjective/adverb +) noun or preposition + noun | → e.g. "last year", "winter", "in the night" |
| **Component of *How*** | | |
| • *How.1*—how something looked, felt, sounded, etc. | → adjectives | → e.g. "sad" |
| • *How.2*—how something was done | → adverbs of degree and manner, conjunction "with" | → e.g. "quickly", "with a shovel [tool]" |
| **Component of *Why*** | | |
| • *Why.1*—weak sequential causality | → events listed with an implicit causal sequence | → e.g. "he couldn't do it, then he was sad" |
| • *Why.2*—stronger inferred causality | → using explicit causal connectives or explicating a purpose/goal | → e.g. "because" or "so that", "in order to" |

as Sound Effects. Any repetitions were also coded separately as Repetitions to avoid them exerting any biases on the statistical analysis of the data.

The **Figures 1**, **2** below depict example utterances taken from the transcripts of two different children from our sample as well as how these utterances were coded. **Figure 1** presents an example of an utterance with a low level of narrative elaboration while **Figure 2** shows an example of an utterance with a much higher level of elaboration.

In the interests of replicability, we provide clear examples of children's utterances from our sample and how they were coded in **Figures 3–5** below. **Figure 3** demonstrates some of the other narrative components and conversational elements that we coded, which are not shown in **Figures 1**, **2** above (*what.2, how.1, how.2, meta-talk, repetition*), while **Figure 4** depicts an example of the weaker sequential causality or consequences component (*why.1*). Some readers might question whether the spatial components *where.1* and *where.2* could actually appear independently of one another within children's utterances and **Figure 5** illustrates this difference quite effectively. The component *where.2* does not correspond to every noun that could follow a spatial preposition (reflected in *where.1*), rather *where.2* represents mentions of specific locations and settings from a story perspective: Those with contextual narrative importance. So, "in the hand" would only be coded for *where.1* while "through the meadow" would be coded for both *where.1* and *where.2*, because the meadow is a setting in the story in which scenes take place.

Our coding system bridges perspectives on the development of cognitive, linguistic and narrative skills as well as the acquisition of concrete language structures/categories. In this sense, there are also different scopes to story vs. linguistic elaboration. As this is an entirely novel coding schema, questions remain about its validity, including whether the dimensions are related and whether there is any progression from Dimension 1 → Dimension 2 → Dimension 3. Our statistical analysis was designed to assess and respond to these questions and will be discussed further in the Results section. To evaluate coding reliability, 15% of the data was independently coded by two coders. We used Cohen's kappa to measure inter-rater agreement on the coding schema ($\kappa = 0.609$).

# RESULTS

## The Dimensions of Elaboration

All statistical data analysis was conducted using the software IBM SPSS 25 for Windows. **Table 4** below shows the children's average use of each of the dimensions as a proportion of total intonation phrases within the narrative retelling setting as well as the percentage of children who used at least one example of an item coded for each of the dimensions and their (sub)components. All of the children used at least one instance of Dimension 1 and Dimension 2 items, with the group percentages dropping progressively from *Who* to *Why*, although this effect varied more strongly on the sublevel rather than on the main level. Only 58.7% of the children used Dimension 3 items and even then mean use of these items was very low, indicating that this area was more challenging for them. The descriptive results suggest

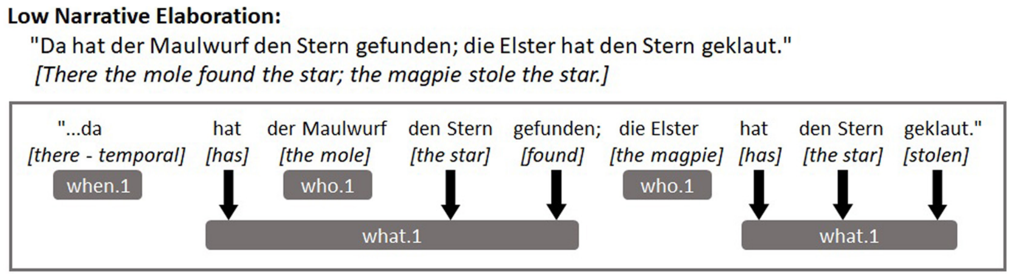


FIGURE 1 | Example of an utterance with a lower level of narrative elaboration and its coding.

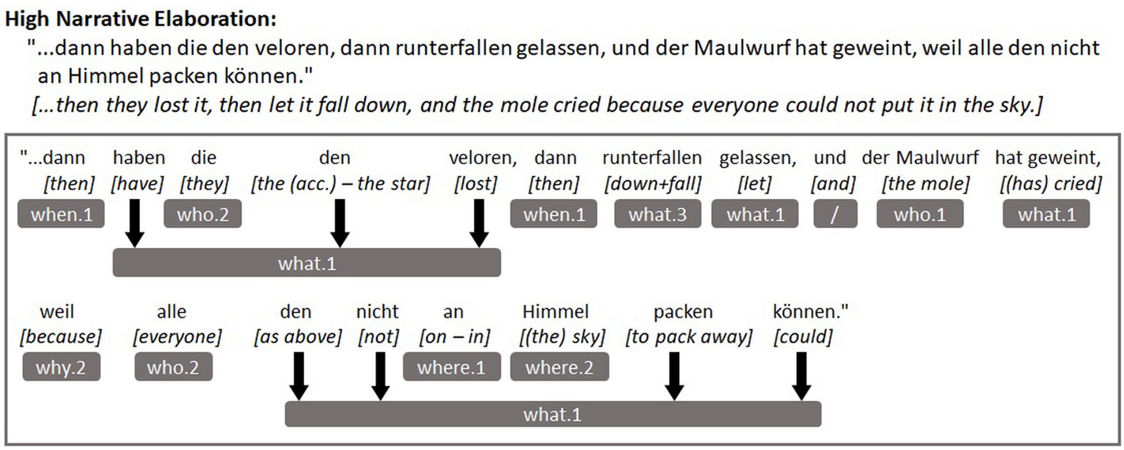


FIGURE 2 | Example of an utterance with high narrative elaboration and its coding.

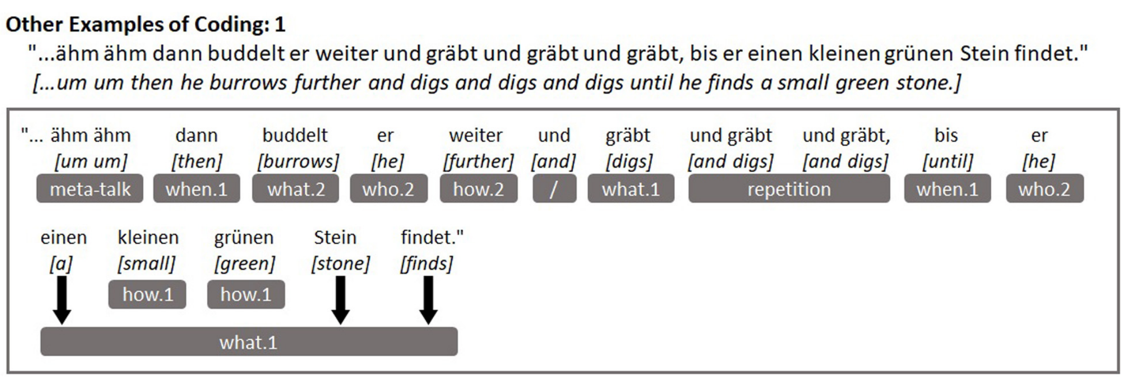


FIGURE 3 | Example utterance demonstrating other coded elements (*what.2, how.1, how.2, meta-talk, repetition*).

that 4-year-old children first narrate along Dimensions 1 and 2 and progress to 3.

To explore whether the three dimensions of elaboration are related and thus sum up children's ability to elaborate, we first conducted Spearman's correlations between children's age, their use of the dimensions and their instances of *Meta-talk*. The results are presented in **Table 5**.

The inclusion of Dimension 1 and Dimension 2 components in the children's narratives were strongly positively correlated with each other, Dimension 2 and Dimension 3 were also significantly positively correlated with one another, as were Dimension 1 and Dimension 3. These results suggest that the dimensions of our coding systems are related and provide support for the idea of one ability being reflected in the three dimensions. There was also a moderate negative correlation between Dimension 1 and *Meta-talk*, as well as between Dimension 2 and *Meta-talk* suggesting that they capture different abilities, but we found no relation between Dimension 3 and

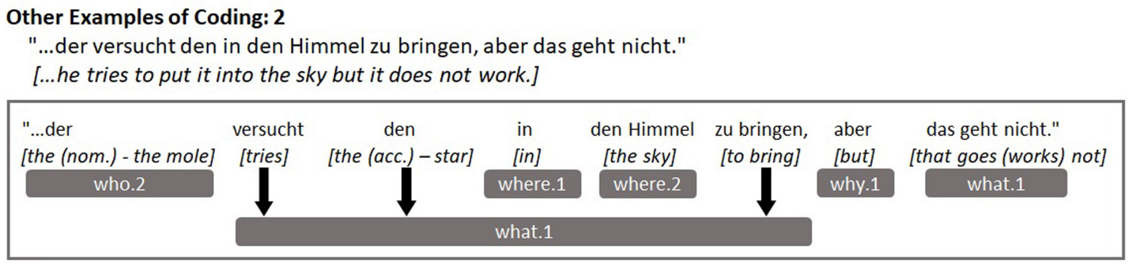


**FIGURE 4 |** Example utterance demonstrating other coded elements (*why.1*).

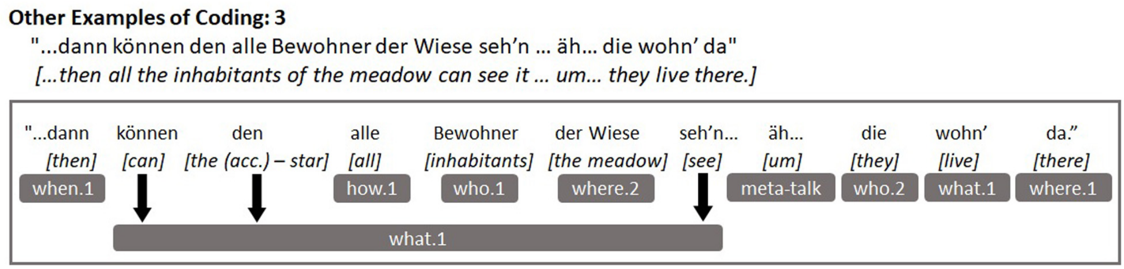


**FIGURE 5 |** Example utterance demonstrating other coded elements (occasions during which *where.1* and *where.2* can occur separately).

*Meta-talk*. No significant correlations were found between the dimensions and the age in months of the children suggesting that the narrative elaboration dimensions are not a matter of children's age in months.

## Dimensions of Elaboration Under Medial Conditions and in Relation to IQ

In the next part of the analysis, we investigated how the extent of children's elaboration differed depending upon whether their narrative was a retelling of the video or the book input. Here, we followed the hypothesis that children's retellings would demonstrate higher narrative elaboration and incorporate more narrative details if they had experienced the original story stimuli in a video format in contrast to a storybook format. In order to conduct our analyses, we combined our hypotheses with those reported in the literature that children's IQ is related to their performance on narrative retelling tasks (Humphries et al., 2004; Shamir et al., 2018).

We first considered whether the two groups (book vs. video condition) were comparable when it came to their IQ scores. Shapiro-Wilk tests indicated a normal distribution in the wider sample ($n = 39$, $p = 0.945$) as well as in the book ($n = 23$, $p = 0.865$) and video conditions ($n = 16$, $p = 0.127$), so we then conducted an independent samples $t$-test. Our analysis revealed that the two groups differed significantly, $t(37) = -2.807$, $p < 0.01$, with a large effect size of $r = 0.42$ according to Cohen (1992) suggesting that the participants in the video condition ($n = 16$; $M = 111.88$; $SD = 7.34$) had higher IQ scores than the participants in the book condition ($n = 23$; $M = 103.48$; $SD = 10.26$). As a consequence of this significant difference, we conducted analyses of covariance (ANCOVAs) for further group comparisons to assess the effect of the medial conditions on narrative (sub-)components in retellings under consideration of the children's IQ scores. The inclusion of children's IQ scores as a covariate results in a corrected model.

Including children's IQ as a covariate (ANCOVA) when comparing the groups (those who received book vs. video input) across Dimension 1 (**Table 6**), we found a moderate effect suggesting that proportions of use were higher in the video condition ($n = 16$; $M = 0.90$; $SD = 0.41$) than the book condition ($n = 23$; $M = 0.63$; $SD = 0.22$), $F(1, 37)$, $p = 0.03$, $eta^2 = 0.13$. To reveal what content was narrated differently, we further conducted additional ANCOVAs at the sublevel and found that both the *Who* and *What* components differed significantly between conditions, with the video group outperforming the book group in each of them. When the next sublevel was considered, these significant between-condition effects appeared to be driven by children's *What.1* and *Who.2* use (see **Table 6**).

Conducting an ANCOVA to investigate group differences across children's Dimension 2 usage, we found a moderate effect, according to which, again, the proportions of use were significantly higher in the video condition ($n = 16$; $M = 0.83$; $SD = 0.49$) than the book condition ($n = 23$; $M = 0.53$; $SD = 0.24$), $F(1, 37)$, $p < 0.05$, $eta^2 = 0.11$. Further ANCOVAs on the sublevel (see **Table 7**) revealed that this effect appeared to be driven predominantly by the *Where.2* subcomponent.

Regarding the Dimension 3 *Why* component and other coded conversational elements (Meta-talk, Associative Talk, Sound Effects, and Reported Speech), no significant effects of condition were found suggesting that the beneficial effects of the video condition pertain to Dimensions 1 and 2.

**TABLE 4 |** Children's average use of all narrative elaboration dimensions as a proportion of their total intonation phrases and the percentage of total children ($N$ = 46) who used that (sub)component at least once in their narrative.

| Narrative Elaboration Coding Schema: | | Mean (*SD*) use | | | Percentage of children | | |
|---|---|---|---|---|---|---|---|
| Dimension 1 | | 0.75 (0.31) | | | 100% | | |
| Who | | | 0.36 (0.15) | | | 100% | |
| | Who.1 | | | 0.18 (0.098) | | | 100% |
| | Who.2 | | | 0.18 (0.10) | | | 95.7% |
| What | | | 0.39 (0.19) | | | 100% | |
| | What.1 | | | 0.28 (0.14) | | | 100% |
| | What.2 | | | 0.055 (0.046) | | | 87% |
| | What.3 | | | 0.062 (0.048) | | | 95.7% |
| Dimension 2 | | 0.68 (0.38) | | | 100% | | |
| Where | | | 0.23 (0.14) | | | 100% | |
| | Where.1 | | | 0.16 (0.11) | | | 97.8% |
| | Where.2 | | | 0.070 (0.045) | | | 95.7% |
| When | | | 0.23 (0.15) | | | 100% | |
| | When.1 | | | 0.20 (0.13) | | | 100% |
| | When.2 | | | 0.027 (0.029) | | | 67.4% |
| How | | | 0.22 (0.14) | | | 97.8% | |
| | How.1 | | | 0.10 (0.069) | | | 93.5% |
| | How.2 | | | 0.12 (0.11) | | | 93.5% |
| Dimension 3 | | 0.035 (0.052) | | | 58.7% | | |
| Why | | | 0.035 (0.052) | | | 58.7% | |
| | Why.1 | | | 0.020 (0.028) | | | 50% |
| | Why.2 | | | 0.015 (0.032) | | | 30.4% |

**TABLE 5 |** Spearman's correlations ($N$ = 46).

| | Dimension 1 | Dimension 2 | Dimension 3 | Meta-talk | Age |
|---|---|---|---|---|---|
| Dimension 1 | – | 0.78*** | 0.34* | −0.48** | 0.14 |
| Dimension 2 | 0.78*** | – | 0.29* | −0.53*** | 0.13 |
| Dimension 3 | 0.34* | 0.29* | – | −0.070 | 0.15 |
| Meta-talk | −0.48** | −0.53*** | 0.070 | – | −0.019 |
| Age | 0.14 | 0.13 | 0.15 | −0.019 | – |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

In summary, after applying ANCOVAs which took children's IQ scores into account as a covariate, we found moderate to large significant effects of medial condition on children's proportion of use of the narrative components *Who*, *What* and *Where*, reflected predominantly in their use of the *Who.2*, *What.1,* and *Where.2* subcomponents. For each of these (sub-)components, children from the video condition used them more frequently than the children from the book condition.

## DISCUSSION

The emergence of new digital media and technologies is dynamically influencing how children interact with other people, objects, and the world around them. Previous studies have found that narrative input conveyed through diverse media influences the structure and content of children's narrative retellings as well as differentially affecting their word learning and story comprehension. Visual information conveyed by televised (but not storybook) narratives may be easier for kindergarten/pre-school children to process than verbal or language-based input, promoting greater story comprehension, supporting mental encoding processes and facilitating a more detailed event recall (Beck and Clarke-Stewart, 1998; Linebarger and Piotrowski, 2009). The mode of presenting information may play a further role, with bimodal (visual and verbal) presentation and audiovisuals that convey more obvious emotional content having additive effects on memory (Beck and Clarke-Stewart, 1998). Narratives presented in a televised format or in the form of a digital storybook with visual film-like enhancements appear to boost story knowledge and elicit richer and more detailed narrative retellings than traditional, orally transmitted storybook media, which have been shown to better promote word learning and character references (Beentjes and van der Voort, 1991a,b; Podszebka et al., 1998; Linebarger and Piotrowski, 2009; Sarı et al., 2019; Diehm et al., 2020). These findings all suggest that the linguistic content and plot components of children's narratives might be differentially affected by the medium of input to which they are exposed. Since narrative content has to be construed, a great challenge for children is to make inferences about and remember the original story's plot. This cognitive effort is reflected in studies indicating that children's narrative retelling is related to individual differences in IQ and (socio-)cognitive development (Humphries et al., 2004; Genereux and McKeough, 2007; Nicolopoulou and Richner, 2007; Dore et al., 2018; Shamir et al., 2018). Our study attempted to address this issue, evaluating the linguistically encoded story components of narrative retellings as a function of differing media inputs, with additional consideration of children's IQ as an influential variable.

In our study, 46 typically developing children from Germany, aged 4–5 years, participated. They were randomly assigned to one of two medial conditions (watching a DVD vs. reading a storybook). They were assessed during two sessions: One, in which they retold a story to a different caregiver than the person with whom they had experienced the stimuli story (from either watching a DVD or joint reading of a storybook); and two, in which the children's IQ was assessed by conducting the SON-R test (Tellegen et al., 2007). The children's retellings were coded using a specifically developed coding system that captures their use of narrative elaboration and its different dimensions. Our analyses compared children's retellings between the medial conditions by taking their IQ scores into consideration as a covariate. Our results showed that the children from the video condition gave significantly more elaborated retellings, particularly across various *Who*, *What*, and *Where* components on the sublevel, whereas differences between the medial conditions in the components *When*, *How*, and *Why* did not reach statistical significance. Given the findings of previous studies, we did expect that the narrative retellings of the children from the video condition would be more detailed than those from the book condition and our results are consistent with this line of research. Despite having this expectation, it is still striking to find that such differences exist, since the children in the book condition had access to rich verbal input and linguistic information while children in the video condition only experienced non-verbal visual input with minor background sound effects. This could have easily primed the children from the book condition for success in the retelling task by pre-furnishing them with the necessary vocabulary and grammatical structures, but the children from the video condition still appeared to outperform them. It is possible then that for children at this age, the advantages of visually conveyed information supersede that of audially conveyed information.

Examining the dimensions' particular components more closely, we found that information from the sublevel about *What*, *Who*, and *Where* were more frequently incorporated within the retellings of the children from the video condition than the book condition, but differences between the conditions for *When*, *How*, and *Why* did not reach statistical significance. To distinguish more finely between the different language and story content narrated by the children, we also analysed the children's use of the sublevels of the *What*, *Who*, *Where*, *When*, *How,* and *Why* components.

In the video condition, children used more Dimension 1 components as a whole than children from the book condition but there were also specific differences. On the sublevel, *What* was separated into: (1) general verbs and actions, (2) verbs of manner (e.g. shines, hops), and (3) (German) verbs that encode an additional spatial element (e.g. climbs high). We found significantly higher use of the first component in the video condition. Since this subcomponent is encoded in children's use of more general or basic verbs and these are often syntactically necessary for an utterance, it is possible that frequency of use of this subcomponent may reflect frequency of narrative detail inclusion. Equally, it might also be a language-specific effect of syntax. From our findings concerning the *What* component, it is likely that experiencing visually transmitted information about the actions that constitute a story (literally seeing them happen) benefits encoding of actions in general and resulted in a stronger memory trace for children from the video condition in contrast to the children in the book condition who only heard about these actions occurring.

*Who* was separated into: (1) direct references to the characters in the story (e.g. "the mole") and (2) indirect references to characters (e.g. "he," "they," etc.). In German, the possibilities for using indirect references are more extensive than in English, as the genders of nouns allow for the use of only the article to distinguish characters. In our study, we only found significant effects between the conditions regarding the use of the second subcomponent (*Who.2*). Use of the *Who.1* subcomponent was not different. However, as indicated by the large effect size, the children in the video condition used more *Who.2* (indirect character reference) items than those in the book condition. It is possible that having experienced the visual input from the video, those children may have been better supported in their mental encoding of the characters within the story and consequently mentioned these characters more frequently, providing more information about them in their retellings. Having a potentially stronger memory trace of the characters from which to construe their retelling might have led to the children feeling less need to directly name them for their audience. It might be the case that this subcomponent better reflects children's performance on the *Who* component in general, as it would be syntactically and pragmatically unnatural to constantly refer to the full name of the character (encoded by *Who.1*). However, there are also quite a large number of characters in the stimuli story so it could still pragmatically make sense to refer to the main character by fully naming them regularly. Since the video was non-verbally presented, it may be the case that children from the book-condition received more input directly naming the character nouns than those children from the video condition.

Regarding the Dimension 2 components (*Where*, *When,* and *How*), the participants from the video condition used more of these components on the whole but here too there were specific differences at the level of the individual (sub-)components. After taking the children's differences in IQ into consideration, only an intermediate effect concerning the second subcomponent of *Where* (*Where.2*) was found to be statistically significant. The two subcomponents of *Where* represented: (1) spatial location prepositions and directions (e.g. up, in, above) and (2) explicit mentioning of specific story-related setting locations (e.g. the nest, the cave, the forest). Children in the video condition used the second subcomponent significantly more in their retellings than those in the book condition. It is likely that the specific story setting locations involved in the story were more obviously conveyed to the children in the video condition through the visual format, influencing their memories of the scenes. This effect could also have been continuously reinforced by their witnessing of the scenes taking place within these specific story

**TABLE 6 |** Dimension 1 (D1) differences between conditions with Mean (Standard Deviation), $n = 39$.

| | D1 | What | What.1 | What.2 | What.3 | Who | Who.1 | Who.2 |
|---|---|---|---|---|---|---|---|---|
| Book $n = 23$ | 0.63 (0.22) | 0.32 (0.12) | 0.23 (0.09) | 0.04 (0.04) | 0.05 (0.04) | 0.31 (0.13) | 0.18 (0.12) | 0.14 (0.07) |
| Video n = 16 | 0.90 (0.41) | 0.48 (0.25) | 0.32 (0.19) | 0.07 (0.05) | 0.08 (0.06) | 0.42 (0.18) | 0.18 (0.09) | 0.25 (0.12) |
| **ANCOVA with IQ as covariate** | | | | | | | | |
| *p* | 0.03* | 0.04* | 0.01* | 0.06 | 0.12 | 0.04* | 0.90 | 0.003** |
| *F* | 5.30 | 4.79 | 2.91 | 3.66 | 2.55 | 4.37 | 0.01 | 10.54 |
| *eta*$^2$ | 0.13 | 0.12 | 0.08 | 0.09 | 0.07 | 0.11 | 0.01 | 0.28 |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

**TABLE 7 |** Dimension 2 (D2) differences between conditions with *M* (*SD*), $n = 39$.

| | D2 | Where | Where.1 | Where.2 | When | When.1 | When.2 | How | How.1 | How.2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Book $n = 23$ | 0.53 (0.24) | 0.18 (0.11) | 0.13 (0.09) | 0.05 (0.03) | 0.17 (0.10) | 0.15 (0.08) | 0.02 (0.03) | 0.18 (0.10) | 0.10 (0.07) | 0.09 (0.06) |
| Video n = 16 | 0.83 (0.49) | 0.28 (0.17) | 0.20 (0.13) | 0.09 (0.05) | 0.28 (0.18) | 0.24 (0.15) | 0.04 (0.03) | 0.27 (0.18) | 0.10 (0.06) | 0.17 (0.16) |
| **ANCOVA with IQ as covariate** | | | | | | | | | | |
| *p* | 0.048* | 0.07 | 0.12 | 0.04* | 0.08 | 0.08 | 0.26 | 0.10 | 0.57 | 0.08 |
| *F* | 4.20 | 3.57 | 2.51 | 4.49 | 3.31 | 3.36 | 1.27 | 2.84 | 0.33 | 3.20 |
| *eta*$^2$ | 0.11 | 0.09 | 0.07 | 0.11 | 0.08 | 0.09 | 0.03 | 0.07 | 0.01 | 0.08 |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

settings/background locations (as well as the transitions between them) in contrast to the children in the book condition who would have had to construct their own mental representation of the scene on the basis of audial descriptions mentioned in the book only at the beginning of the narrative and therefore occurring less frequently. It might also be the case that the video facilitated stronger mental encoding of the spatial axis locations but that these were also frequently explicitly named, i.e., linguistically encoded by parents during the oral reading of the book, allowing them to perform in a manner similar to children from the video condition.

The subcomponents of *When* were divided along similar principles to *Where* into: (1) sequential aspects of the story (e.g. before, then, after) and (2) explicit mentioning of specific points in time (e.g. in the spring, at night). After children's IQ had been taken into account, neither of these subcomponents were found to be significantly different when the conditions were compared. If children used the first subcomponent (*When.1*) more frequently, it may be simply that they remembered more information about the story as a whole and thus included more instances of sequencing of these story elements. Since children acquire the temporal sequencing aspect of narrative structure very early on, it is possible that no significant differences were found between the conditions because they were already developmentally past this point. The second subcomponent (*When.2*) was the least frequently used of all of the Dimension 1 and 2 (sub-)components (see **Tables 4**, **6**, **7**) by children across the sample, so that it is possible that we simply did not have enough instances in the data to appropriately evaluate this component. Clearly, further research is needed in larger samples matched for IQ with targeted stimuli to systematically manipulate and better evaluate children's use of this component.

The component *How* was separated into: (1) how something looked or felt (adjectives), and (2) how something was done (adverbs and with what tools). Neither subcomponent reached statistical significance once the children's IQ differences were considered. With regard to the lack of findings concerning the first subcomponent (*How.1*), it is possible that the adjectives most relevant to the particular story stimuli used in our study (e.g. the colour of a particular star and the size of the mole) were both integral or explicit enough information to the story in both conditions. According to this explanation, we simply had very few differences between the children's retellings. This first subcomponent also included information about characters' feelings or traits (e.g. sad, happy) which might have been equally or even more explicit in the book condition (as discussed above regarding the previous work on character references: Beentjes and van der Voort, 1991a,b; Podszebka et al., 1998). This means that there could have been confounding effects within this first subcomponent because of the way in which we grouped adjectives in our coding schema. On the one hand, the visual input may have made the visual characteristics of adjectives more explicit but the relevant emotional adjectives less so, while the audial storybook input might have done the opposite. Further research may need to narrow down the types of adjectives used by the children in order to find more fine-grained differences between the conditions. Theoretically, the second subcomponent (adverbs conveying how something was done or extra information about the tools used) could have potentially led to between-condition differences because of the inherently visual elements that adverbs often convey about an action: additional information about its degree, speed or visual features, which might have been visually reinforced for the children in the video condition. It is difficult to pinpoint the reason for a lack of an effect in this subcomponent. It would require more fine-grained research on the individual participant level but children in the book condition may have performed similarly as a result of experiencing reinforced linguistic encoding of these elements. It is also possible that individual differences in IQ, access to linguistic means, and cognitive performance could offer potential avenues to pursue this topic further.

The Dimension 3 component *Why* was separated into: (1) weak sequential causality and consequence (*Why.1*: something happened, then a related other thing happened) and (2) strong inferred causality (*Why.2*: children would have to infer and encode something about the character mental reasons for doing something). Between medial condition, neither of these subcomponents was different. The lack of difference in children's use of *Why* between conditions might be due to the inherent cognitive complexity in construing causality (Makdissi et al., 2019). As the children in our study were only between 4 and 5 years old, it may be that they are not yet at a point in their development where they can cognitively and consistently cope with more complex questions about the *whys* (explicit causality). Only half of all participants used at least one instance of weak sequential causality and just under a third used a least one instance of the stronger inferred causality. The *Why* (sub-)components were not significantly correlated with the children's IQ scores in our sample. Previous research has found that incorporation of these elements (explanatory and interpretative clauses about character motivations and causality) within narrative retellings is related to children's age and sociocognitive development in later childhood (Genereux and McKeough, 2007; Nicolopoulou and Richner, 2007; Colletta et al., 2010; Pavias et al., 2016; Hamilton et al., 2020). In order to talk about the *whys* of the story presented to them, children are required to both comprehend and infer a number of implicit story details and then construe them mentally and linguistically to make them accessible to their narrative audience. It is possible that if the study were to be repeated with older children, that those in a book condition might be more effective at incorporating elements of causality and underlying character motives, as written narratives often present these more explicitly than visual narratives. Prior research has found increased levels of such character references in those reading storybooks rather than watching televised narratives (Beentjes and van der Voort, 1991a,b; Podszebka et al., 1998). Cognitive and affective perspective-taking may also be tapped differently by media of input: a video might place the child into the role of a more distanced observer required to infer many implicit details about the characters' motives while a book offers a more direct, explicit and involved insight into a character's mind.

Taken together, the findings presented here indicate that under the consideration of children's individual differences in IQ scores different medial condition entail variation in narrative retellings. The current paper extends the work of previous authors by pinpointing differences in the specific story components that children include in their narrative retellings after watching a non-verbal video versus being read a traditional storybook. Together with previous research, we propose that the differences stem from memories that are specific to a medium (video or book). Overall, children who had experienced the video input were better supported and included a greater proportion of distinct narrative details in their retellings than those who had been read the storybook. Our study was also particularly interesting because the caregivers involved had no prior experience of the story being retold to them and were not "knowing co-tellers," so the children had epistemic primacy in this situation and ownership of the story (Takagi, 2019, p. 107) allowing us to hone in authentically on their individual narrative skills.

## LIMITATIONS

We are aware of some limitations of our study: Firstly, our sample sizes were unbalanced with regard to several aspects. This was unfortunately due to the recruitment and random assignment of participants as well as the emergent issues discussed in the methods section leading to the data of some children having to be excluded from the analysis. As a result, we had fewer participants for the medial condition analyses ($n$ = 39) than the wider narrative elaboration coding schema analyses ($N$ = 46). For the narrative elaboration analyses which examined the coding schema in general, we had 4 fewer participants in the video condition ($n$ = 21; 10 male) than the book condition ($n$ = 25; 17 male). Although the genders were fairly balanced in the video-condition group, there were many more boys than girls in the storybook condition. Due to unforeseen circumstances preventing the collection of all the IQ data, for the medial condition analyses, we had 7 fewer participants in the video condition ($n$ = 16; 9 male) than in the book condition ($n$ = 23; 16 male). Again, the genders were fairly balanced in the video condition but there were many more boys than girls in the story condition. Clearly, thus, the comparisons between the conditions need to be interpreted with caution, also because in our sample and by random assignment, children from the video condition did differ in their IQ scores from children of the other condition significantly. Future research with larger groups could consider more fine-grained analytical approaches with the assignment of participants to higher and lower IQ groups in order to investigate differences in narrative elaboration on a more individual level.

Secondly, the storybook that we used did also have some supporting illustrated pictures scattered throughout it. This may have aided the children in the book condition in a similar way to the visuals presented in the video condition. Despite this potential issue that could have weakened the effects between the conditions, our results still revealed significant (moderate to large) differences between conditions.

Finally, our study concentrated on the linguistically encoded story content of narrative retellings; for future research, it might be informative to examine potential differences between the conditions in the structure of the retellings, as the children experiencing storybook narratives are exposed to an arguably more explicitly linguistically schematised structure (e.g. "There was once a . . .", "then one day . . . happened", "later that day . . .", "the end.", etc.) than those watching televised narratives who have to infer these details. Further longitudinal studies might also focus on how the dimensions of our coding schema match levels of increasing competence.

## IMPLICATIONS AND FUTURE OPPORTUNITIES

Our findings line up with previous research and indicate that today's digital technologies can offer a positive environment for children's development, education, and their interaction with the world around them. The results of this study have ramifications within three main areas: (1) child development, (2) education, and (3) further research.

Regarding children's development and education: If exposure to visual input supports children's comprehension and encoding of information as well as their subsequent retelling of that information, then these formats could be utilised to scaffold children's learning and development. While our results only confirm the advantages of visual media input on a few narrative components once the IQ is taken into account, at the very least no disadvantages could be found. This means that children might learn storytelling from movies just as well as they do from books, at least regarding the content-based components under investigation within this paper. In all aspects of life, children learn from their experience of the world around them. Information conveyed in a visual format is crucial to this process and storytelling may be no different. For this reason, it is possible that children may gain much more from simply viewing media content than might be initially anticipated. Perhaps experiencing a more visual source of input frees up the cognitive resources needed to best process and encode that information (Goldin-Meadow et al., 2009). Educators could thus consider developing a dual system that takes advantage of the opportunities available to get children actively engaging with and building upon information or media content that has first been presented to them through a more visual means. The benefits of visual input might even extend to children's comprehension of oral storytelling when supported with iconic gestures. If this is the case, then discourse, parenting, and teaching techniques that make greater use of visual supports (both manual and digital) could be developed for use at home, in school and in intervention settings.

While filling some gaps, our study has also identified new directions and opportunities for research in our field. Future work should take a more finely grained approach to investigate which kinds of stories and language are best supported by which format and how these formats can be most effectively deployed to individually scaffold children's development. Future studies could identify and systematically manipulate the presentation of each narrative component (the *Who*, *What*, *Where*, *When*, *How,* and *Whys* of a story) to explore how their encoding and retelling might be best supported through visual input and how it resonates with children who score differently in an IQ test. Other work could also examine the differences in the event structuring of children's narrative retellings and explore how each media format differs in promoting this aspect of their narrative skill development. Traditional storybooks may provide interaction training with a modelled structure whereas video input might require the child to construct a narrative retelling more independently. It would also be interesting to explore multimodality in children's retellings and the function of their gestures that accompany their verbal behaviour: Differences between the conditions in the use of plot components might also be reflected in their use of gestures and gestural viewpoints. Combining gesture and language analysis might then tell us more about children's underlying representations of the narrative events. Finally, there is the question of research design and the selection of stimuli for narrative retelling tasks: If narrative elaboration is better supported by visually conveyed input, then researchers have an ethical responsibility to take this into consideration when designing their experiments and interpreting their data.

## DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because: the datasets generated for this study cannot be made publicly available because participants did not consent to future re-use of their data by other researchers. Requests to access the datasets should be directed to Camilla Crawshaw, camilla.crawshaw@tu-dortmund.de.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethical Committee of the Bielefeld University (EUB 2014-111). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin and the children were given the opportunity to withdraw from the experimental interaction at any time.

## AUTHOR CONTRIBUTIONS

KR and FK contributed to the conception, design, and piloting of the wider study. FK, KR, and UM recruited participants and conducted data collection. KR and CC developed the coding schema. UM and FK contributed to discussions about the coding schema. CC and UM coded the data. CC, KR, and UM conducted data analysis. CC, FK, KR, and UM drafted the manuscript. All authors commented on, edited, and revised the manuscript prior to submission.

## FUNDING

This work was supported by the German Research Foundation (DFG) under the grant numbers to KR (RO 2443) and FK (KE 1627).

## ACKNOWLEDGMENTS

We are very grateful to all the participating families and our research assistants: Claudia Jeronski, Monique Koke, Bettina Wagner, Hanne Brockow, Marcel Kolisch, Moritz Pottkämper, Niklas Krome, and Jakob Naurath.

## REFERENCES


Beck, R. J., and Clarke-Stewart, K. A. (1998). Improving 5-year-olds' narrative recall and comprehension. *J. Appl. Dev. Psychol.* 19, 543–569. doi: 10.1016/S0193-3973(99)80055-0

Beentjes, J. W. J., and van der Voort, T. H. A. (1991a). Children's written accounts of televised and printed stories. *Educ. Technol. Res. Dev.* 39, 15–26. doi: 10.1007/BF02296435

Beentjes, J. W. J., and van der Voort, T. H. A. (1991b). Recall and language usage in retellings of televised and printed stories. *Poetics* 20, 91–104. doi: 10.1016/0304-422X(91)90035-N

Brown, D., and Pipe, M. E. (2003a). Individual differences in children's event memory reports and the narrative elaboration technique. *J. Appl. Psychol.* 88, 195–206. doi: 10.1037/0021-9010.88.2.195

Brown, D., and Pipe, M. E. (2003b). Variations on a technique: enhancing children's recall using narrative elaboration training. *Appl. Cogn. Psychol.* 17, 377–399. doi: 10.1002/acp.876

Bühler, K. (1934/2011). *Theory of Language: The Representational Function of Language* (trans. D. F. Goodwin and A. Eschbach). Amsterdam: John Benjamins.

Burdelski, M., and Evaldsson, A. C. (2019). Young children's multimodal and collaborative tellings in family and preschool interaction. *Res. Child. Soc. Int.* 3, 1–5. doi: 10.1558/rcsi.38982

Camparo, L. B., Wagner, J. T., and Saywitz, K. J. (2001). Interviewing children about real and fictitious events: revisiting the narrative elaboration procedure. *Law Hum. Behav.* 25, 63–80. doi: 10.1023/A:1005691926064

Cohen, J. (1992). A power primer. *Psychol. Bull.* 112, 155–159. doi: 10.1037/0033-2909.112.1.155

Colletta, J. M., Pellenq, C., and Guidetti, M. (2010). Age-related changes in co-speech gesture and narrative: evidence from French children and adults. *Speech Commun.* 52, 565–576. doi: 10.1016/j.specom.2010.02.009

Diehm, E. A., Wood, C., Puhlman, J., and Callendar, M. (2020). Young children's narrative retell in response to static and animated stories. *Int. J. Lang. Commun. Disord.* 55, 359–372. doi: 10.1111/1460-6984.12523

Dore, R. A., Amendum, S. J., Golinkoff, R. M., and Hirsh-Pasek, K. (2018). Theory of mind: a hidden factor in reading comprehension? *Educ. Psychol. Rev.* 30, 1067–1089. doi: 10.1007/s10648-018-9443-9

Doskočilová, H., Miler, Z., and Jähn, K.-H. (1998/2013). *Der Maulwurf und der Grüne Stern [The Mole and the Green Star]*. Leipzig: Leiv.

Eaton, J. H., Collis, G. M., and Lewis, V. A. (1999). Evaluative explanations in children's narratives of a video sequence without dialogue. *J. Child Lang.* 26, 699–720. doi: 10.1017/S0305000999003967

ELAN, (2019). *The Language Archive: (Version 5.8) [Computer software]*. Nijmegen: Max Planck Institute for Psycholinguistics.

Flavell, J. H. (1970). "Developmental studies of mediated memory," in *Advances in Child Development and Behavior*, eds H. W. Reese, and L. P. Lipsitt, (New York: Academic Press), 181–211.

Genereux, R., and McKeough, A. (2007). Developing narrative interpretation: structural and content analyses. *Br. J. Educ. Psychol.* 77, 849–872. doi: 10.1348/000709907X179272

Goldin-Meadow, S., Cook, S. W., and Mitchell, Z. A. (2009). Gesturing gives children new ideas about math. *Psychol. Sci.* 20, 267–272. doi: 10.1111/j.1467-9280.2009.02297.x

Haden, C. A., Ornstein, P. A., Rudek, D. J., and Cameron, D. (2009). Reminiscing in the early years: patterns of maternal elaborativeness and children's remembering. *Int. J. Behav. Dev.* 33, 118–130. doi: 10.1177/0165025408098038

Hamilton, L. G., O'Halloran, I., and Cutting, N. (2020). Individual differences in narrative production in late childhood: associations with age and fiction reading experience. *First Lang.* 1–21. doi: 10.1177/0142723720946553

Heller, V. (2019). Embodied displacements in young German children's storytelling. *Res. Child. Soc. Int.* 3, 168–195. doi: 10.1558/rcsi.37311

Humphries, T., Cardy, J. O., Worling, D. E., and Peets, K. (2004). Narrative comprehension and retelling abilities of children with nonverbal learning disabilities. *Brain Cogn.* 56, 77–88. doi: 10.1016/j.bandc.2004.06.001

Hyvärinen, M. (2008). "Narrative form and narrative content," in *Methodological Challenges in Childhood and Family Research*, eds I. Järventie, and M. Lähde, (Tampere: Tampere University Press), 43–63.

Kemper, S. (1984). "The development of narrative skills: explanations and entertainments," in *Discourse Development: Progress in Cognitive Development Research*, ed. S. A. Kuczaj, II (New York: Springer), 99–124.

Kern, F., and Quasthoff, U. (2005). "Fantasy stories and conversational narratives of personal experience. Genre-related, interactional and developmental perspectives," in *Narrative Interaction*, eds U. Quasthoff, and T. Becker, (Amsterdam: Benjamins), 15–56.

Krendl, K. A., and Watkins, B. (1983). Understanding television: an exploratory inquiry into the reconstruction of narrative content. *ECTJ* 31, 201–212. doi: 10.1007/BF02766633

Labov, W. (1972). *Language in the Inner City*. Philadelphia, PA: University of Pennsylvania Press.

Labov, W., and Waletzky, J. (1967). "Narrative analysis: oral versions of personal experience," in *Essays on the Verbal and Visual Arts*, ed. J. Helan, (Seattle, WA: University of Washington Press).

Liles, B. Z., Coelho, C. A., Duffy, R. J., and Zalagens, M. R. (1989). Effects of elicitation procedures on the narratives of normal and closed head-injured adults. *J. Speech Hear. Disord.* 54, 356–366. doi: 10.1044/jshd.5403.356

Linebarger, D. L., and Piotrowski, J. T. (2009). TV as storyteller: how exposure to television narratives impacts at—risk preschoolers' story knowledge and narrative skills. *Br. J. Dev. Psychol.* 27, 47–69. doi: 10.1348/026151008X400445Makdissi

Makdissi, H., Boisclair, A., Sirois, P., Baron, M.-P., and Sanchez Arce, C. E. (2019). "Storybooks to promote emergent literacy in kindergarten classrooms," in *Narrative, Literacy and Other Skills*, eds E. Veneziano, and A. Nicolopoulou, (Amsterdam: John Benjamins Publishing Company), 43–68.

Mandelbaum, J. (2012). "Storytelling in conversation," in *The Handbook of Conversation Analysis*, eds J. Sidnell, and T. Stivers, (Malden, MA: John Wiley & Sons), 492–508.

Mandler, J. M., and Johnson, N. S. (1977). Remembrance of things parsed: story structure and recall. *Cogn. Psychol.* 9, 111–151. doi: 10.1016/0010-0285(77)90006-8

McCabe, A., and Peterson, C. (eds.) (1991). *Developing Narrative Structure*. Hillsdale, NJ: Erlbaum.

McCabe, A., and Rollins, P. R. (1994). Assessment of preschool narrative skills. *Am. J. Speech Lang. Pathol.* 3, 45–56. doi: 10.1044/1058-0360.0301.45

McPake, J., Plowman, L., and Stephen, C. (2013). Pre—school children creating and communicating with digital technologies in the home. *Br. J. Educ. Technol.* 44, 421–431. doi: 10.1111/j.1467-8535.2012.01323.x

Melzi, G., Schick, A. R., and Kennedy, J. L. (2011). Narrative elaboration and participation: two dimensions of maternal elicitation style. *Child Dev.* 82, 1282–1296. doi: 10.1111/j.1467-8624.2011.01600.x

Merritt, D. D. S., and Liles, B. Z. (1989). Narrative analysis: clinical applications of story generation and story retelling. *J. Speech Hear. Disord.* 54, 438–447. doi: 10.1044/jshd.5403.438

Miler, Z. (1969). *Krtek a Zelená Hvìzda [The Mole and the Green Star]. [Television Broadcast (00:07:30)] From: Krteček [The Little Mole]. Animated Cartoon Series From 1957-2002*.

Nelson, K. (1986). *Event Knowledge: Structure and Function in Development*. Hillsdale, NJ: Lawrence Erlbaum.

Nicolopoulou, A. (2019). "Using a storytelling/story-acting practice to promote narrative and other decontextualized language skills in disadvantaged children," in *Narrative, Literacy and Other Skills*, eds E. Veneziano, and A. Nicolopoulou, (Amsterdam: John Benjamins Publishing Company), 263–284.

Nicolopoulou, A., and Richner, E. S. (2007). From actors to agents to persons: the development of character representation in young children's narratives. *Child Dev.* 78, 412–429. doi: 10.1111/j.1467-8624.2007.01006.x

Norbury, C. F., and Bishop, D. V. (2003). Narrative skills of children with communication impairments. *Int. J. Lang. Commun. Disord.* 38, 287–313. doi: 10.1080/136820310000108133

Norrick, N. R. (2004). Humor, tellability, and conarration in conversational storytelling. *Text* 24, 79–111. doi: 10.1075/ni.15.2.07nor

Ornstein, P. A., Haden, C. A., and Hedrick, A. M. (2004). Learning to remember: social-communicative exchanges and the development of children's memory skills. *Dev. Rev.* 24, 374–395. doi: 10.1016/j.dr.2004.08.004

Pavias, M., van den Broek, P., Hickendorff, M., Beker, K., and Van Leijenhorst, L. (2016). Effects of social-cognitive processing demands and structural

importance on narrative recall: differences between children, adolescents, and adults. *Discourse Processes* 53, 488–512. doi: 10.1080/0163853X.2016.1171070
Peterson, C., and McCabe, A. (1983). *Developmental Psycholinguistics: Three Ways of Looking at a Child's Narrative*. New York: Plenum.
Podszebka, D., Conklin, C., Apple, M., and Windus, A. (1998). "Comparison of video and text narrative presentations on comprehension and vocabulary acquisition," in *Paper Presented at the SUNY-Geneseo Annual Reading and Literacy Symposium*, Geneseo, NY.
Polanyi, L. (1985). *Telling the American Story: A Structural and Cultural Analysis of Conversational Storytelling*. Cambridge, MA: MIT Press.
Quasthoff, U., Heller, V., and Morek, M. (2017). On the sequential organization and genre-orientation of discourse units in interaction: an analytic framework. *Discourse Stud.* 19, 84–110. doi: 10.1177/1461445616683596
Sarı, B., Baal, H. A., Takacs, Z. K., and Bus, A. G. (2019). A randomized controlled trial to test efficacy of digital enhancements of storybooks in support of narrative comprehension and word learning. *J. Exp. Child Psychol.* 179, 212–226. doi: 10.1016/j.jecp.2018.11.006
Saywitz, K. J., and Snyder, L. (1996). Narrative elaboration: test of a new procedure for interviewing children. *J. Consult. Clin. Psychol.* 64, 1347–1357. doi: 10.1037/0022-006X.64.6.1347
Saywitz, K. J., Snyder, L., and Lamphear, V. (1996). Helping children tell what happened: a follow-up study of the narrative elaboration procedure. *Child Maltreat.* 1, 200–212. doi: 10.1177/1077559596001003003
Schiffrin, D. (1980). Meta−talk: organizational and evaluative brackets in discourse. *Sociol. Inq.* 50, 199–236. doi: 10.1111/j.1475-682X.1980.tb00021.x
Schreier, M. (2012). *Qualitative Content Analysis in Practice*. New York, NY: Sage Publications.
Shamir, A., Segal-Drori, O., and Goren, I. (2018). Educational electronic book activity supports language retention among children at risk for learning disabilities. *Educ. Inform. Technol.* 23, 1231–1252. doi: 10.1007/s10639-017-9653-7
Stadler, M. A., and Ward, G. C. (2005). Supporting the narrative development of young children. *Early Childh. Educ. J.* 33, 73–80. doi: 10.1007/s10643-005-0024-4
Stein, N., and Glenn, C. (1978). *The Role of Temporal Organization in Story Comprehension* (Technical Report No. 71). Urbana: University of Illinois, Center for Study of Reading.
Stein, N. L., and Glenn, C. (1979). "An analysis of story comprehension in elementary school children," in *New Directions in Discourse Processing*, ed. R. O. Freedle, (Norwood, NJ: Ablex), 53–120.
Stetter, M. E., and Hughes, M. T. (2010). Using story grammar to assist students with learning disabilities and reading difficulties improve their comprehension. *Educ. Treat. Child.* 33, 115–151.
Takada, A., and Kawashima, M. (2019). Caregivers' strategies for eliciting storytelling from toddlers in Japanese caregiver-child picture-book reading activities. *Res. Child. Soc. Int.* 3, 196–223. doi: 10.1558/rcsi.37287
Takagi, T. (2019). Referring to past actions in caregiver–child interaction in Japanese. *Res. Child. Soc. Int.* 3, 92–118. doi: 10.1558/rcsi.37384
Tellegen, P. T., Laros, J. A., and Petermann, F. (2007). *SON-R 2½- 7 Non-verbaler Intelligenztest. Testmanual mit Deutscher Normierung und Validierung [Nonverbal Intelligence Test. Testmanual with German Standardisation and Validation]*. Göttingen: Hogrefe.
Theobald, M. (2019). Scaffolding storytelling and participation with a bilingual child in a culturally and linguistically diverse preschool in Australia. *Res. Child. Soc. Int.* 3, 224–247. doi: 10.1558/rcsi.37294
Veneziano, E., and Nicolopoulou, A. (2019). "Introduction to narrative, literacy and other skills. Studies in intervention," in *Narrative, Literacy and Other Skills*, eds E. Veneziano, and A. Nicolopoulou, (Amsterdam: John Benjamins Publishing Company), 1–18.

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 03 September 2020
doi: 10.3389/fpsyg.2020.02158

# Preschoolers Benefit Equally From Video Chat, Pseudo-Contingent Video, and Live Book Reading: Implications for Storytime During the Coronavirus Pandemic and Beyond

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OPEN ACCESS

**Edited by:**
Rachel Barr,
Georgetown University, United States

**Reviewed by:**
Georgene Troseth,
Vanderbilt University, United States
Lauren J. Myers,
Lafayette College, United States

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**Specialty section:**
This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology

**Received:** 01 June 2020
**Accepted:** 03 August 2020
**Published:** 03 September 2020

**Citation:**
Gaudreau C, King YA, Dore RA, Puttre H, Nichols D, Hirsh-Pasek K and Golinkoff RM (2020) Preschoolers Benefit Equally From Video Chat, Pseudo-Contingent Video, and Live Book Reading: Implications for Storytime During the Coronavirus Pandemic and Beyond. Front. Psychol. 11:2158. doi: 10.3389/fpsyg.2020.02158

During the unprecedented coronavirus disease (COVID-19) crisis, virtual education activities have become more prevalent than ever. One activity that many families have incorporated into their routines while at home is virtual storytime, with teachers, grandparents, and other remote adults reading books to children over video chat. The current study asks how dialogic reading over video chat compares to more traditional forms of book reading in promoting story comprehension and vocabulary learning. Fifty-eight 4-year-olds ($M_{age}$ = 52.7, *SD* = 4.04, 31 girls) were randomly assigned to one of three conditions (Video chat, Live, and Prerecorded). Across conditions, children were read the same narrative storybook by a female experimenter who used the same 10 scripted dialogic reading prompts during book reading. In the *Video chat* (*n* = 21) and *Live conditions* (*n* = 18), the experimenter gave the scripted prompts and interacted naturally and *contingently*, responding in a timely, relevant manner to children's behaviors. In the *Prerecorded condition* (*n* = 19), children viewed a video of an experimenter reading the book. The Prerecorded condition was *pseudo-contingent*; the reader posed questions and paused for a set period of time as if to wait for a child's response. After reading, children completed measures of vocabulary and comprehension. Results revealed no differences between conditions across six different outcome measures, suggesting that children comprehended and learned from the story similarly across book formats. Further, children in the three experimental conditions scored significantly higher on measures than children in a fourth condition (control) who had never read the book, confirming that children learned from the three different book formats. However, children were more responsive to the prompts in the *Live* and *Video chat* conditions than the *Prerecorded* condition, suggesting that children recognized that these interactions were contingent with their responses, a feature that was lacking in the *Prerecorded* condition.

Results indicate that children can comprehend books over video chat, suggesting that this technology is a viable option for reading to children, especially during the current pandemic.

**Keywords: reading, video chat, vocabulary, online learning, contingency, coronavirus disease, literacy**

## INTRODUCTION

> So please, oh *please*, we beg, we pray,
> Go throw your TV set away,
> And in its place you can install
> A lovely bookshelf on the wall. – Roald Dahl (1964)

Roald Dahl's quote from his beloved book, *Charlie and the Chocolate Factory*, illustrates a belief that is still held today by many parents and educators: reading is beneficial for children's academic success, while time spent watching TV should be limited. The quote is even more relevant today during the current coronavirus disease (COVID-19) pandemic, as caregivers debate how much screen time is allowable for young children while staying at home (e.g., Cheng and Wilkinson, 2020). News reports suggest that many families are engaging in video chatting to keep children connected with family members, teachers, and classmates (Smith, 2020). Some families are also using video chat to engage in *shared book reading* (e.g., Guynn, 2020), a practice where an adult reads a book to a child or group of children and has conversations about the story and related topics (What Works Clearinghouse, 2015). Shared book reading has been linked to a variety of positive outcomes for children, such as increased vocabulary knowledge (Montag et al., 2015), better comprehension of new stories (Clarke et al., 2010), and improved print knowledge (Piasta, et al., 2012). As parents try to navigate the complex world of online educational activities for children during the current stay-at-home orders, research is needed to assess whether virtual shared book reading elicits the same benefits as traditional shared book reading. The current study explored whether preschoolers can learn vocabulary and comprehend stories read to them over video chat.

A large body of research suggests that children benefit most from shared book reading when *dialogic reading* practices are incorporated into reading sessions (e.g., Hargave and Sénéchal, 2000; Strouse et al., 2013). *Dialogic reading* occurs when readers go beyond the text, adding prompts, asking questions, making connections between the book and children's lives, providing the child with praise, and correcting misunderstandings (Whitehurst et al., 1988; Arnold and Whitehurst, 1994; Zevenbergen and Whitehurst, 2003). Dialogic reading aligns with research-based principles for optimal learning (Hirsh-Pasek et al., 2015b). According to learning scientists, children learn best when they are *active* and *engaged*, in *meaningful contexts*, and are *socially interactive* (Hirsh-Pasek et al., 2015b). When using dialogic reading practices, children are *actively* answering questions and responding to prompts posed by adults. Adults *engage* children by following children's interests and focusing children's attention on key points in the story (Hassinger-Das et al., 2019). Adults can also create *meaningful contexts* for children, using "distancing prompts" to relate the story to children's lives (Hassinger-Das et al., 2017). Lastly, adults and children *interact socially* when engaging in dialogic reading as the reading partners converse about the story and adults aid children in processing the story with additional prompts and explanations.

Dialogic reading practices have been linked to a variety of positive outcomes for children's reading comprehension and vocabulary learning. For example, Whitehurst et al. (1988) found that when parents were trained to ask their children questions and expand on the story during a 1-month home book reading intervention, children demonstrated higher expressive vocabulary abilities than children in a control. Hargave and Sénéchal (2000) similarly reported greater vocabulary learning in children when parents used dialogic reading techniques than when parents simply read the text. Additionally, when parents use "distancing prompts," or questions or prompts that relate the story to children's lives, children comprehend more from book reading (Hassinger-Das et al., 2016).

Children's *responses* to prompts and questions posed during dialogic reading relate to their learning, as well. For example, Dickinson and Smith (1994) found that using dialogic reading styles in preschool classrooms led to an increase in children's talk, which in turn predicted an increase in their vocabulary gains. However, although research describes the types of questions and responses shared between adults and children during book reading (e.g., Deshmukh et al., 2019) and children's accuracy in responding to prompts in different instructional conditions (Walsh and Rose, 2013), there is a surprising lack of research on the relationship between children's responses during book reading and their learning, as noted by Walsh and Hodge (2016).

The back-and-forth personalized social interactions that are at the core of dialogic reading are also central to how children learn language in general. Indeed, children learn best in one-on-one contexts, in which a caring adult responds to the child and the dyad takes turns responding in back-and-forth communication (Hirsh-Pasek et al., 2015a). This type of communication is characterized as *contingent* – a speaker's utterance is temporally or topically related to the other speaker's utterances (Troseth et al., 2006). Research shows that this back-and-forth conversation between adults and children is related to later language ability in children (Hirsh-Pasek et al., 2015a). There is also evidence that back-and-forth interactions between parents and children are related to stronger connectivity in the white matter connecting two central language brain areas (Romeo et al., 2018). Although there are likely multiple mechanisms for these effects, in the domain of book reading, one contributing factor appears to be that the one-on-one context allows an adult to tailor reading to a particular child's level of understanding, allowing children to learn at their own pace (Connor and Morrison, 2016).

While dialogic reading is a relatively simple practice (Arnold et al., 1994; Blom-Hoffman et al., 2008), there is wide variability in the extent to which parents use these practices when reading with children (Hindman et al., 2014; Troseth et al., 2019) and not all environments and family situations allow for the one-on-one interaction that is at the core of dialogic reading. Parents who are traveling or live apart from children may not be present for book reading on a daily or even weekly basis. The preschool environment is another potential source of rich dialogic reading interaction, but teachers have limited time to read to children individually and build on children's interests and queries and, in general, teachers rarely engage in extended conversations with individual children (Justice et al., 2008). Dialogic reading may also occur with extended family or other caregivers, but during stay-at-home orders, many children cannot spend time engaging in storybook reading with adults who reside outside of their household, such as babysitters and grandparents. Even within the home, parents may dedicate less time to shared book reading during a pandemic. Working from home with much of their time balancing work and caring for children leaves many parents with little time for rich bouts of dialogic reading. In families where parents are deemed essential workers (e.g., healthcare workers) during the pandemic, parents may choose to self-isolate from their children to protect them from the virus (Fitchel and Kaufman, 2020). In some cases, children of these healthcare workers may be left without the caregiver that typically engages in shared book reading with them.

Regardless of the situation, *video chat* technologies present an exciting opportunity for children to experience one-on-one interactions with caring adults (Ames et al., 2010; McClure and Barr, 2017). While parents have been long concerned with the effects of media exposure on young children, research suggests that video chat may encourage more interactive adult-child exchanges than other media-based activities such as playing solo games (Roseberry et al., 2014). Video chatting engages children for longer periods of time, for example, with long-distance family members than traditional phone calls (Ballagas et al., 2009), promoting social relationships with family and friends. Children have access to devices for video chatting at an early age. Indeed, 98% of children under eight now have access to a mobile device at home, and the average time children spend on mobile devices tripled between 2013 and 2017 (Rideout, 2017). Digital media is also entering the classroom: over half of early childhood teachers report using tablets in their classrooms at least once a week (Blackwell et al., 2015).

Research on toddlers' learning from video chatting suggests that this technology may be effective for promoting literacy and language development because conversations can be *contingent* – adults' responses can be temporally and topically related to children's utterances (Troseth et al., 2006). Roseberry et al. (2014), for example, found that 2-year-olds learned novel words when taught over video chat but not when watching a prerecorded video of an adult teaching the word to another child. Crucially, the prerecorded video lacked well-timed, back-and-forth communication or contingency. Similarly, Myers et al. (2016) had 12–25-month-olds participate in six sessions in which they either video chatted with a researcher or watched a prerecorded video of a researcher on a tablet. Children demonstrated more synchronous behavior (e.g., waving when the experimenter waved) during video chat than when watching prerecorded videos. Children were also more likely to prefer the partner they interacted with to a new partner in the video chat condition than the prerecorded condition. Finally, older children (between 22 and 24 months) in the video chat condition performed significantly better on word learning tasks than children in the prerecorded condition.

Findings concerning how toddlers are affected by contingency may extend to older children, as well. For example, one study showed that 3-year-olds only passed a stringent test of verb learning when verbs were taught over a prerecorded video in addition to a live adult training session (Roseberry et al., 2009). Children were unsuccessful in passing the stringent test when they were taught through video alone. Other research has demonstrated that 4- and 5-year-olds comprehend an e-book better after reading with a parent than after viewing the e-book independently with audio narration, again suggesting that the contingent interactions that occur with an adult may promote learning (e.g., Dore et al., 2019). In the current study, we assess how preschoolers learn from being read a book over video chat. Given the known importance of dialogic reading, children may similarly benefit from the socially contingent interactions that occur over video chat. For many children, video chat may be a familiar and effective way to connect children with caring adults as reading partners, even if they are not physically present. We chose to examine preschoolers for several reasons. First, little research has explored learning over video chat with this age range, although they likely have the attention and social skills needed to have extensive, meaningful interactions over video chat (e.g., Tarasuik et al., 2011). Second, given that preschoolers benefit from contingent interactions during dialogic reading, video chat affords these interactions, even when adults and children are physically apart.

Although research suggests that video chat can help children's language skills, having previous experience with this technology may be important for learning outcomes. Similar effects have been demonstrated with TV; Crawley et al. (2006), for example, found that 3- and 5-year-olds with previous exposure to *Blue's Clues* are more likely to respond to characters' questions in the show than children who did not previously watch the show. Similarly, Kirkorian and Choi (2017) found that toddlers who use more interactive media (apps and games) learn better from media in general, suggesting that experiences with interactivity may have shown them that media can be responsive and a reliable source of information. Increased experience with video chat may also help children understand that the partner on the screen can communicate with them and will respond to them in meaningful ways. Previous research on children's learning from video chat reports no relationship between exposure to video chat and performance in lab-based studies (Myers et al., 2018; Strouse et al., 2018). However, children in these studies were younger than children in the current sample. By preschool, the degree to which children have had video chat experience may have an effect on their learning, with years of experience to help them understand the nature of video chat. Therefore, we asked parents in the current study how frequently their children video chatted. We expected to find a moderate effect of previous video chat use, such that children with more experience video chatting would benefit most from video chat book reading.

In the current study, we focus on two key skills that follow from book reading, story comprehension and vocabulary learning. The current study compares how dialogic reading practices over video chat affect children's story comprehension and vocabulary learning. We focus on these outcomes because they are well-established benefits of storybook reading and dialogic reading practices (e.g., Whitehurst et al., 1988; Hargave and Sénéchal, 2000; Clarke et al., 2010; Montag et al., 2015). We tested comprehension to assess the extent to which children can comprehend a story *via* video chat, a prerequisite to any additional learning or other benefits of storybook reading. To ensure a stringent test, we used three measures of comprehension: an open-ended retell task in which children tell the story to the experimenter, an explicit comprehension task in which children are asked questions about events occurring in the story's plot, and an implicit comprehension task in which children are asked questions assessing their ability to make inferences based on the story. Second, we tested vocabulary to assess the extent to which children can learn new vocabulary words *via* video chat. Again, we used three measures to ensure a robust test of this question. These were: a recognition task in which children had to link the vocabulary word to a related image from the book, a transfer task in which children had to link the vocabulary word to a novel image, and an expressive vocabulary task in which children had to provide the meanings of the vocabulary words.

To evaluate the possible benefits of video chat reading, different children were read to by a live experimenter, an experimenter over video chat, or an experimenter in a prerecorded video in a between-subject design. In addition to testing the effectiveness of video chat, these three conditions were chosen to assess the unique roles of (a) screen media and (b) contingency (See **Table 1**). The first aim of the study was to assess whether children could comprehend a book when read to through a digital screen. Children's comprehension in the Live condition was compared to their comprehension in the Video Chat and Prerecorded conditions to assess whether children understood more from the story simply from interacting with a live reader, rather than a reader over a screen. The second aim of the study was to assess the role of contingency in children's comprehension of the book. Both the Live and the Video chat conditions contained *contingency*; the reader could provide time-sensitive responses tailored to children's individual behaviors. In contrast, the Prerecorded condition lacked these elements of true contingency and provided only predetermined responses to children. Children's comprehension in the Live and Video chat conditions was compared to their comprehension in the Prerecorded condition to assess the role of contingency in children's understanding of the book. The third aim of the study was to assess whether children's responsiveness *during* book reading explained the effect of different reading formats (i.e., Live, Video chat, and Prerecorded) on their performance on outcome measures. Based on the literature, we hypothesized the following:

1. Children's story comprehension and vocabulary learning in the Live and Video chat conditions will not differ, as both conditions include socially contingent partners.
2. Children's story comprehension and vocabulary learning will be better in the Live and Video chat conditions than the Prerecorded condition, as the Prerecorded condition is not contingent.
3. Children will be more responsive to the reader (e.g., answer questions and respond to prompts) during book reading in the Live and Video chat conditions than in the Prerecorded condition.
4. Children's responsiveness to questions and prompts used during book reading will be related to their story comprehension and vocabulary learning.

**TABLE 1** | Outline of condition affordances.

| | Prerecorded | Video chat | Live |
|---|---|---|---|
| Dialogic reading prompts | √ | √ | √ |
| Contingent | × | √ | √ |
| Non-mediated (not on a screen) | × | × | √ |

# MATERIALS AND METHODS

## Design

We first randomly assigned participants to our three primary conditions (Prerecorded, Video chat, and Live) and conducted book reading and measures of comprehension and learning. We subsequently added a small sample of children who completed the comprehension and learning measures but were not exposed to the book as a control group for comparison.

## Participants

A total of 58 4-year-olds (31 girls, $M_{age}$ = 52.70, $SD_{age}$ = 4.04) were randomly assigned to the three primary conditions. Sixteen additional participants were tested but excluded due to failure to complete the procedure ($n$ = 8), being out of age range ($n$ = 1), having already read the book ($n$ = 1), audio recording malfunction ($n$ = 4), experimenter error ($n$ = 1), or a diagnosed developmental delay ($n$ = 1). All data were collected prior to the COVID-19 pandemic. Our sample was largely homogeneous; participants were predominately white (74% of children), middle-class (78% of primary caregivers held at least a bachelor's degree), and spoke English as their primary language (100% of sample).

Demographic information about the sample is provided in **Table 2**. Participants were recruited and the study was conducted at two separate sites. At one site, participants were recruited by telephone and email from databases of families willing to participate in research at laboratories based at a Mid-Atlantic University. At the second site, a Midwestern University, participants were recruited from local early childcare centers. As reading practices have been shown to differ across socioeconomic status (SES; Huebner, 2000), we assessed whether conditions differed by caregivers' education, a core dimension of SES (Molborn et al., 2014). Two ANOVA's revealed that primary caregivers' [$F(2,55) = 0.565$, $p = 0.571$] and secondary caregivers' [$F(2,54) = 0.405$, $p = 0.669$] education did not differ by condition.

Note that sample sizes for each outcome measure differed slightly ($N = 54$ for expressive vocabulary, 57 for receptive vocabulary, 58 for transfer vocabulary, 56 for explicit comprehension, 53 for page-by-page retell, and 52 for implicit comprehension) due to issues with children's cooperativeness. When children appeared uninterested in completing a particular task after multiple attempts to reengage them, the researcher moved onto the next task.

Participants in the control condition were 11 children (6 girls). Nine children were tested at site 1 and two were tested at site 2; this distribution was similar to the original sample (experimental: 72.4% at site 1, control: 81.8% at site 1). Primary and secondary caregiver education did not differ between the experimental and control conditions, [primary caregiver: $t(67) = 0.673$, $p = 0.503$; secondary caregiver: $t(66) = -1.72$, $p = 0.089$]. An independent-samples $t$-test revealed that children in the control condition ($M_{age} = 50.70$, $SD = 2.32$) were slightly younger than children in the experimental groups ($M_{age} = 52.70$, $SD = 4.04$), $t(23.49) = 2.29$, $p = 0.032$ (adjusting degrees of freedom in light of unequal variances in Levene's test, $F = 9.35$, $p = 0.003$). However, notably we found no main effects of age or interactions between age and condition for any outcome measures $p$s > 0.265.

Parents provided written informed consent, and children provided verbal assent before entering the testing room. This project was approved by the University of Delaware Institutional Review Board and the Purdue University Review Board. All children received a certificate of appreciation and a sticker or a picture book after completing the study.

**TABLE 2** | Demographic characteristics of sample by condition.

| | Live | Video chat | Prerecorded | Control |
|---|---|---|---|---|
| Age in months (*SD*) | 52.01 (3.01) | 52.25 (4.42) | 53.05 (4.40) | 50.70 (2.32) |
| **Site** | | | | |
| Site 1 | 11 | 16 | 15 | 9 |
| Site 2 | 7 | 5 | 4 | 2 |
| **Gender** | | | | |
| Male | 8 | 10 | 9 | 5 |
| Female | 10 | 11 | 10 | 6 |
| **Primary caregiver education** | | | | |
| Less than bachelor's degree | 3 | 4 | 6 | 4 |
| Bachelor's degree | 3 | 6 | 4 | 2 |
| Graduate degree | 12 | 11 | 9 | 5 |
| No response | 0 | 0 | 0 | 0 |
| **Secondary caregiver education** | | | | |
| Less than bachelor's degree | 5 | 9 | 6 | 1 |
| Bachelor's degree | 6 | 6 | 5 | 2 |
| Graduate degree | 7 | 5 | 8 | 8 |
| No response | 0 | 1 | 0 | 0 |
| **Race/ethnicity** | | | | |
| White | 15 | 16 | 12 | 9 |
| Black | 1 | 1 | 1 | 0 |
| Hispanic | 0 | 0 | 1 | 0 |
| Asian | 1 | 2 | 2 | 1 |
| Other/multiple races | 1 | 0 | 1 | 1 |
| No response | 0 | 2 | 2 | 0 |

*Experimental N = 58 for transfer vocabulary measure, 57 for receptive vocabulary measure, 56 for explicit comprehension measure, 54 for expressive vocabulary, 53 for page-by-page retell, and 52 for implicit comprehension; Control N = 11.*

## Procedure

In the three experimental conditions, children saw two experimenters; one reader and one tester. Children never saw the reader until the actual reading session, to ensure children did not have any prior interactions with the reader beforehand. Across the three book reading conditions to which participants were randomly assigned, children were read the same book, *The Busy Beaver*, by Nicholas Oldland. This commercially available book was engaging for children of a similar age and demographic in previous research (Dore et al., 2018). Some of the words in the story were replaced with new words to make the vocabulary more challenging for 4-year-olds. Specifically, *forest*, *moose*, *chewed*, and *built* were replaced with *woodland*, *caribou*, *gnawed*, and *constructed*. These words, as well as additional target vocabulary words, were chosen because they were unlikely to be known by children of this age group (Dale and O'Rourke, 1981). Children in all three experimental conditions were read to by the same two female experimenters, one at each site. Furthermore, across all three experimental conditions, the reader used the same 10 scripted dialogic reading prompts during book reading. These prompts, adapted from the CROWD strategy (Whitehurst et al., 1988), included *recall* prompts (i.e., "What looks different now?"), *open-ended* prompts (i.e., "How do you think the birds felt now that they have a new home?"), *Wh*-prompts, (i.e., "What do you think the beaver's going to do?"), and *distancing* prompts (i.e., "Have you ever gotten a booboo? What happened?"); see **Table 3** for a full list of prompts used during book reading. In the Live and Video chat conditions, readers gave the children personalized feedback, based on children's responses to prompts. Rather than providing children with more content than in the Prerecorded condition, the feedback in these conditions functioned to expand children's responses or correct their answers (**Table 4**). The reader often repeated what children said, expanded on their response, and prompted them to continue to respond. In the Prerecorded condition, however, the readers' feedback was scripted and did not vary based on children's responses. Book reading took 7 min and 46 s on average and did not differ by condition, $F(2,51) = 0.368$, $p = 0.694$.

**TABLE 3 |** Questions posed during book reading.

| Question type | Questions |
|---|---|
| *Warm up* | What's your favorite color?<br>What do you see on the cover?<br>Are you ready to find out what happens in the story? |
| *Dialogic reading questions* | Why do you think he (the beaver) thought the caribou's leg was a tree?*<br>Do you see something else that happened when the tree was falling?*<br>Have you ever gotten a booboo? What happened?<br>What do you think the beaver's going to do?*<br>How do you think the birds feel now that they have a new home?*<br>Have you ever had to apologize to one of your friends? What happened?<br>What looks different now?* |

*Included as book-relevant questions for accurate response coding.*

**TABLE 4 |** Examples of reader's feedback to children during reading.

| Condition | Response Example |
|---|---|
| *Live* | *R*: What looks different now? |
| | *C*: The beaver's swimming. |
| | *R*: He's swimming? Anything else? |
| | *C*: He's building. |
| | *R:* He's building, yes. It all looks cleaner, huh? |
| *Video chat* | *R*: What looks different now? |
| | *C*: Yup. |
| | *R*: Huh? |
| | *C:* Yup. |
| | *R*: What looks different in the story? |
| | C: The house. |
| | *R:* The house looks better now? And it's a little cleaner and there are no more trees anywhere? |
| | *C*: Yeah. |
| *Prerecorded* | *R*: What looks different now? |
| | *C:* No response. |
| | *R:* That's right! He cleaned up his mess. Now there are no more trees and branches anywhere and they all look happier. |

*R, reader; C, child.*

In the *Live* condition ($n$ = 18), a first experimenter (i.e., tester) brought the child into the testing room and had them sit down at a table. A second experimenter (i.e., the reader) sat in the testing room across from the child in a second chair. The tester introduced the child to the reader, telling the child, "My friend is going to read you a story today!" The tester left the room during book reading. The reader greeted the child by name and introduced herself. The reader asked the child an opening question (i.e., "What's your favorite color?") and responded appropriately to the child (i.e., "I like [color child previously stated], too!"). The reader then held up the storybook and introduced the story to the child (i.e., "Today, I'm going to read you a story. The name of the story is *The Busy Beaver*"). The reader asked what the child saw on the cover of the book and provided a neutral comment to the child's response. The reader also asked the child whether they were ready to see what happens in the story. After the initial warm up was complete, the reader read *The Busy Beaver* to the child, pausing the reading to use prompts and questions to encourage the child to talk about the book. After the book was completed, the reader left the room and the tester returned.

The procedure in the *Video Chat* ($n$ = 21) condition was identical to the Live condition, except that the reader interacted with the child solely through FaceTime video chatting technology. The tester brought the child into the testing room, where the child was instructed to sit at the table. The tester angled an iPad tablet in front of the child, so that the camera on the tablet captured the child's face. The tester then told the child, "My friend is going to read you a story today!" and then proceeded to call the reader over FaceTime. Once the reader answered the FaceTime call, she followed the same procedure as in the Live condition, beginning with a greeting and warm up and then reading the story and stopping to prompt the child and ask questions about the story. The tester remained in the room with the child to resolve any technical issues but sat behind the child during reading and did not interact with the reader or pay overt attention to the reading activity. After reading, the tester turned off the tablet and sat down across from the participant.

In the *Prerecorded* ($n$ = 19) condition, children were also led into the testing room by the tester, placed in front of the iPad, and told, "My friend is going to read you a story today!" Instead of calling the reader over FaceTime, the tester turned on the tablet to reveal a prerecorded video of the reader. The tester remained in the room with the child to resolve any technical issues but sat behind the child during reading and did not pay overt attention to the reading activity. Prerecorded videos were created for each site to match the average reader word count and reading time of the first four live and first four video chat reading sessions. Specifically, the videos created at each university had word counts of 313 (8 min long) and 305 (9 min long), reflecting the average of the four video chat and live reading sessions at each site. This prerecorded video was *pseudo-contingent* in nature; the reader posed questions to the child during the story and paused for a set period of time (on average, 6.28 s after each question, $SD$ = 2.78) as if to wait for a child response. Then, the reader provided the same generic feedback to the child's response, regardless of the presence or the accuracy of the response. For example, after asking "What's your favorite color?", the reader always waited for a period of time and then responded, "I like that color, too!" After reading, the tester turned off the tablet and sat down across from the participant.

In the *Control* condition, children completed the outcome measures prior to reading the storybook. For each task, children were given the same instructions as children in the experimental conditions. However, testers gave additional emphasis on "doing your best" and mentioned that "these games might seem a bit silly" to ensure that children would not become frustrated by answering questions about a book they had not yet read. After completing the tasks, children watched the prerecorded video on the tablet.

## Outcome Measures

All children completed tasks in the same order: (1) expressive vocabulary, (2) receptive vocabulary, (3) transfer vocabulary, (4) page-by-page retell, (5) explicit comprehension, and (6) implicit comprehension. Tasks were always presented in the same sequential order so that earlier tasks would not provide information that could influence children's later responses (e.g., the comprehension questions could provide information about the book that could be used to complete the page-by-page retell).

### Expressive Vocabulary

The expressive measure was adapted from the New Word Definition Test–Modified (Hadley et al., 2015). Children were asked for the meanings of 10 vocabulary words from the book (i.e., *beaver*, *dam*, *felled*, *leaky*, *homeless*, *careless*, *caribou*, *construct*, *woodland*, and *gnaw*). Although the words appeared in the book, they were never explicitly taught to children, as research suggests that caregivers do not typically teach vocabulary during shared book reading (Evans et al., 2011). Additionally, research suggests that preschoolers can learn vocabulary words that are repeated during book reading, even in the absence of word definitions (O'Fallon et al., 2020). For nouns, children were asked, for example, "What is a dam?" and then, "Can you tell me or show me anything else about a dam?" For verbs, children were asked, for example, "What is gnawing?" and "Can you tell me or show me anything else about gnawing?" Testers gave children neutral feedback regardless of their accuracy, e.g., "You're working so hard!" Prior to beginning the test words, children responded to two practice words (*drinking* and *tree*) to ensure that they understood the task. In the middle of the task, children were asked an additional practice word, *hat*, to ensure that they were responding attentively and to encourage them with an easier question. Responses to test words were coded for each information unit the child provided. We coded for eight information unit categories: perceptual qualities, functional information, part/whole, synonyms, antonyms, gestures, meaningful context, and basic context. Children's verbal responses and relevant gestures were considered when coding responses. For example, if children gestured to represent hammering in response to *construct*, they received a point. Children received one point for each information unit provided from the first seven categories and half of a point for giving basic context of a word (e.g., "He was *constructing* a dam."). To examine reliability for the expressive task, 20% of the participants ($n = 11$) were randomly selected and double-coded by a second coder. Reliability was high, Kappa = 0.814.

### Receptive Vocabulary

Children were tested on the same 10 vocabulary words in the expressive task. However, children demonstrated their receptive knowledge of words instead of providing productive responses. For each word, children were shown images on two cards taken directly from the story and were asked to identify the image representing the target word. For example, children were shown images of the beaver and the caribou and asked, "Can you show me the beaver?" Foil images in the receptive task were all images from the book that were perceptually comparable to the image representing the target word. For example, for the word *beaver*, both choices showed images of a single character; one image was a bear standing upright on a white background and the other image was a beaver standing upright on a white background. For the word *homeless*, children saw two options, both containing three birds. In the target option, the birds held sacks and walked on the ground. The children had previously seen this image in the book when the birds were described as *homeless*. In the foil option, the three birds were shown in their nest, representing birds in their home. Children received one point for a correct answer and zero points for an incorrect answer.

### Transfer Vocabulary

In this stringent test of word knowledge, children viewed four photographs from real-world contexts not represented in the book. Children were tested on the same 10 words as in the expressive and receptive tasks. As in Dore et al. (2019), foil selection was guided by research on lexical development (e.g., Golinkoff et al., 1995) and included three types of foils: (1) *thematic* (frequently found in the same event or situation, e.g., a forest for the word *beaver*); (2) *conceptual* (shares a common category, e.g., animal, as in a panther for *beaver*); and (3) *phonological* (rhymes with the target word, e.g., fever for *beaver*). In the task, children must generalize beyond the book's picture to a new exemplar and choose between meaningfully-related options. Children were instructed to point to the target word and received one point for selecting the target and zero points for selecting any of the three foils.

### Page-by-Page Retell

Adapted from Dore et al. (2018), the researcher showed children printed screenshots of the book's pages with the text removed and asked children to retell what happened on each page of the story. Instructions were revised slightly for the control condition; rather than being asked to retell the story, children were asked, "On each page, can you tell me what you think is happening?" Across conditions, on the first page, researchers would say "I'll get you started… There once was a…." If needed, children were given encouraging comments in a set order (e.g., "What happened here?" or "Do you remember anything else?"). If children pointed, were vague, or said "this" or "that," researchers would prompt them to verbalize (e.g., "Who?" and "What is that?"). Researchers did not include any specific information in their prompts or give children any feedback. Responses were coded by counting how many of a predetermined set of possible elements children recalled from the story, based on coding established in Dore et al. (2018). To examine inter-coder reliability, a second trained coder, blind to the original coding, coded a randomly selected 20% of the data. For each of the identified possible elements children could retell, agreement between the two coders was examined. After removing 65 of the identified elements that were never recalled by any of the children, average agreement for the elements children recalled was 94.12%. Where there were disagreements, the original coder's decision was retained. Kappa was also calculated with all possible elements included. Reliability was high, Kappa = 0.858.

### Explicit Comprehension Questions

In the explicit comprehension task (adapted from Dore et al., 2018), children were asked five multiple-choice comprehension questions about the content of the story with two response options, such as "How did the beaver get better at saying 'I'm sorry?' (A) He read a book about it. (B) He practiced in the mirror." Response options were read and also represented visually by showing children two cards with illustrations from the story. Questions were developed to assess children's understanding of basic story events. Children could not realistically answer these questions solely from looking at the photos. In the previous example, for instance, the beaver both read a book and practiced something in the mirror during the story. Beyond identifying pictures from the story, children had to assess which picture from the story accurately answered the question. If needed, questions were repeated to make sure that the child understood the question and the response options. Children who were unsure or reluctant to provide an answer were told to give their best guess.

### Implicit Comprehension Questions

The implicit task, adapted from Paris and Paris (2001), assessed children's ability to make appropriate inferences about photos using information from pages in the book. Children were asked five questions that focused on making inferences about characters' feelings, causation, dialogue between characters, predictions, and overall theme. For example, children were shown a photo of a bear with a bandage on his head and asked, "Tell me what the bear is feeling in this picture. Why do you think so?" Children received a score of 2 for responses that indicated an inference that drew on events from multiple pages in the book, a 1 for an appropriate inference that was limited to events on the page, and a 0 for an inappropriate inference or response. Scoring was based on a coding scheme established in Paris and Paris (2001). To examine inter-coder reliability, a second trained coder, blind to the original coding, coded a randomly selected 20% of the data. Reliability was high, Kappa = 0.848.

## Responsiveness Without Regard to Accuracy

Children's responsiveness to questions posed during book reading was coded by a trained research assistant and the first two authors. Coders watched videos of the reading sessions and noted whether a child provided a response for each of the 10 questions during book reading. Any meaningful verbal or nonverbal (e.g., a head nod in response to a yes/no question) behavior was coded as a response. For each of the 10 questions, children received either a 1 for a response or a 0 for no response. As this measure was focused purely on whether children gave a response, accuracy was not considered. To examine inter-coder reliability, a second trained coder, blind to the original coding, coded a randomly selected 20% of the data. Reliability was perfect, Kappa = 1.

## Accurate Responding

Next, children's accurate responding to book-relevant questions was coded. A coding scheme was developed to give children points for answering the question with accurate information. Only questions that were specific to the book plot were included (see **Table 3**). For example, for the question "Why do you think the beaver thought the caribou's leg was a tree?", children received points for mentioning "it's brown," "it's skinny," or "it looks like a tree." Children received one point for each unit of accurate information provided. In the previous example, if the child responded "because it's brown and skinny," the child would receive two points for the question. To examine inter-coder reliability, a second trained coder, blind to the original coding, coded a randomly selected 20% of the data. Reliability was substantial, Kappa = 0.79.

# RESULTS

Results from the six comprehensions and vocabulary measures are presented first as the primary aim of the study was to assess how different book formats affected children's reading comprehension. This is followed by results of children's responsiveness to the story during book reading. Diagnostic analyses identified one outlier in the receptive vocabulary task (low score of 2), one outlier on the expressive vocabulary task (high score of 12), and two outliers in the implicit comprehension task (low scores of 1 and 2). These outliers, which were defined as more than 1.5 times the interquartile range above third quartile or below the first quartile, were excluded in analyses conducted on their respective outcome measures. Separate independent-samples $t$-tests were conducted to assess differences on the outcome measures between the two testing sites. One difference emerged, such that children at site 1 ($M$ = 6.69, $SD$ = 1.64) scored significantly higher on the transfer vocabulary test than children at site 2 ($M$ = 5.25, $SD$ = 1.95), $t(56) = 2.83$, $p = 0.006$. Thus, an ANOVA was run to test for an interaction between condition and site for the transfer task. This model was not significant, $p = 0.846$. No other differences on the remaining outcome measures between the two testing sites were observed ($p$s > 0.236). Non-parametric tests were conducted for the receptive vocabulary and explicit comprehension tasks as scores on these measures were not normally distributed.

## Story Comprehension and Vocabulary Learning

Next, we assessed whether the experimental conditions differed on the six outcome measures. To test our first two research questions, (1) whether children learned equally well through video chat and live book reading and (2) whether contingency in book reading affected children's reading comprehension and vocabulary, separate ANOVAs and nonparametric Kruskal-Wallis tests were conducted. Note that the control condition is presented separately from analyses comparing the three conditions, as this data was collected after the original sample and was *post hoc* in nature. Additionally, the control group is presented separately to maximize statistical power and avoid comparing unequal sample sizes in the main analyses. Children's performance on each outcome measure was compared across conditions. No main effects of condition were found for the expressive vocabulary, [$F(2,51) = 0.323$, $p = 0.725$, $d = 0.217$, $n = 54$], transfer vocabulary [$F(2,57) = 0.382$, $p = 0.684$, $d = 0.073$, $n = 58$], implicit comprehension [$F(2,49) = 0.054$, $p = 0.948$, $d = 0.090$, $n = 52$], page-by-page retell task [$F(2,50) = 0.908$, $p = 0.410$, $d = 0.372$, $n = 53$], explicit comprehension [$X^2$ (2) = 1.58, $p = 0.453$, $d = 0.204$, $n = 56$], or receptive vocabulary [$X^2(58) = 2.54$, $p = 0.281$, $d = 0.316$, $n = 57$] tasks. Children performed similarly on comprehension and vocabulary measures across conditions, suggesting that they were not affected by the differing levels of contingency in book reading sessions (see **Table 5** and **Figure 1**).

To test whether younger children (i.e., closer to 4 years) were more affected by contingency (i.e., performing better in the Live and Video chat conditions) than older children (i.e., closer to 4.9 years), analyses were also conducted to examine whether children's age moderated the effect of condition on outcome measures. Separate two-way ANOVAs tested whether there were any interactions between age (entered as a continuous variable) and condition for outcome measures. Models were not significant for any of the tasks, $p$s > 0.265. Based on their performance on comprehension and vocabulary tasks, older and younger children learned similarly across different book formats.

Preliminary analyses indicated that children were at floor for some words on the expressive vocabulary task. On average, children scored less than 0.10 point for *felled* ($M = 0.065$, $SD = 0.22$), *caribou* ($M = 0.083$, $SD = 0.27$), and *gnaw* ($M = 0.09$, $SD = 0.35$). Thus, an ANOVA was conducted to compare children's performance on the expressive task by condition excluding these three words. As with the initial model, no condition differences were observed after excluding the three challenging words, $F(2,52) = 0.230$, $p = 0.795$.

Analyses were also conducted to examine whether parent-reported video chat use moderated the effect of condition on outcome measures. Separate two-way ANOVAs tested whether there were any interactions between video chat use and condition for outcome measures. Models were not significant for any of the tasks, $p$s > 0.305.

## Responsiveness During Reading Sessions

Next, we tested our third research question, whether children were more responsive to the scripted prompts in the Live and Video chat conditions than the Prerecorded condition. Children's responsiveness during book reading was analyzed based on coding any meaningful verbal or nonverbal response to the reader's question or prompt. As responsiveness was not normally distributed, non-parametric tests were employed. A Kruskal-Wallis test revealed that the frequency with which children responded to the reader's prompts during book reading differed by condition, $X^2(2) = 10.48$, $p = 0.005$, with a median of 5.67 ($SD = 4.03$) for Prerecorded, 9.19 ($SD = 1.91$) for Video chat, and 9.27 ($SD = 0.80$) for Live. Children in the Video chat ($p = 0.001$) and Live ($p = 0.038$) conditions responded more to the reader's questions during book reading than those in the Prerecorded condition. There was no difference in children's responsiveness between the Video chat and Live conditions, $p = 0.381$.

To test our fourth research question, Pearson and Spearman correlations were conducted to assess relationships between children's overall responsiveness during reading and performance on outcome measures. No significant correlations were observed for the expressive vocabulary ($r = 0.008$, $p = 0.957$), transfer ($r = -0.120$, $p = 0.400$), implicit comprehension ($r = 0.229$, $p = 0.126$), retell ($r = 0.119$, $p = 0.388$), explicit comprehension ($r_s = -0.052$, $p = 0.718$), or receptive ($r_s = -0.166$, $p = 0.248$) tasks. Separate two-way ANOVAs were run to test whether responsiveness was differentially related to children's outcomes across conditions. Models were not significant for any of the measures ($p$s > 0.216), suggesting that although children's responsiveness differed by condition, their responsiveness did not moderate the effect of condition on their comprehension or vocabulary scores.

Next, children's accurate responding to prompts during book reading was analyzed. A Kruskal-Wallis test found no differences between conditions on accurate responding, $X^2(2) = 1.37$, $p = 0.504$. Pearson and Spearman correlations were conducted to compare children's performance on each task and their total

**TABLE 5 |** Descriptive results for vocabulary and comprehension measures by condition.

| | Expressive vocabulary | Receptive vocabulary | Transfer vocabulary | Explicit comprehension | Implicit comprehension | Page-by-page retell |
|---|---|---|---|---|---|---|
| Possible range | 0–85 | 0–10 | 0–10 | 0–5 | 0–10 | 0–133 |
| *Live* | 4.24 (2.27) | 7.33 (1.37) | 6.06 (1.66) | 3.06 (1.11) | 4.75 (1.98) | 19.94 (6.45) |
| *Video chat* | 3.67 (2.38) | 6.65 (1.42) | 6.24 (2.00) | 2.85 (0.99) | 4.58 (2.50) | 16.44 (8.68) |
| *Prerecorded* | 3.87 (1.66) | 7.16 (1.46) | 6.58 (1.86) | 3.28 (1.02) | 4.82 (2.35) | 18.61 (7.93) |

*Experimental N = 58 for transfer vocabulary measure, 57 for receptive vocabulary measure, 56 for explicit comprehension measure, 54 for expressive vocabulary, 53 for page-by-page retell, and 52 for implicit comprehension.*

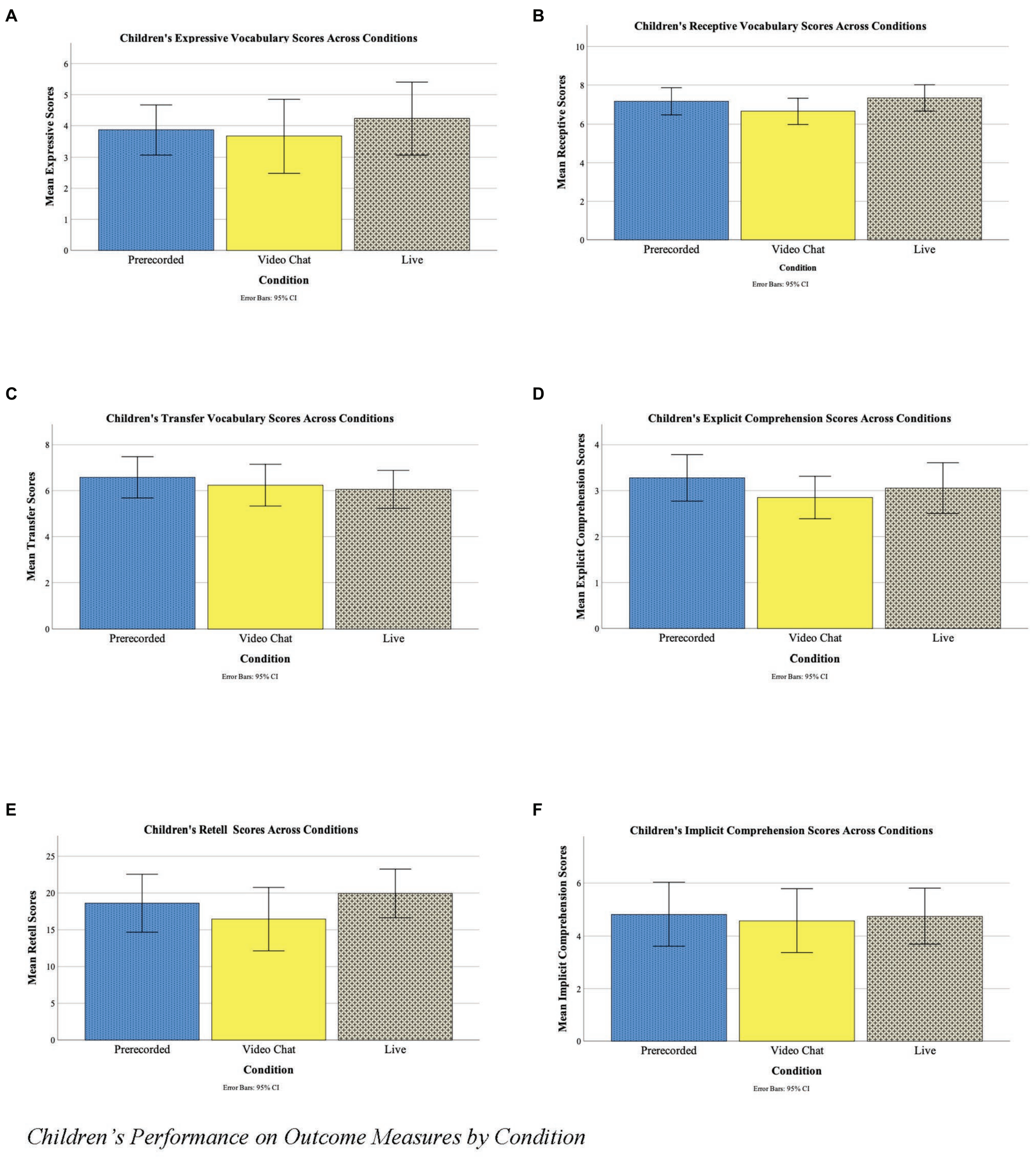


**FIGURE 1** | Children's performance on outcome measures by condition. **(A)** Children's expressive vocabulary scores across conditions. **(B)** Children's receptive vocabulary scores across conditions. **(C)** Children's transfer vocabulary scores across conditions. **(D)** Children's explicit comprehension scores across conditions. **(E)** Children's retell scores across conditions. **(F)** Children's implicit comprehension scores across conditions.

number of accurate responses during reading. Children who provided more accurate responses to questions relevant to the book during book reading performed better on the expressive vocabulary ($r = 0.472$, $p = 0.001$), implicit ($r = 0.499$, $p < 0.001$), retell ($r = 0.429$, $p = 0.002$), explicit comprehension ($r_s = 0.300$, $p = 0.029$), receptive ($r_s = 0.276$, $p = 0.044$), and marginally, transfer ($r = 0.254$, $p = 0.061$) tasks. Based on these correlations, separate two-way ANOVAs were conducted to test for interactions between condition and children's accurate responding predicting performance on outcome measures. Models were not significant for the receptive ($p = 0.174$), transfer ($p = 0.237$), or implicit comprehension ($p = 0.144$) tasks. The model for the page-by-page retell task was significant, $F(23) = 1.98$, $p = 0.047$. A marginal interaction was observed between children's accurate responding and condition for the retell measure, $F(9,49) = 2.04$, $p = 0.075$. This interaction was further explored through correlations. Children's accurate responding during book reading prompts was positively related to the retell measure in the Video Chat ($r = 0.666$, $p = 0.003$) and in the Live conditions ($r = 0.523$, $p = 0.045$) but not in the Prerecorded condition, $r = 0.072$, $p = 0.782$.

## Results From the Control Condition

Lastly, analyses were conducted to assess whether children in the three experimental groups outperformed children in the control condition, who had not read the book. Results revealed a similar pattern across measures (see **Table 6**). Children in the experimental conditions scored significantly higher than children in the control condition on the receptive vocabulary test ($U = 497.50$, $z = 2.97$, $p = 0.003$) and the explicit comprehension test, $U = 446.00$, $z = 2.28$, $p = 0.022$. Independent-samples *t*-tests were conducted to compare children's performance on the expressive vocabulary, transfer vocabulary, retell, and implicit measures. Children in the experimental conditions outperformed children in the control condition on the transfer vocabulary [$t(67) = -2.07$, $p = 0.043$] and retell [$t(62) = 3.91$, $p < 0.001$] tasks and marginally outperformed the control condition on the implicit comprehension task, $t(63) = 1.74$, $p = 0.087$. However, children in the experimental conditions did not score significantly higher on the expressive vocabulary task than children in the control condition, $t(64) = 1.54$, $p = 0.129$.

# DISCUSSION

The current study tested whether preschoolers would comprehend a book differently if read to by a live experimenter, an experimenter on video chat, or an experimenter on a prerecorded video. Results revealed that children responded more to dialogic prompts and questions posed during book reading in the contingent conditions (i.e., Live and Video chat) than in the pseudo-contingent condition (i.e., Prerecorded). Despite this difference, results ultimately suggest that 4-year-old children comprehended a storybook similarly regardless of book reading format. Additionally, neither children's age nor previous video chat use affected how children comprehended the book in different formats.

Importantly, children's comprehension did not differ between the *Video chat* and *Live* conditions. Although we expected children to comprehend major story elements in both the Video chat and Live conditions as both were conducted by contingent social partners, children might be expected to comprehend more from reading with a live adult who might provide more social cues to children during video chatting. However, the 4-year-olds in this study comprehended just as much from the story when they were read to over video chat as when read to by a live experimenter. One reason children may have comprehended the story equally well is the prevalence of video chat in children's lives – even before the COVID-19 pandemic, participants had experience with video chatting. In the current sample, parents were asked about their child's use of video chat technologies (e.g., Skype or FaceTime), and out of 58 parents, 51 reported that their child had video chatted in the past. Considering that at least 87.9% of children in the current study had already used video chat, these children may have been well-accustomed to interacting with digital partners over screens, leading to equal comprehension across the Video chat and Live conditions. Contrary to our expectations, children's previous experience with video chat did not moderate the effect of condition on any of the outcome measures. Other research similarly reports a null relationship between children's prior experience with video chatting and their performance in lab-based video studies (Myers et al., 2018; Strouse et al., 2018). Perhaps the contingent interactions in video chat conversations are so similar to live, in-person conversations that children do not need extensive experience with video chatting to learn from it. Although the children in the current study were familiar with video chatting, even children with less experience may learn from the book reading activity.

Children's comparable performance in the Prerecorded condition to the other two conditions was still somewhat surprising in light of the literature on the role of contingency in children's learning (Troseth et al., 2006; Lauricella et al., 2010; Roseberry et al., 2014). This research would suggest that the Video chat and Live conditions, including the element of contingent interactions, would outperform the Prerecorded condition, which lacked true contingency. Although we hypothesized that the 4-year-olds in our study would similarly struggle to learn from a prerecorded video and benefit from *social* contingency, previous work was mostly conducted with toddlers. By the preschool years, children's learning may not be as sensitive to contingency. Indeed, several studies suggest that *touch screen* contingency (e.g., requiring children to touch the screen to reveal a hidden object) may actually be detrimental for older children's learning. For example, some studies found

**TABLE 6** | Descriptive results for experimental and control conditions; Mean (standard deviation).

| Measure | Experimental conditions | Control condition | Effect size(Cohen's *d*) |
|---|---|---|---|
| *Expressive vocabulary* | 4.06 (2.34) | 2.82 (2.99) | 0.46 |
| *Receptive vocabulary* | 6.84 (1.80)* | 5.27 (1.42) | 0.97 |
| *Transfer vocabulary* | 6.16 (2.00)* | 4.82 (1.78) | 0.71 |
| *Explicit comprehension* | 3.00 (1.10)* | 2.09 (1.22) | 0.78 |
| *Implicit comprehension* | 4.54 (2.39)† | 3.18 (2.14) | 0.60 |
| *Page-by-page retell* | 18.30 (7.75)** | 8.64 (5.77) | 1.41 |

†*Indicates* $p < 0.10$.
**Indicates* $p < 0.05$.
***Indicates* $p < 0.001$.

that while children around 2 years old learn better from a contingent touchscreen interaction, children closer to 3 years of age learn equally well or even better from watching a non-contingent video, devoid of touchscreen interaction (Choi and Kirkorian, 2016; Kirkorian et al., 2016). A similar study found that preschoolers learned better from watching a recording of game play than from playing the digital game themselves, possibly because cognitive load is too high during play for children to encode new information (Schroeder and Kirkorian, 2016; see also Aladé et al., 2016). Although there are fewer studies of social contingency with preschool-aged children, it is possible that learning from social contingency and touch screen contingency may pattern similarly, and in the current study, 4-year-olds no longer needed true social contingency to learn from the story. One study mimicking social contingency compared 3- and 5-year-olds with previous exposure to *Blue's Clues*, a TV show with elements of pseudo-contingency, to children who had not been exposed to the show media (Crawley et al., 2006). Children who had previously watched *Blue's Clues* responded more to prompts both during a *Blue's Clues* episode and during a new TV show than children who had not been previously exposed to *Blue's Clues*, suggesting that children are responsive to the pseudo-contingent style in the domain of social communication. Beyond comprehending the story, children in the Prerecorded condition also performed just as well as children in the other two conditions on measures of vocabulary. Although contingent conversations may be best for early language development (Hirsh-Pasek et al., 2015a), some research suggests children can learn vocabulary words even when listening to a book read a single time verbatim (Sénéchal and Cornell, 1993). Perhaps by 4 years of age, children can gain some vocabulary knowledge even through passively listening to a story.

Similarly, by 4 or 5 years of age, children may not be as sensitive to book formats in general, in line with a previous study showing that, unlike 3-year-olds, 5-year-olds did not demonstrate decreased comprehension from the distracting features in that study's console book, the predecessor of e-books (Parish-Morris et al., 2013). Parish-Morris et al. (2013) suggested that the 5-years-olds in their study comprehended the basic narrative structure from e-books, even when hotspots and sound effects disrupt the 3-year-olds' comprehension of the book.

As we did not originally include any pretest measures, we tested a sample of children on the measures *before* reading them the book to create a control group. These results confirmed that children in all three experimental conditions (i.e., Live, Video chat, and Prerecorded) indeed learned from hearing the book. Children gained significant plot information from the story, as demonstrated in the explicit comprehension and retell tasks, and learned vocabulary words, as seen in the receptive and transfer tasks. Crucially, these vocabulary words were never taught explicitly in the book. Our results align with previous research (O'Fallon et al., 2020), which suggests that young children can learn new vocabulary words during book reading without explicit instruction. However, although children in the experimental conditions scored higher than children in the control condition on the expressive vocabulary measure, this difference did not reach traditional levels of statistical significance. This finding was somewhat inconsistent with previous research, as studies commonly find that dialogic reading improves children's *expressive* vocabulary, but not necessarily children's *receptive* vocabulary (e.g., Whitehurst et al., 1988, 1994; Lonigan and Whitehurst, 1998; Hargave and Sénéchal, 2000). Additionally, research using a similar expressive vocabulary task found that after a book reading intervention, preschoolers did show significant improvements in their knowledge of target vocabulary words (Toub et al., 2018), suggesting that the task was not beyond children's ability level in the current study. However, reading occurred over multiple sessions in the prior studies that found positive effects on expressive vocabulary. Previous research suggests children struggle to perform on expressive vocabulary tasks after a single book reading session (Sénéchal and Cornell, 1993). In the current study, although children identified vocabulary words from corresponding photos, a single book reading session may not have been sufficient for them to talk about the meanings of the new words. When looking across all outcome measures, results from the control condition suggest that children comprehended the story and gained receptive vocabulary knowledge through reading the story across all three book reading conditions.

Despite a lack of differences between our experimental conditions on outcome measures, children were overall more responsive in the Live and Video chat conditions than the Prerecorded condition, indicating that they were sensitive to the fact that these interactions contained contingency that was lacking in the Prerecorded condition. Yet, across conditions, children's responsiveness did not relate to their performance on the comprehension and vocabulary measures. However, analyzing the *content* of children's responses during book reading revealed an interesting interaction. Children's accurate responding during book reading prompts was marginally positively related to the retell measure in the Video chat and Live conditions, but not in the Prerecorded condition. One explanation for this finding is that in the Video chat and Live conditions, the reader could tailor her reactions to individual children's responses, adding relevant information and expanding on children's comments directly. Children in the Prerecorded condition had the opportunity to respond to questions and prompts during book reading, but the reader could not give the personalized feedback that was possible in the other two conditions. Beyond simply giving children the opportunity to respond to a question, the readers in the Live and Video chat conditions also asked children for further clarifications of their responses and asked children to give additional information. This additional feedback may have been key for promoting children's comprehension of the story. As a consequence, some children engaged in back-and-forth communication with the reader in their responses (See **Table 4**), adding details to their answers. The Live and Video chat readers' comments may have encouraged children to further clarify and expand on their responses, helping keep children focused on key story elements. Future research on dialogic reading should focus on how readers' feedback to children affects their reading comprehension and learning from the story in both digital and live contexts.

Importantly, these results reflect 4-year-olds' learning from the book irrespective of any adult co-viewing behaviors. Although children did not seem to notice the testers' lack of overt attention to the tablet during book reading sessions, it is possible that it affected their reading experience. Some research has shown that 30-month-olds learned novel words best when watching a contingent video with a parent who modeled responsiveness to the video than when the parent was out of the child's view (Strouse et al., 2018). In fact, even having a parent co-view a prerecorded video aided children's learning. In the current study, *preschoolers* responded more frequently to the contingent video chat reader than to the pseudo-contingent, prerecorded reader, suggesting that even without an adult co-viewer, by 4 years of age, children were able to differentiate between the video chat and prerecorded videos. Regardless of their responses, preschoolers learned from both video formats, without the presence of an attentive adult co-viewer.

## Other Potential Benefits of Reading With a Live Adult

The findings of this study have several practical implications. First, our findings suggest that 4-year-olds can glean story details from simply watching a prerecorded video of a storybook reading. Although it might be tempting to conclude that watching TV or video content would be comparable to live interactive book reading, it is possible that commercially-available videos (e.g., TV, DVDs, and YouTube) would not yield the same effects. Specifically, because of the experimental nature of this study, the Prerecorded condition was explicitly designed to be as closely matched to the other two contingent conditions as possible. The video focused exclusively on the reader, who sat in a room with bare walls. Typical TV programs are likely to include more engaging features (e.g., animation, sound effects, and scene transitions) that could detract from children's attention to the story (see Bus et al., 2015, for an example in the domain of e-books). Furthermore, although some TV shows and other video content include characters directly addressing the viewer, many do not. The current findings suggest that, in line with some prior research (Krcmar and Cingel, 2017), having video characters directly address viewers may facilitate comprehension (see also Crawley et al., 2006). Storybooks read over video that lack this feature may not be as effective.

Additionally, even if children in this age range can comprehend stories from videos, a live adult is required for many of the positive outcomes traditionally associated with shared book reading. For example, research suggests that contingent, back-and-forth communication is best for promoting children's language skills in general, at least, for younger children (Hirsh-Pasek et al., 2015a; Romeo et al., 2018; Merz et al., 2019). Children can practice back-and-forth conversation during book reading both in person and over video chat by responding to adults' dialogic reading questions and receiving feedback catered specifically to their response but not when watching a prerecorded video. Additionally, during storybook reading, children gain print knowledge (Leseman and deJong, 1998; Justice et al., 2008; Korat, et al., 2009), learn to identify the relationship between printed text and oral words, and begin to understand the function of printed text (Mason, 1980; Hiebert, 1981; Justice and Ezell, 2001). The current study did not address whether children can also gain these important skills in a prerecorded book reading format. Another potential advantage over the prerecorded format relates to the emotional experience of shared book reading. Preliminary results from an ongoing study (Avelar et al., in preparation) suggest that reading with a parent is a different emotional experience than reading an e-book independently, with shared reading associated with greater physiological arousal and more positive emotion in 4-year-olds (Dore et al., 2019), a difference that may not extend to watching a video of prerecorded book reading.

## Implications for Families During COVID-19 and Beyond

Although prior research shows that reading with an adult in person has widespread advantages for children, the results of the current study suggest that even when they are physically apart, adults can support preschoolers' reading comprehension with video chat. This finding has promising implications for many families. Primarily, these results suggest that during the current COVID-19 crisis and any similar stay-at-home orders in the future, 4-year-olds *can learn* when read to over video chat. When allowing their children to read a book over video chat with a distant family member, parents can feel confident that children are likely comprehending the story and may even be learning new vocabulary words. Without knowing how long the current pandemic will last or whether we will face another wave of the pandemic in the future, it is imperative for parents to be armed with knowledge of virtual activities that are beneficial for their young children. Furthermore, preschoolers with separated or divorced parents living in separate homes, incarcerated parents, and parents living in other countries could all potentially benefit from reading with parents through video chat, both during the pandemic and in typical times. For example, programs have been developed to help incarcerated parents record videos of themselves reading to their children (Barker, 2019). The current study suggests that by age 4, children may comprehend these stories. Although more research is needed, children may experience benefits in other domains (language skills and emotional bonding) from reading over video chat.

Additionally, children from disadvantaged backgrounds who are likely to experience less and lower-quality language input (e.g., Hirsh-Pasek et al., 2015a) may benefit from video chat reading experiences, perhaps facilitated by programs that pair children with adult volunteers or through educators organizing virtual reading sessions. Providing children from low-SES backgrounds with opportunities to read with a caring adult virtually is extremely relevant, as many children are currently home without the resources to continue learning as they did in schools. Although the gap has narrowed somewhat in recent years, families experiencing poverty are still less likely to have access to books and engage in fewer bouts of shared book reading (Bassok et al., 2016). Caregivers of children in poverty often have less time to spend reading to their children (Neuman and Celano, 2001), with a 2017 report finding that

53% of low-SES children read or are read to every day compared to 68% of children from high-SES families (Rideout, 2017). Low-SES caregivers are also less likely to read in a style that is related to positive child language outcomes (van Kleeck, 1998; Berkule et al., 2007; Bornstein and Putnick, 2012). Thus, especially while schools and daycares are closed, preschoolers from low-income homes may be in an ideal position to profit from engaging in video chat storybook reading with a volunteer reader or a teacher. Indeed, the current findings suggest that 4-year-olds may benefit from reading over video chat with volunteers trained to use dialogic reading practices. Although programs like Jumpstart have demonstrated effectiveness by pairing children with adult mentors to work on reading through in-person experiences (Jumpstart, 2018), remote reading over video chat may have some additional advantages. It could alleviate barriers to volunteering by allowing participants to engage with children without the inconvenience of spending time in travel to a childcare site or to children's homes (e.g., Sundeen and Raskoff, 2000). In the current moment, video chat reading would circumvent concerns about the spread of COVID-19.

Notably, based on the current findings, these advantages of video chat may also apply equally to prerecorded storybook reading. Indeed, it is promising that 4-year-olds in the current study learned equally well from a prerecorded video, which could be easily scaled and does not require additional time from an adult for each reading session. However, although more research is needed, we expect that over multiple sessions, children may benefit more from video chat reading due to the responsive feedback and the presence of a caring adult who can learn about the child's skills and interests and tailor the reading experience.

## Limitations and Future Directions

Although the current findings are promising, some limitations must be considered. First, our sample was largely homogeneous. Given that children from disadvantaged backgrounds are likely to have lower cognitive and academic skills than their wealthier group counterparts (e.g., Morgan et al., 2011), children from more disadvantaged backgrounds might need more support than the children in the current sample. Like the younger children in prior studies (e.g., Parish-Morris et al., 2013; Kirkorian et al., 2016), children who come into the reading experience with lower levels of cognitive skills or less familiarity with book reading and dialogic reading practices may benefit from the socially contingent interactions in the Live and Video chat reading or from the social cues present in the Live condition specifically, and not perform as well in the Prerecorded condition. An additional limitation is that the current study was conducted in controlled settings, within quiet rooms containing minimal distractions. While children appeared to comprehend the prerecorded video without having an adult keep them on task or redirect their attention, a more naturalistic setting, such as the home or a classroom, may require a responsive adult to keep children engaged with the reading activity.

Future research should also assess which elements of the prerecorded video are essential to maintain high levels of comprehension. For example, research should disentangle the importance of a prerecorded video including a reader who directly addresses questions toward the camera, who uses dialogic reading prompts, and who pauses for potential responses from viewers. Additionally, it would be helpful to investigate if the style of video we used (i.e., minimal flashy or potentially distracting multimedia features) is the only type that promotes learning. Previous research suggests that these features can be either distracting or supportive depending on children's age (Parish-Morris et al., 2013). The effect of these features on children's learning also may depend on the nature of the feature (i.e., multimedia vs. interactive elements). One meta-analysis of e-books suggests that preschoolers and kindergarteners benefit from multimedia features, such as animations and sound effects, triggered by the story narration, rather than children's touch (Takacs et al., 2015). However, the meta-analysis suggests that children may be distracted by interactive hotspots and games in the book. Further research in a prerecorded book reading context is warranted. Research should also test whether the prerecorded video maintains children's attention and contingent book reading formats. Over multiple reading sessions, children may require additional prompts to stay focused on the story. In contingent reading sessions, the reader can use strategies, such as asking the child a question, to re-engage children's attention if it falters. As the novelty of reading over a tablet fades over multiple sessions, children may become less attentive to the prerecorded video over time. Identifying the essential components of shared book reading is a crucial next step for promoting literacy and language learning in an increasingly digital age. Further research will help elucidate what specific components of book reading activities are essential for learning.

# CONCLUSION

Despite these limitations, the findings of the current study provide insight into 4-year-olds' flexibility in understanding stories from different types of book reading activities. Specifically, in addition to comprehending books from live reading experiences, 4-year-olds reading with an adult over video chat, and even watching a video of an adult reading to them, also prospered. During the COVID-19 school and daycare closures, children may be exposed to more screen time than ever before. The current study provides some positive evidence that watching a video of book reading or reading over video chat can be an educational, engaging activity for children during the pandemic and beyond. When used thoughtfully, media and technology can facilitate the type of traditional shared reading that is the gold standard educational activity for young children.

# DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Delaware Institutional Review Board and Purdue University Research Protection Program and Institutional Review Board. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

YK, RD, DN, and RG conceptualized the idea for the project. YK, RD, and HP developed the study methodology and materials. CG, YK, HP, and research staff collected the data. CG, YK, HP, and research assistants coded the data. CG conducted statistical analyses and wrote the first draft. RD and YK provided critical feedback and edits. All authors contributed to the article and approved the submitted version.

## ACKNOWLEDGMENTS

We thank Lindsey Foster, Allison Chatham, Danielle Kanosky, Alexandria Camille Bien, Katherine Genovese, and Michelle Mehta for their assistance with data collection, Calla Pritulsky for participant recruitment, and Tyler Merrow, Emma Greenberg, and Theresa Manganiello for coding data. We are grateful to parents and children who took part in the research.

## REFERENCES

Aladé, F., Lauricella, A. R., Beaudoin-Ryan, L., and Wartella, E. (2016). Measuring with Murray: touchscreen technology and preschoolers' STEM learning. *Comput. Hum. Behav.* 62, 433–441. doi: 10.1016/j.chb.2016.03.080

Ames, M. G., Go, J., Kaye, J. J., and Spasojevic, M. (2010). "Making love in the network closet: the benefits and work of family video chat." in *Proceedings of the 2010 ACM Conference on Computer Supported Cooperative Work*. February 6–10, 2010. 145–154.

Arnold, D. H., Lonigan, C. J., Whitehurst, G. J., and Epstein, J. N. (1994). Accelerating language development through picture book reading: replication and extension to a videotape training format. *J. Educ. Psychol.* 86, 235–243. doi: 10.1037/0022-0663.86.2.235

Arnold, D. S., and Whitehurst, G. J. (1994). "Accelerating language development through picture book reading: a summary of dialogic reading and its effect" in *Bridges to literacy: Children, families, and schools*. ed. D. K. Dickinson. Blackwell Publishing, 103–128.

Ballagas, R., Kaye, J. J., Ames, M., Go, J., and Raffle, H. (2009). "Family communication: phone conversations with children" in *Proceedings of the 8th International Conference on Interaction Design and Children*. June 3–5, 2009. 321–324.

Barker, D. (2019). Books and puzzles bring family time to prison visitation. *USA Today*. Available at: https://www.usatoday.com/story/news/humankind/2019/01/22/incarcerated-parents-bond-their-kids-through-books-and-activities/2649863002/ (Accessed January 22, 2019).

Bassok, D., Finch, J. E., Lee, R., Reardon, S. F., and Waldfogel, J. (2016). Socioeconomic gaps in early childhood experiences: 1998-2010. *AERA Open* 2, 1–22. doi: 10.1177/2332858416653924

Berkule, S. B., Dreyer, B. P., and Huberman, H. S. (2007). Attitudes about shared reading among at-risk mothers of newborn babies. *Ambul. Pediatr.* 7, 45–50. doi: 10.1016/j.ambp.2006.10.004

Blackwell, C. K., Wartella, E., Lauricella, A., and Robb, M. (2015). Technology in the lives of educators and early childhood programs: trends in access, use, and professional development. Report for the Center on Media and Human Development, School of Communication, Northwestern University & The Fred Rogers Center.

Blom-Hoffman, J., O'Neil-Pirozzi, T., Volpe, R., Cutting, J., and Bissinger, E. (2008). Instructing parents to use dialogic reading strategies with preschool children: impact of a video-based training program on a caregiver reading behaviors and children's related verbalizations. *J. Appl. Sch. Psychol.* 23, 117–131. doi: 10.1300/J370v23n01_06

Bornstein, M. H., and Putnick, D. L. (2012). Stability of language in childhood: a multiage, multidomain, multimeasure, and multiscore study. *Dev. Psychol.* 48, 477–491. doi: 10.1037/a0025889

Bus, A. G., Takacs, Z. K., and Kegel, C. A. T. (2015). Affordances and limitations of electronic storybooks for young children's emergent literacy. *Dev. Rev.* 35, 79–97. doi: 10.1016/j.dr.2014.12.004

Cheng, E. R., and Wilkinson, T. A. (2020). Agonizing over screen time? Follow the three C's. *The New York Times*. Available at: https://www.nytimes.com/2020/04/13/parenting/manage-screen-time-coronavirus.html (Accessed April 13, 2020).

Choi, K., and Kirkorian, H. L. (2016). Touch or watch to learn? Toddlers object retrieval using contingent and noncontingent video. *Psychol. Sci.* 27, 726–736. doi: 10.1177/0956797616636110

Clarke, P., Snowling, M. J., Truelove, E., and Hulme, C. (2010). Ameliorating children's reading-comprehension difficulties: a randomized control trial. *Psychol. Sci.* 21, 1106–1116. doi: 10.1177/0956797610375449

Connor, C. M., and Morrison, F. J. (2016). Individualizing student instruction in reading: implications for policy and practice. *Policy Insights Behav. Brain Sci.* 3, 54–61. doi: 10.1177/2372732215624931

Crawley, A. M., Anderson, D. R., Santomero, A., Wilder, A., Williams, M., Evans, M. K., et al. (2006). Do children learn how to watch television? The impact of extensive experience with Blue's clues on preschool children's television viewing behavior. *J. Commun.* 52, 264–280. doi: 10.1111/j.1460-2466.2002.tb02544.x

Dale, E., and O'Rourke, J. (1981). *The living word vocabulary, the words we know: A national vocabulary inventory*. Chicago: World Book.

Deshmukh, R. S., Zucker, T. A., Tambyraja, S. R., Pentimonti, J. M., Bowles, R. P., Justice, L., et al. (2019). Teachers' use of questions during shared book reading: relations to child responses. *Early Child. Res. Q.* 49, 59–68. doi: 10.1016/j.ecresq.2019.05.006

Dickinson, D. K., and Smith, M. W. (1994). Long-term effects of preschool teachers' book readings on low-income children's vocabulary and story comprehension. *Read. Res. Q.* 29, 104–122. doi: 10.2307/747807

Dore, R. A., Avelar, D. A., Hassinger-Das, B., Schwichtenberg, A. J., Roben, C., Brezack, N., et al. (2019). "Comprehension and emotion in independent and parent-child e-book reading" in K. Choi (chair) Direct and indirect learning from digital media. *Symposium conducted at the Digital Media & Cognitive Development Preconference at the Biennial Meeting of the Cognitive Development Society*. Louisville, KY.

Dore, R. A., Hassinger-Das, B., Brezack, N., Valladares, T. L., Paller, A., Vu, L., et al. (2018). The parent advantage in fostering children's e-book comprehension. *Early Child. Res. Q.* 44, 24–33. doi: 10.1016/j.ecresq.2018.02.002

Evans, M. A., Reynolds, K., Shaw, D., and Pursoo, T. (2011). Parental explanations of vocabulary during shared book reading: a missed opportunity. *First Lang.* 31, 195–213. doi: 10.1177/0142723710393795

Fitchel, C., and Kaufman, S. (2020). Fearing COVID-19 spread to families, health care workers self-isolate at home. *NBC News*. Available at: https://www.nbcnews.com/health/health-news/fearing-covid-19-spread-families-health-care-workers-self-isolate-n1171726 (Accessed March 31, 2020).

Golinkoff, R. M., Hirsh-Pasek, K., Mervis, C. B., and Frawley, W. B. (1995). "Lexical principles can be extended to the acquisition of verbs" in *Beyond names for things: Young children's acquisition of verbs*. eds. M. Tomasello and W. E. Merriman (Mahwah, NJ: Lawrence Erlbaum Associates), 185–221.

Guynn, J. (2020). COVID-19 social distancing: together apart, screen time connects isolated kids with family, friends. *USA Today*. Available at: https://www.usatoday.com/story/tech/2020/03/27/coronavirus-covid-19-social-distancing-screen-time-parents-children-zoom-facetime-fortnite-minecraft/5084998002/ (Accessed March 27, 2020).

Hadley, E. B., Dickinson, D. K., Hirsh-Pasek, K., Golinkoff, R. M., and Nesbitt, K. T. (2015). Examining the acquisition of vocabulary knowledge depth among preschool students. *Read. Res. Q.* 51, 181–198. doi: 10.1002/rrq.130

Hargave, A. C., and Sénéchal, M. (2000). A book reading intervention with preschool children who have limited vocabularies: the benefits of regular reading and dialogic reading. *Early Child. Res. Q.* 15, 75–90. doi: 10.1016/S0885-2006(99)00038-1

Hassinger-Das, B., Dore, R., and Zosh, J. M. (2019). "The four pillars of learning: e-books past, present, and future" in *Reading in the digital age: Young children's experiences with e-books*. eds. J. E. Kim and B. Hassinger-Das (Cham, Switzerland: Springer), 11–21.

Hassinger-Das, B., Ridge, K., Parker, A., Golinkoff, R. M., Hirsh-Pasek, K., and Dickinson, D. K. (2016). Building vocabulary knowledge in preschoolers through shared book reading and gameplay. *Mind Brain Educ.* 10, 71–80. doi: 10.1111/mbe.12103

Hassinger-Das, B., Toub, T. S., Hirsh-Pasek, K., and Golinkoff, R. M. (2017). A matter of principle: applying language science to the classroom and beyond. *Transl. Issues Psychol. Sci.* 3, 5–18. doi: 10.1037/tps0000085

Hiebert, E. H. (1981). Developmental patterns and interrelationships of preschool children's print awareness. *Read. Res. Q.* 16, 236–260. doi: 10.2307/747558

Hindman, A., Skibbe, L. E., and Foster, T. D. (2014). Exploring the variety of parental talk during shared book reading and its contributions to preschool language and literacy: evidence from the Early Childhood Longitudinal Study-Birth Cohort. *Read. Writ.* 27, 287–313. doi: 10.1007/s11145-013-9445-4

Hirsh-Pasek, K., Adamson, L. A., Bakeman, R., Owen, M. T., Golinkoff, R. M., Pace, A., et al. (2015a). The contribution of early communication quality to low-income children's language success. *Psychol. Sci.* 26, 1071–1083. doi: 10.1177/0956797615581493

Hirsh-Pasek, K., Zosh, J. M., Golinkoff, R. M., Gray, J. H., Robb, M. B., and Kaufman, J. (2015b). Putting education in "educational" apps: lessons from the science of learning. *Psychol. Sci. Public Interest* 16, 3–34. doi: 10.1177/1529100615569721

Huebner, C. E. (2000). Promoting toddlers' language development: a randomized-controlled trial of a community-based intervention. *J. Appl. Dev. Psychol.* 21, 513–535. doi: 10.1016/S0193-3973(00)00052-6

JumpStart (2018). Major findings for children participating in JumpStart's traditional programming: 2016-2017 program year. Available at: https://www.jstart.org/wp-content/uploads/2018/11/Major-Findings-for-Children-Participating-in-Traditional-Jumpstart-Programming.pdf (Accessed August 20, 2020).

Justice, L. M., and Ezell, H. K. (2001). Word and print awareness in 4-year-old children. *Child Lang. Teach. Ther.* 17, 207–225. doi: 10.1177/026565900101700303

Justice, L. M., Mashburn, A., Hamre, B., and Pianta, R. (2008). Quality of language and literacy instruction in preschool classrooms serving at-risk pupils. *Early Child. Res. Q.* 23, 51–68. doi: 10.1016/j.ecresq.2007.09.004

Kirkorian, H. L., Choi, K., and Pempek, T. A. (2016). Toddlers' word learning from contingent and noncontingent video on touch screens. *Child Dev.* 87, 405–413. doi: 10.1111/cdev.12508

Kirkorian, H. L., and Choi, K. (2017). Associations between toddlers' naturalistic media experience and observed learning from screens. *Infancy* 22, 271–277. doi: 10.1111/infa.12171

Korat, O., Segal-Drori, O., and Klien, P. (2009). Electronic and printed books with and without adult support as sustaining emergent literacy. *J. Educ. Comput. Res.* 41, 453–475. doi: 10.2190/EC.41.4.d

Krcmar, M., and Cingel, D. R. (2017). Do young children really learn best from the use of direct address in children's television? *Media Psychol.* 22, 1–20. doi: 10.1080/15213269.2017.1361841

Lauricella, A. R., Pempek, T. A., Barr, R., and Calvert, S. L. (2010). Contingent computer interactions for young children's object retrieval. *J. Appl. Dev. Psychol.* 31, 362–369. doi: 10.1016/j.appdev.2010.06.002

Leseman, P. P. M., and deJong, P. F. (1998). Home literacy: opportunity, instruction, cooperation, and social-emotional quality predicting early reading achievement. *Read. Res. Q.* 33, 294–318. doi: 10.1598/RRQ.33.3.3

Lonigan, C. J., and Whitehurst, G. J. (1998). Examination of the relative efficacy of parent and teacher involvement in a shared-reading intervention for preschool children from low-income backgrounds. *Early Child. Res. Q.* 13, 263–290. doi: 10.1016/S0885-2006(99)80038-6

Mason, J. M. (1980). When do children begin to read: an exploration of four year old children's letter and word reading competencies. *Read. Res. Q.* 15, 203–227. doi: 10.2307/747325

McClure, E. R., and Barr, R. (2017). "Building family relationships from a distance: supporting connections with babies and toddlers using video and video chat" in *Media exposure during infancy and early childhood: The effect of content and context on learning and development*. eds. R. Barr and D. Linebarger (New York, NY: Springer), 227–248.

Merz, E. C., Maskus, E. A., Melvin, S. A., He, X., and Noble, K. G. (2019). Socioeconomic disparities in language input are associated with children's language-related brain structure and reading skills. *Child Dev.* 91, 846–860. doi: 10.1111/cdev.13239

Molborn, S., Lawrence, E., James-Hawkins, L., and Fomby, P. (2014). When do socioeconomic resources matter most in early childhood? *Adv. Life Course Res.* 20, 56–59. doi: 10.1016/j.alcr.2014.03.001

Montag, J. L., Jones, M. N., and Smith, L. B. (2015). The words children hear: picture books and the statistics for language learning. *Psychol. Sci.* 26, 1489–1496. doi: 10.1177/0956797615594361

Morgan, P. L., Farkas, G., and Qu, Q. (2011). Kindergarten children's growth trajectories in reading and mathematics: who falls increasingly behind? *J. Learn. Disabil.* 44, 472–488. doi: 10.1177/0022219411414010

Myers, L., Crawford, E., Murphy, C., Aka-Ezoua, E., and Felix, C. (2018). Eyes in the room trump eyes on the screen: effects of a responsive co-viewer on toddlers' responses to and learning from video chat. *J. Child. Media* 3, 275–294. doi: 10.1080/17482798.2018.1425889

Myers, L. J., LeWitt, R. B., Gallo, R. E., and Maselli, N. M. (2016). Baby FaceTime: can toddlers learn from online video chat? *Dev. Sci.* 20, 1–15. doi: 10.1111/desc.12430

Neuman, S. B., and Celano, D. (2001). Access to print in low-income and middle-income communities: an ecological study of four neighborhoods. *Read. Res. Q.* 36, 8–26. doi: 10.1598/RRQ.36.1.1

O'Fallon, M., Von Holzen, K., and Newman, R. S. (2020). Preschoolers' word-learning during storybook reading interactions: comparing repeated and elaborated input. *J. Speech Lang. Hear. Res.* 63, 814–826. doi: 10.1044/2019_JSLHR-19-00189

Paris, A. H., and Paris, S. G. (2001). Report No.: 3-012. Children's comprehension of narrative picture books. Center for Improvement of Early Reading Achievement Report, 1–31.

Parish-Morris, J., Mahajan, N., Hirsh-Pasek, K., Golinkoff, R. M., and Collins, M. F. (2013). Once upon a time: parent-child dialogue and storybook reading in the electronic era. *Mind Brain Educ.* 7, 200–211. doi: 10.1111/mbe.12028

Piasta, S. B., Justice, L. M., McGinty, A. S., and Kaderavek, J. N. (2012). Increasing young children's contact with print during shared reading: longitudinal effects on literacy achievement. *Child Dev.* 83, 810–820. doi: 10.1111/j.1467-8624.2012.01754.x

Rideout, V. (2017). The Common sense census: media use by kids age zero to eight. San Francisco, CA: Common Sense Media.

Romeo, R. R., Leonard, J. A., Robinson, S. T., West, M. R., Mackey, A. P., Rowe, M. L., et al. (2018). Beyond the 30-million-word gap: children's conversational exposure is associated with language-related brain function. *Psychol. Sci.* 29, 700–710. doi: 10.1177/0956797617742725

Roseberry, S., Hirsh-Pasek, K., and Golinkoff, R. M. (2014). Skype me! Socially contingent interactions help toddlers learn language. *Child Dev.* 85, 956–970. doi: 10.1111/cdev.12166

Roseberry, S., Hirsh-Pasek, K., Parish-Morris, J., and Golinkoff, R. M. (2009). Live action: can young children learn verbs from video? *Child Dev.* 80, 1360–1375. doi: 10.1111/j.1467-8624.2009.01338.x

Schroeder, E. L., and Kirkorian, H. L. (2016). When seeing is better than doing: preschoolers' transfer of STEM skills using touchscreen games. *Front. Psychol.* 7:1377. doi: 10.3389/fpsyg.2016.01377

Sénéchal, M., and Cornell, E. (1993). Vocabulary acquisition through shared reading experiences. *Read. Res. Q.* 28, 360–324. doi: 10.2307/747933

Smith, S. (2020). Children – but also parents – adapt to life online over video chat during coronavirus pandemic. *NBC News*. Available at: https://www.nbcnews.com/tech/tech-news/children-also-parents-adapt-life-over-video-chat-during-coronavirus-n1174311 (Accessed April 3, 2020).

Strouse, G. A., O'Doherty, K., and Troseth, G. L. (2013). Effective coviewing: preschoolers' learning from video after a dialogic questioning intervention. *Dev. Psychol.* 49, 2368–2382. doi: 10.1037/a0032463

Strouse, G. A., Troseth, G. L., O'Doherty, K., and Saylor, M. M. (2018). Co-viewing supports toddlers' learning from contingent and non-contingent video. *J. Exp. Child Psychol.* 166, 310–326. doi: 10.1016/j.jecp.2017.09.005

Sundeen, R. A., and Raskoff, S. A. (2000). Ports of entry and obstacles: teenagers' access to volunteer activities. *Nonprofit Manag. Leadersh.* 11, 179–197. doi: 10.1002/nml.11204

Takacs, Z. K., Swart, E. K., and Bus, A. G. (2015). Benefits and pitfalls of multimedia and interactive features in technology-enhanced storybooks: a meta-analysis. *Rev. Educ. Res.* 85, 698–739. doi: 10.3102/0034654314566989

Tarasuik, J. C., Galligan, R., and Kaufman, J. (2011). Almost being there: video communication with young children. *PLoS One* 6:e17129. doi: 10.1371/journal.pone.0017129

Toub, T. S., Hassinger-Das, B., Nesbitt, K. T., Ilgaz, H., Weisberg, D. S., Hirsh-Pasek, K., et al. (2018). The language of play: developing preschool vocabulary through play following shared book-reading. *Early Child. Res. Q.* 45, 1–17. doi: 10.1016/j.ecresq.2018.01.010

Troseth, G. L., Saylor, M. M., and Archer, A. H. (2006). Young children's use of video as a source of socially relevant information. *Child Dev.* 77, 786–799. doi: 10.1111/j.1467-8624.2006.00903.x

Troseth, G. L., Strouse, G. A., Flores, I., Stuckelman, Z., and Russo Johnson, C. R. (2019). An enhanced eBook facilitates parent-child talk during shared reading by families of low socioeconomic status. *Early Child. Res. Q.* 50, 45–58. doi: 10.1016/j.ecresq.2019.02.009

van Kleeck, A. (1998). Preliteracy domains and stages: laying the foundations for beginning reading. *J. Child. Commun. Dev.* 20, 33–51.

Walsh, R. L., and Hodge, K. A. (2016). Are we asking the right questions? An analysis of research on the effect of teachers' questioning on children's language during shared book reading with young children. *J. Early Child. Lit.* 18, 264–294. doi: 10.1177/1468798416659124

Walsh, B. A., and Rose, K. K. (2013). Impact of adult vocabulary noneliciting and eliciting questions on the novel vocabulary acquisition of preschoolers enrolled in Head Start. *J. Res. Child. Educ.* 27, 31–45. doi: 10.1080/02568543.2012.712085

What Works Clearinghouse (2015). Shared book reading. Available at: https://ies.ed.gov/ncee/wwc/Docs/InterventionReports/wwc_sharedbook_041415.pdf (Accessed April 2015).

Whitehurst, G. J., Arnold, D. S., Epstein, J. N., Angell, A. L., Smith, M., and Fischel, J. E. (1994). A picture book reading intervention in day-care and home for children from low-income families. *Dev. Psychol.* 30, 670–680. doi: 10.1037/0012-1649.30.5.679

Whitehurst, G. J., Falco, F. L., Lonigan, C. J., Fischel, J. E., DeBaryshe, B. D., Valdez Menchaca, M. C., et al. (1988). Accelerating language development through picture book reading. *Dev. Psychol.* 24, 552–559. doi: 10.1037/0012-1649.24.4.552

Zevenbergen, A. A., and Whitehurst, G. J. (2003). "Dialogic reading: a shared picture book reading intervention for preschoolers" in *On reading books to children: Parents and teachers*. eds. A. van Kleeck, S. A. Stahl and E. B Bauer (Mahwah, NJ: Lawrence Erlbaum Associates), 177–200.

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

CONCEPTUAL ANALYSIS
published: 26 October 2020
doi: 10.3389/fpsyg.2020.589281

# The Distance Between the "Self" and the "Other" in Children's Digital Books

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This conceptual paper contributes toward our understanding of the underlying mechanisms in children's understanding of self and the other with media. We synthesize diverse bodies of literature, concerned with children's reading with digital and traditional (print) books, to explicate the parameters that may, in part, explain positive learning outcomes and further illuminate the patterns across various measures. We propose the "Distance Model," which suggests that a child's interest in a reading activity depends on its proximity to the child's funds of identity (Esteban-Guitart and Moll, 2014). The closer the proximity, the more salient the impact on the child's cognitive understanding and sense of belonging. The familiarity of the reading content and the relevance of the reading medium for a child's personal life can be evoked through a number of reading strategies and design techniques, which we discuss in relation to children's literature and the contemporary design of children's interactive e-books. We conclude with some suggestions regarding future applications of the Distance Model in children's media research.

**Keywords: reading, theory, IDE, socio-cultural, technology**



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***Specialty section:***
*This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology*

***Received:*** *30 July 2020*
***Accepted:*** *08 October 2020*
***Published:*** *26 October 2020*

***Citation:***
*Kucirkova N and Littleton K (2020) The Distance Between the "Self" and the "Other" in Children's Digital Books. Front. Psychol. 11:589281. doi: 10.3389/fpsyg.2020.589281*

## INTRODUCTION

Since the accelerated adoption of media worldwide, the discussion of children's reading on screen has carried considerable distortions of the correlation-causality relationship in both popular and scientific discourse. Children's use of technology has been blamed for causing a number of broader societal issues, including, for example, loneliness (Turkle, 2017) or unhappiness (Twenge, 2017) and there has been a lack of nuanced discussion about the diverse uses of media in families (for a critique see e.g., Livingstone and Helsper, 2008; Przybylski and Weinstein, 2019). Significant progress has been made in research, with interdisciplinary studies evidencing the complexities of how children's cognitive, emotional, and social outcomes correspond to the use of diverse media in a variety of everyday contexts. Such progress has, we have argued previously (Kucirkova, 2019), been enabled through interdisciplinary, cross-cultural conversations and considerations of the relationships between individual children's learning outcomes, individual characteristics and the design features of media. An area that needs much further development concerns the *theoretical advancement of children's use of digital books*, and the implications that may be taken from empirical studies to the wider field of children's interactions with technologies and social resources. In this conceptual paper we argue that the theoretical significance of diverse responses to individual features of digital books can lead to new insights in existing interpretative models of children's learning. In particular, e-reading studies could push the boundaries of the interconnected fields of psychology and education in ways that broaden current understandings of learning. We posit that the study of *distance* between the "self" and "other" on the identity level, and the distance between "familiarity" and "unfamiliarity" on the cognitive level, could provide illuminating insights that can be applicable to future research strategy and design of children's digital books. Although we present the two levels separately, they are mutually constitutive and exist in interplay, so they should be considered in tandem for future studies.

The argument is structured in three parts: first, we review the literature relevant to identity/cognitive distance, which we divide into three conceptual areas: psychological, phenomenological and chronological distance. Second, we provide an overview of the key theoretical concepts that substantiate the underlying mechanisms that enhance learning. Third, we draw on examples from children's literature and e-book research to exemplify how the focus on the distance between the "self" and "other" and between "familiar" and "unfamiliar" stories, can push the boundaries of research with children's digital books, and technology use more broadly.

Our intention is to generate discussion and new thinking, rather than attempt to summarize the comprehensive work concerning identity/cognitive research (for an overview see Garton, 2008; Schwartz et al., 2011). In accordance with the tradition of conceptual papers (see Beins and Beins, 2012), we discuss empirical studies with an emphasis on the evidence for grounding an opinion that explains new parameters and assigns a fundamental role to theoretical concepts, which are "scattered" across in the literature but that have not been related to each other and the empirical observations before. Within children's media studies, we focus on children's stories and digital books as a context that can contribute to the development of an understanding of the learning processes involved in children's engagement with digital books and technology.

## A SHORT NOTE ON TERMINOLOGY

The terms "media" and "technologies" are often used interchangeably but they are not the same: technologies are the tools, such as smartphones or tablets, while media refers to the vehicles of engagement with technologies, using a range of communicative/literacy/textual practices, such as apps, e-books, computer games or films (see Marsh et al., 2005; Burnett et al., 2016). In this article, we selectively focus on a specific type of media: children's books, e-books and digital books. We use the terms *digital books* to refer to digital versions of children's books that combine images (photographs or illustrations) and text to engage children in a language-stimulating, aesthetically pleasing cultural experiences. Children's digital books provide rich multimodal, multimedia literacy experiences through making it possible for the child to directly interact with the story characters on the digital screen by moving them across the page, hearing the book speak to the child, play songs and tunes (Ozturk and Hill, 2018). Thus, digital books are not the same as e-books, which are typically paper books translated into a digital format, without any interactivity or design adjustments (for example a novel in a PDF format read on a PC is an e-book).

The texts carried by children's (e-)books can be fictional or non-fictional and we focus this conceptual analysis on fictional texts, which carry a story written in a narrative form. It is also important to underscore that such narratives are not neutral—they are shaped by and "carry" the psychological perspective(s) of those who developed them. Therefore, to turn a narrative into a different medium (for example, a story that first appeared in a board book into an interactive e-book), requires a translation of both the discourse (the way the story is told) as well as of the story (the sequence of events). It follows that digital stories need to go beyond the surface translation of print stories and adjust their discourse if they are to become successful in innovating the digital landscape of stories (Ryan, 2009). Lastly, the activity that stories and narratives support is that of reading and writing, or literacy. We approach literacy as plural "literacies" that are constituted through an embodied interaction with communities and everyday practices (Pahl, 2014) and that are contingent on the power dynamics and possibilities of place (Comber, 2015).

## LEARNING: DEFINITION

Children's reading experiences are typically mediated by parents, teachers, or other adults reading together with the child. But these experiences can also be mediated through prompts and design features embedded inside digital books. The dual human and material mediation, with linguistic and visual prompts, gives rise to dynamic interactions. Such interactions have been recognized, with children's print books, as events that happen between readers and texts (Rosenblatt, 1978). When children encounter new information about self or other, they stretch their current understanding beyond what they already know, that is they *learn*. The present, (lived by the reader), and the past or future (depicted in the story) and the "here" experienced by the child and the "there" imagined or implied by the story events, need to be traversed through the act of reading. This gives rise to a learning opportunity, and this learning opportunity can be theorized as a practice of (re-)negotiating and exchanging meanings, internally and externally and thereby approximating the lived reality of two or more human minds and bodies. Neo-Vygotskian scholars, for instance, conceive of learning and meaning-making in terms of dialogue (e.g., Mercer, 1994). We work within the neo-Vygotskian tradition, according to which a dynamic learning process is usefully characterized within socio-cultural theories that emphasize the participatory and pluralistic ways of negotiating meanings and understandings (see Wegerif, 2007). Adopting a neo-Vygotskian stance on learning, we focus on the distance a learner needs to "travel" to reach the understanding of the adult/more-advanced peer. It is this focus that, we argue, provides the ground for innovation in research concerning children's reading with digital books and that raises the fundamental moral question of how we, as educators and educational professionals, work with difference and alterity (see Baudrillard and Guillaume, 2008).

## THEORETICAL FRAMEWORK

Theories can help us better understand the complex interactions between the technological and human aspects of reading and it is important that we situate this conceptual piece within an explanatory theoretical framework. The theory that frames this paper, and the perspective that shapes the first author's most recent work on children's digital books, is that of socio-materiality. Socio-materiality "involves attending to other kinds of relations: from the physicality of digital devices (e.g., their interactivity and the "screen-ness" of screens), through to the intended and unintended affordances of apps" (Burnett and Merchant, 2019, p. 265). The techno-social (or socio-material) entanglement implies that media can be used to strengthen literacy pedagogy and literacy pedagogy can strengthen digital media; one necessitates the other for securing children's rich learning experiences. The socio-material perspective supports the notion of child-content-context-community interrelationships practices (Kucirkova, 2019), that is the combination of children's characteristics, context of reading, content of the text and the community reading practices, that *together* shape children's lives. What socio-materiality does not specify, however, are the mechanisms through which the context, content and individual child's characteristics interact for stronger or weaker relations. This is, we argue, the gap that can be addressed by a consideration of findings that are connected to the theoretical basis of "distance".

### Distance

A physicist's understanding of distance is that of a "separation in space of the locations of two objects" (Swyt, 1992, p. 115), which, when it becomes dynamic, can be calculated as the rate of speed multiplied by time. Our understanding of distance in children's literacies is less mechanical. To simplify, distance in children's stories can be either experienced on the existential, identity level, or on the cognitive level of perceived awareness. Both levels are connected and inseparable. The former, identity-related distance, focuses on the gap between the "self," the reader, and the "other," the story character represented through the author's work. The cognitive distance relates to the gap between familiar and unfamiliar experiences lived by the reader and depicted by the story author. Such a conceptualization of distance in children's stories gives rise to three types, or three levels, of possible distances: (1) the psychological distance; (2) the phenomenological distance and (3) the chronological distance. These conceptual distances are realized in diverse forms in children's literature and they can be traced back to some of the landmark studies in children's reading and learning.

## THE PSYCHOLOGICAL DISTANCE IN CHILDREN'S TEXTS

The psychological distance between the "self" and "other" in texts has been researched in relation to the use of linguistic cues that help readers orient themselves in text. One such linguistic tool is the use of the generic "you," that "allows the individual to construct a generalizable lesson surrounding their experience that extends beyond the self, thus enhancing psychological distance and promoting meaning making" (Orvell et al., 2019, p. 184). Addressing readers as "you" enables them to relate the text information to their own self and build rapport with the text. The achievement of such psychological distance helps with children's processing of the difficult emotions that they experience in an immediate situation (Orvell et al., 2017). Another way of tapping into the psychological distance in reading is to evoke self-referencing through the inclusion of the reader's own self as subject in the text. In this instance, relatedness is established through explicitly naming the reader by name or using first personal pronouns (me, myself and I). The use of such self-referencing was tested by Turk et al. (2015) in relation to literacy attainments in experiments with 7–9-years-old and was shown to increase children's writing and spelling skills. The self-referencing advantage extends beyond literacy benefits to increased memory effects (Cunningham et al., 2014), and has been documented in children as young as three-and-half-year-old (Ross et al., 2011). The psychological distance, then, can be bridged not only by the reader but also by the author. More specifically, the author can call for active reading through the use of "you" or through the recall of personal memories in the reader. Authors can use various techniques to support readers' navigation of the psychological distance and readers move along the spectrum of lived and imagined stories as they navigate texts. This theoretical concept is schematically represented in **Figure 1**.

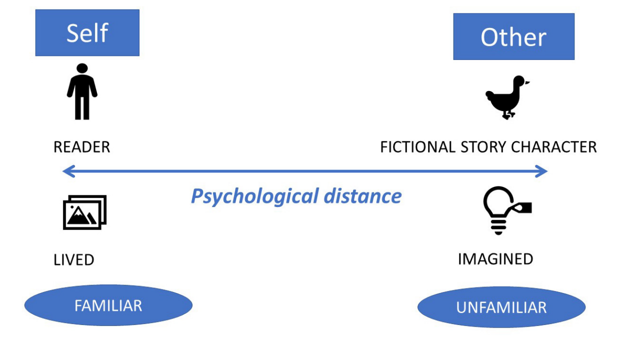


**FIGURE 1** | Schematic representation of the psychological distance in stories.

A fitting example that exemplifies how the two poles of the cognitive distance between the reader's lived experience and the imagined experience of the story character become approximated is that of personalized books. Personalized books are books that have been customized, either commercially or by the readers or their relatives/friends, based on the reader's personal information. Personalized books can be both digital or print-based; what matters from the distance perspective is whether they are personalized or not. For example, the publisher Wonderbly Ltd., uses the letters of a child's name to customize a story about a child who lost her/his name. The story plot concerns a child looking for the letters of his/her name, which s/he finds at the end of the story. Personalized books challenge what children don't know to a lesser extent than non-personalized books because they provide familiar clues and evolve around familiar scenarios, or at least scenarios that involve story characters and settings the child is familiar with. This lowers the threshold for participation and invites the children to see themselves in a world they are already part of. With a metaphor based on the notion of "distance," the child readers are not traveling to meet another story character but rather they meet themselves, they stay in the destination of the familiar story, so to speak. Whilst this has its benefits, it also has significant limitations. On the positive side, personalized books can be used as tools for empowerment, which can be used for therapeutic purposes, such as raising children's self-esteem, confidence and enjoyment of reading (Demoulin, 1999). On the other hand, the reading of children's personalized books was found in our own prior work to be correlated with children's self-referential speech, indicating a heightened focus on self (Kucirkova et al., 2014).

The distance between fictional and personal worlds can be enlarged or reduced through prompts that are perceived not only on the cognitive and linguistic levels, but phenomenologically, that is, through the whole body.

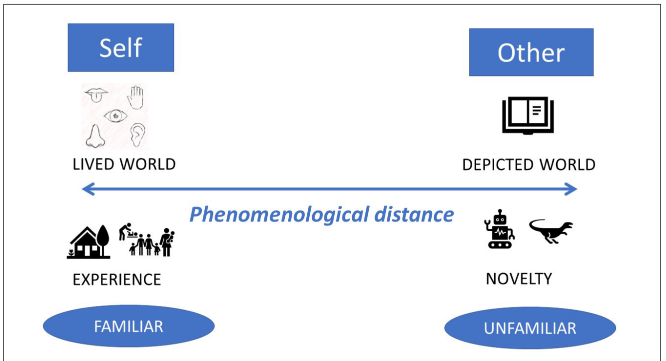


**FIGURE 2 |** Schematic representation of the phenomenological distance in stories.

## THE PHENOMENOLOGICAL DISTANCE

Phenomenology is a broad term but in the study of literacies and literature it is defined as the "study of the phenomenon," "that which appears," that is to say, an occurrence perceptible by the senses' (Mildenberg, 2017, p. 13). Children's books "tap into" children's visual perception through images and illustrations, while audio stories stir children's imagination through the auditory system, and multimedia stories typically engage visual, audio and tactile senses. Merleau-Ponty's (1982) account of phenomenology is concerned with the lived body between ideas and objects and the meanings that the body holds. It positions childhood as an embodied experience (Welsh, 2013), whereby language is not restricted to linguistic or cognitive studies but expanded to a corporeal language of being. Studies show that contemporary readers move between various story formats and story representations, thus accommodating the multiple ways of being.

For example, Rowsell (2014) documented how students traveled between print, videos or blogs to connect their narratives in classrooms, and Hackett (2016) described the experience of 2- and 3-years-old connecting their remembered and immediate experiences of stories with the unfamiliar stories represented as objects in museums. The distance in the phenomenological sense thus refers not only to the gap between the physical experiences of the reader and the physical object of a print or digital book, but also to the depiction of these experiences in various story genres and through various story techniques. In terms of story content, the distance is larger when the story illustrations evoke environments further from those that the child has seen or experienced before (as in, for example, fantasy literature) and the distance is shorter when the story representations approximate the lived experience through story plots and story scenes familiar to the reader. In terms of story formats, the embodiment possibilities with digital books, and their links to lived experiences, are even more diverse than with analog books as visual perception is extended to audio perception and tactile feedback from the book (for example touching the story character makes it change color or perform an action). Although empirically yet to be verified, some researchers hypothesize that this physically close relationship between the story characters and the child's body (finger moving on the screen) impacts children's understanding of the characters' emotions and children's empathy (Zhao and Unsworth, 2016). The phenomenological distance in children's stories is schematically represented in **Figure 2**.

## CHRONOLOGICAL DISTANCE

In Bakhtin's (1981) chronotope theory, the space in the story corresponds to the movement of time, while the time *places* the story characters' actions and movements. In his study of literary narratives, Bakhtin (1981) suggested the use of the term "chronotope," derived from the Greek "chronos" that stands for time and "topos" that stands for place, to unify time and space in a deep entanglement of time-space as one word and phenomenon. Given that in chronotopes time and space are interlinked, the Bakhtinian account provides a powerful explanatory structure for the distancing necessary to bridge the time depicted in books and the time experienced individually by the readers. As Johnston (2002, p. 137) puts it, the concept of chronotope: "helps us to read beyond the mechanics of 'setting' and to rethink depictions of narrative time-spaces in terms of being essentially ideological, that is, as subjective, changeable, multiple and dependent on the position of the observer." In the case of children's literature, the observer is the child, who interprets the words and images in picture books through her own experience. As literary scholars argue, the distance between the chronotopes of literature needs to be supplemented with a contemporary context that connects the experiences and actions of the story characters *with* the temporal ordering in stories (Scholz, 1998). The young reader connects to the narrative structure of stories on the temporal level in terms of their own personal story and the experience of time in the child's immediate environment. For the latter, there are known variations between how children from different cultures

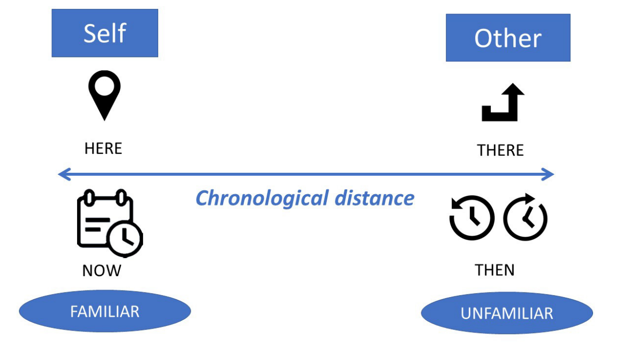


**FIGURE 3 |** Schematic representation of chronological distance.

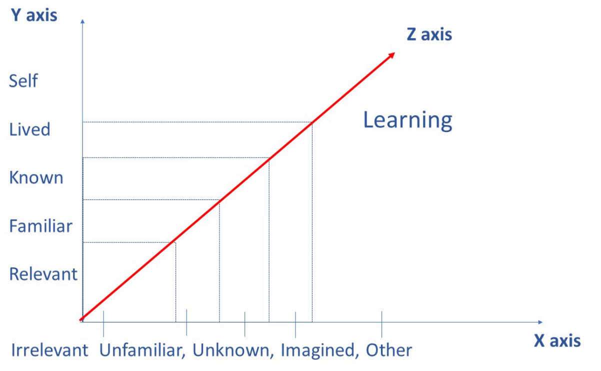


**FIGURE 4 |** A schematic representation of the Distance Model.

respond to the classic temporal arrangements of story beginning, middle, and end (Peterson and McCabe, 1994). This is because despite shared clocks and biological rhythms, the experience of time is very individual (Leaton Gray, 2017) and depends on a range of socio-material factors (e.g., the waiting time in a doctor's office might be the same length for everyone but is perceived differently by each person). From the perspective of chronological distance, the distance between the story and the reader can be fairly abstract in terms of "lived time," which is the time experienced socially, and the time lived individually by the story characters in the text. It follows that for a meaningful reading experience, authors need to draw links between the collectively shared and the personally experienced time-space. In historical or futuristic novels, this is achieved through various visual and linguistic techniques.

For example in wordless picture-books, "without integrating a clock, a calendar, or a similar device, precise time and passage of time is difficult to represent in a wordless picture book" (Beckett, 2013, p. 128). Given that children have a very different understanding of time than adults and given that most children's books are written by adults for children, the bridging across the time-space often happens through literary techniques that reverse adult-child roles (O'Sullivan, 2005). Readers cross, to a greater or lesser extent, the chronological distance as they negotiate their understanding of the stories' time and space. **Figure 3** provides an illustration of this journey.

Our summary of the research that could be attributed to the psychological, phenomenological and chronological distance in children's literacies is necessarily short in this paper but discussed more fully in Kucirkova (2021). The summary here, nevertheless, serves as a reference point for understanding the Distance Model.

## The Distance Model

For future replicability and expansion of empirical findings, there needs to be a model that viably explains the mechanisms of observed phenomena and that provides a common language for conceptualizing future studies in children's interactions with digital books and children's technology more broadly. The Distance Model is not an analytic framework, but a conceptual tool that can be used to explain existing findings and propose new directions for future research. The Distance Model positions learning as a spectrum, or as being like an elastic band that is not fixed but that can be increased or decreased, depending on how close the learner is psychologically, phenomenologically or chronologically positioned to the other. The foundation of the model is that of an optimal negotiation of psychological, phenomenological and chronological distances between the familiar and the unfamiliar experience/event. In this depiction (see **Figure 4**), the self, and the familiar world the self stands for, is shown along the *Y*-axis and the other, and the unfamiliar, new, world the other stands for, along the *X*-axis. The *Z*-axis (depicted in red) in the figure represents the optimal meeting point between these two poles, which is the point, where learning happens.

Why does the Distance Model position learning as a measure of the distance between the familiar self and the unfamiliar other? There are several plausible explanations for why the self-other negotiation supports learning, and these explanations have been gauged in terms of the "relevance" or "learners' identification" with learning materials. These terms, however, only relate to surface characteristics that do not account for why learning occurs. To understand the "why" of self-other distancing, we need to turn to theory. For purposes of this discussion, we selectively focus on the funds of identity theory (Esteban-Guitart and Moll, 2014) as it affords a powerful characterization of the identity formation between self and other, that can provide the foundations for the Distance Model.

## WHY DOES LEARNING OCCUR WHEN BRIDGING THE SELF-OTHER DISTANCE?

All readers and writers have their own "funds of knowledge," that is a collection of skills, wisdoms and understandings that they use to define themselves and the world around them (Moll et al., 1992). A dialogue is the dynamic process of opening up to the voice of the other, which widens an individual's perspective and prompts an individual to not only internalize but also externalize his or her understanding. Wegerif (2007) conceives of dialogue as occurring in a dialogic space, which further extends the meaning-exchange on a cognitive level to a whole-body resonance of feelings and thoughts. A dialogic space connects to Merleau-Ponty's phenomenology as well as the socio-material notion of entanglement between humans and non-humans. A dialogue in a dialogic space is not only about exchanging individual and collective knowledge in a narrow, educational, sense but also the ways of being and doing in a socio-historical sense (Wegerif, 2011). The cultural understanding of meanings and sense-making that all children have and all children bring to their learning environments is known as "funds of knowledge," originally Moll et al. (1992) and recently expanded to funds of identity by Esteban-Guitart and Moll (2014). Predicated on Vygotskian thinking, Esteban-Guitart and Moll (2014, p. 37) define funds of identity as: "historically accumulated, culturally developed, and socially distributed resources that are essential for people's self-definition, self-expression, and self-understanding. In other words, the term 'funds of identity,' which we are using here, denotes a set of resources or box of tools and signs." Building on this, we see the distance between self/familiar and other/unfamiliar played out in terms of the difference between the historically accumulated resources implicated in the negotiation/(joint) construction of selfhood and the reading approach in question.

This points to a balancing process that rests on shortening and enlarging the distance between the two poles, as represented by the *Z*-axis in **Figure 4**. Theories of the "dialogic" and "dialogic space" have been embraced by many educational researchers, who have developed a body of empirical research that documents the various conditions under which learning occurs (see e.g., Ludvigsen et al., 2019). An interesting point of convergence in the studies, from the Distance Model perspective, is that of the conditions that contribute to optimal learning where meanings between self and other are exchanged, challenged and acquired. In some circumstances, the distance becomes too large and in others it can be easily bridged with some support. This brings us to the idea of thresholds and the educational theories that specify the learning conditions in which children appropriate new knowledge.

## HOW CAN DISTANCES BE BRIDGED?

Moving on from the account of how dialogue and dialogic space rest on the notion of distance between the "self" and the "other," we now use the Distance Model to explain how the psychological, phenomenological and chronological distances can be bridged in the context of children's digital books. With a nature- or biology-oriented perspective that emphasizes the role of genetic factors, and is different from the socio-cultural view on learning, the threshold when the "self" (or *a priori* cognitive schemas) become established is an important milestone for acquiring new knowledge (see e.g., Piaget, 1950; Bogard et al., 2013). As a good example, take the study by Sui and Zhu (2005), in which they tested 4, 5, and 10-years-old children's response to cartoon figures with the children's own or another child's face. The 5 and 10-years-old remembered more objects associated with the figure showing their own face, but for the 4-years-old, there was no such "self-advantage." While from the nature-oriented developmental perspective, there is a threshold for when self-referential encoding turns into a learning advantage, from the educational perspective, the learning tipping points happen at less predictable stages. Adopting a nurture-oriented perspective that emphasizes the role of environmental factors, researchers Adams et al. (2015) introduce the terms of "liminal spaces" and "threshold concepts." Drawing on the time-space boundaries in learning elaborated by Maaninen-Olsson and Müllern (2009), Adams et al. (2015) use threshold concepts to indicate that the progress to an individual's understanding involves crossing a boundary that is not inherent to the individual but to the learning environment. A threshold concept is conceptualized as a doorstep, which, when crossed, allows students to reach a higher level of understanding but if not understood, leaves students disengaged and unable to progress their learning (Cruz et al., 2016). It follows that classrooms are conceptualized around shared values and acquisition of new knowledge and facts, and this focus is actively fostered through social upbringing and collective perceptions.

From a socio-cultural perspective, "dialogic space" in contemporary classrooms is, as envisioned by Wegerif (2013), a fertile ground for learning and problem-solving when there is a difference of ideas, perspectives and understandings. This opens up a space of possibility, full of potential for exploration and dialogue. It is thus not similarly/proximity of viewpoint(s) but rather differences in perspective, which leverages the building of understanding. Whether we place a more nature- or nurture-oriented lens on these approaches, we see that both converge on the question of boundaries and that these boundaries relate to how big the gap between familiar and unfamiliar is. In this respect, the Distance Model provides a thinking tool for depicting the learning process as a sliding scale, which increases or decreases depending on the learner's dispositions and the environmental scaffolds available to this learner. If we map these insights onto the skeleton of the Distance Model, we find a neat mapping on what Vygotsky (1978a, original in 1935) described as the Zone of Proximal Development: "the distance between the actual developmental level and as determined by independent problem solving and the level of [potential development as determined by problem solving under adult guidance or in collaboration with more capable peers p. 86." Learning is thus the distance a learner needs to travel to reach the understanding of the adult/more advanced peer (this peer could be the adult or the digital book designed to support the individual).

Vygotsky's ZPD is helpful, and it specifies the departure and arrival areas, metaphorically speaking, but it does not focus on the joint journey that needs to be undertaken by both the self and the other. Vygotsky wrote that "Every function in the child's cultural development appears twice: first, on the social level, and later on the individual level; first, between people (interpsychological), and then inside the child (intrapsychological) p. 57." This applies equally to voluntary attention, to logical memory, and to the formulation of concepts. All the higher functions originate as actual relations between human individuals (Vygotsky, 1978b, p. 57). In Vygotsky's writings, learning is positioned as a cognitive trip from the collective to the individual. Yet, neo-Vygotskian scholars argue that intramental and intermental learning need to be combined, in the activity of "interthinking," which often leads to better results than individual thinking (Littleton and Mercer, 2013). Adopting this perspective, we argue that the focus on the distance, on the journey, so to speak, allows us to forge more accurate results in terms of innovative research focus.

In the following section, we discuss these insights in relation to the type of distance (psychological, phenomenological and chronological), and we illustrate how the self/familiar-other/unfamiliar distance is addressed in practice, design and research of digital books. We conclude each example with recommendations for future approaches to push the boundaries of current knowledge in children's digital books.

## BRIDGING THE DISTANCES AND ADVANCING FUTURE RESEARCH WITH THE DISTANCE MODEL

Prior research has progressed our understanding of expected outcomes when learners interact with digital books and make progress in vocabulary learning (e.g., Korat and Shamir, 2012) or story comprehension (Dore et al., 2018), as well as of the obstacles that learners face in assimilating meaning from highly interactive digital books that distract from the main story content (Takacs et al., 2015). The empirical advancement has also identified the specific features of digital books that hold the promise of digital books to innovate children's reading (Bus et al., 2020), or the specific mediation strategies used by adults to facilitate children's comprehension (Chen et al., 2020). Studies also show that considerable individual variation exists in respect to these findings, which is attributable to cognitive capabilities, including children's executive functioning (Richter and Courage, 2017) or attention (O'Toole and Kannass, 2018). What is less known is the joint journey that "self" and "other" can undertake to expand the boundaries of their familiar and unfamiliar story worlds.

## PSYCHOLOGICAL DISTANCE: FUTURE RESEARCH ON CHILDREN'S PERSONALIZED BOOKS

A future focus that centers on the *distance* could expand the research on personalized books to more imaginative story-worlds and more diverse types of personalized books. This would be particularly useful for exploring the reality of difference and empathic responses to others who are markedly different from self. How close the distance between lived and imagined reality should be in children's books is disputed but there is no doubt that "these images form and inform the unconscious substrate, or what cognitive theorists call the schemas, that we use to process everyday experience (. . .) creating a sense of obviousness that may have extended consequences for children's developing understanding of gender and race in certain cultural contexts" (Coats, 2019, p. 364). Children's authors and illustrators typically capitalize on children's imagination by depicting fantasy story-worlds with supernatural creatures that allow self-projection and that stimulate children's creative thinking (Nikolajeva, 2015). Future research on personalized books could thus probe various kinds of fantasy worlds, such as children's avatars, immersion in alternative worlds with supernatural creatures or children from other cultures and story worlds the child is unlikely to experience because of their living situation. Such titles would still comply with the aim of empowering young readers, with for instance lending young reader superpowers or enabling them to see a natural world they cannot visit because of an illness, displacement or financial resources. Digital books could expand this area, for example if they employ virtual and augmented reality to immerse children in alternative story worlds, such as the recently launched "The Case of the Missing Cleopatra" by AR Market. Empirical research is significantly behind the technological advances in personalized books and the distance perspective could increase researchers' interest in the "self" and "other" relationships in children's contemporary reading. It is necessary to establish the techniques that authors/publishers/designers could use to increase or decrease the self-other distance and for which outcomes. Literature with non-personalized analog books shows variation in the optimal distance between the story character and the child's persona: blurring fantasy with reality in anthropomorphic books was found to be detrimental to children's knowledge about the animals (Ganea et al., 2014) in one study, but did not show any difference to children's factual understanding in another study (Geerdts et al., 2016).

There is a very close link and a functional overlap between autobiographical memory and theory of mind (Spreng et al., 2009) and personalized books are likely to tap more directly into the autobiographical memory domains than non-personalized books, especially if they are produced digitally with photographs or videos showing children's lived experiences. This could be employed for teaching children self-regulation and empathy for others but also for learning new concepts. For example, one could imagine radically impersonal texts such as non-fiction books about animals, with personal cues such as a child's name or photo embedded in the book. The "self" would be stretched from the familiar position to that of others, as suggested by socio-cultural, neo-Vygotskian, scholars. The "self" would bridge the conceptual but also the material, familiar space and thus advance socio-material forms of being in the world.

## PHENOMENOLOGICAL DISTANCE: FUTURE DESIGN OF CHILDREN'S DIGITAL BOOKS

Phenomenological distance relates to the notion that the proximity of a story character to a reader needs to be tempered not only visually (through texts and illustrations), but through the engagement of all senses. A broad look at the children's literature suggests little innovation in the area, so far, with the vast majority of books offering content through visual and tactile engagement (in the form of print or digital books). However, bridging the phenomenological distance would mean engaging also the auditory, olfactory and gustatory sense, and it is with multisensory books that the design of children's digital books could innovate the field.

The representation of stories can be in various formats and each format can afford a distinct experience with so far, little understood benefits. For instance, audiobooks leave the visual depiction of stories entirely to listeners' imagination and they extend the reading experiences in classrooms (Larson, 2015). As a new digital literary experience, they create new learning experiences that, arguably, constitute a new form of reading: "reading by listening is a specific form of semantic listening separate from other forms of semantic listening such as those involved in conversations or consumption of vocal music" (Tattersall Wallin and Nolin, 2020, p. 471, 472). While there are known gender and age differences in the reading of traditional paper-based books, Tattersall Wallin and Nolin (2020) found no significant gender or age differences in the reading of audiobooks. More research is needed to explore the ways in which non-visual engagement with stories might address long-standing discrepancies in learning and expand the possibilities of what reading can achieve.

The Distance Model positions learning as the meeting place of the familiar/unfamiliar self/other, which implies a travel on a two-way roadway. The innovation necessary to bridge the distance should thus not be focused solely on replicating a lived experience with technologies, but also on enabling the reading technology to shape the lived experience. This opens up possibilities for innovations that could initiate a substantial structural change to how we understand the role of stories and what reading might look like. For instance, the use of edible materials has not been traditionally considered as part of children's reading experience, but Alaca (2019) comprehensively summarized the benefits of edible reading for expanding children's enjoyment of texts and tapping into learning domains that combine awareness of healthy eating with texts. Outlining the example of edible books, Alaca (2019) presents a prototype of snacks with printed letters and suggests that adding vitamin letters on edible snacks or print papers (made of rice paper) could engage children and adults in an enjoyable and health-promoting reading experience.

Another book format that carries a significant potential to expand the repertoire of children's reading experiences, are olfactory books. Olfactory books engage children's sense of smell through the release of scents or smells in relation to the concepts depicted on individual pages. Such books are, at the time of writing, in the prototype stage by the first author, so their learning potential can only be hypothesized, but the idea indicates the range of possibilities that are untapped in the current predominantly visual focus of children's literature. Crucially, if we are to bridge and challenge the familiar space of current socio-historical and socio-cultural understanding, then this bridging does need to involve the whole, multisensory nature of a human experience.

## CHRONOLOGICAL DISTANCE: FUTURE STUDIES IN CHILDREN'S LITERATURE

The distance between the "here" and "now" and the "there and then" is bridged successfully when readers immerse in a story, and when they identify with the story characters and engage with the content when the reading experience has ended. Such a reading experience is that of reading for pleasure (rather than for finding specific information or for a specific purpose and it is characterized by desire, diversity and delight (Cremin, 2008). The space-time boundaries shift as the reader navigates the story landscape and provide opportunities for reminiscing and revisiting the readers' own memories of a lived experience, as well as the reader's imagination and projections for the future.

The temporal and the spatial coordinators in books have an "inner diversity" (Luo, 2017), and the extent to which this diversity is taken up by readers depends on readers' agency. A central issue with the Distance Model becomes that of *agency*, where the reader decides himself or herself how a story continues. Such volition is supported through readers' own dispositions, such as their reading ability or interest and social capital, such as access to books (Love and Hamston, 2003). Authors, illustrators and designers introduce their own agency into a story through specific story-telling techniques, which have been studied in detail by literary scholars. Luo (2017), for example, shows how the popular story of Narnia does little to reduce the distance between Aslan and the reader, thus reducing the reader's agency: "meanings and values are complete and determinate, as is specifically presented in the stories as the absolute faith and unconditional obedience Aslan demands. The epic chronotope does not open to human initiative or personal judgment. It demands to be evaluated in the same way by all. This immanent characteristic of the epic chronotope determines that only the role-defined characters—who are given limited inner depth and who are largely subordinate to the plot—can be compatible with it" (p. 76). In contrast, in analysis of the chronotope in three popular children's Scandinavian picturebooks by the author Dahle and illustrator Nyhus, Krogstad (2016) highlights the close proximity between the time-space experienced by the depicted story characters and the intended reader. This gives rise to the child's agency because the child is portrayed "as an independent individual, with the potential to act, develop, and change, which may also actualize ethical aspects connected to the child as an actor, such as the way in which the child relates to others and communicates with other generations" (Krogstad, 2016, p. 10). A methodological focus on readers' and authors' agency is essential for nurturing these relationships. There is, however, no consensus on how to study children's agency in relation to reading.

As outlined in Kucirkova (2018), agency can be studied in relation to three indicators: behavioral indicators of children's control during the book reading (for example how the child holds the book, where the child looks, how the child turns pages), adults' perceptions of reader identities afforded by the content and format of books (this is the so-called social agency), and through specific multi-media and interactive features that are embedded in the books and allow readers to make choices. The latter can, for example, be manifested through books where children can choose the story characters or story endings, and in this way mediate themselves the distance between the "here and now" of their lived experience and the "there and then" of the story. More research into how the concept of distance can be applied methodologically, and how to study children's agency with print and digital books, is needed.

In conclusion, the children's digital books research can be advanced with the Distance Model. This has yet to permeate widely the field of children's media. The distance between the familiar, me-oriented, world of stories and the novel, depicted, world of stories, is the space between reality and the interpretations of reality. By extension, structuring future studies in children's media around the idea of distance is part of researchers' agency to trouble the current interpretations of what is possible when the distance between the "self" and the "other" becomes their joint horizon.

## AUTHOR CONTRIBUTIONS

NK developed the argument, framework, and figures. KL added perspectives drawn from the literatures concerning funds of identity and dialogic space. Both authors contributed to the article and approved the submitted version.

## FUNDING

NK would like to acknowledge the funding from The Research Council of Norway for FILIORUM, Grant No. 275576.

## REFERENCES

Adams, A., Hartnett, E., and Clough, G. (2015). *Turn it on its Head! Juxtaposed Learning. Creative Education*. Milton Keynes: The Open University.

Alaca, I. V. (2019). Honing emergent literacy via food: edible reading. *Libri Liberi* 8, 343–357. doi: 10.21066/carcl.libri.8.2.6

Bakhtin, M. M. (1981). *Marxismo e Filosofia da Linguagem: Problemas Fundamentais do Método Sociológico na Ciência da Linguagem*. São Paulo: Hucitec.

Baudrillard, J., and Guillaume, M. (2008). *Radical Alterity*, 1st Edn. Cambridge, MA: MIT Press. (translated by Hodges, A).

Beckett, S. L. (2013). *Crossover Picturebooks: A Genre for all Ages*. London: Routledge.

Beins, B. C., and Beins, A. M. (2012). *Effective Writing in Psychology: Papers, Posters, and Presentations*. London: John Wiley & Sons.

Bogard, T., Liu, M., and Chiang, Y. H. V. (2013). Thresholds of knowledge development in complex problem solving: a multiple-case study of advanced learners' cognitive processes. *Educ. Technol. Res. Dev.* 61, 465–503. doi: 10.1007/s11423-013-9295-4

Burnett, C., and Merchant, G. (2019). Revisiting critical literacy in the digital age. *Read. Teach.* 73, 263–266. doi: 10.1002/trtr.1858

Burnett, C., Merchant, G., and Parry, B. (2016). "Past, present, future," in *Literacy, Media, Technology: Past, Present and Future*, eds B. Parry, C. Burnett, and G. Merchant, (London: Bloomsbury).

Bus, A. G., Neuman, S. B., and Roskos, K. (2020). Screens, apps, and digital books for young children: the promise of multimedia. *AERA Open* 6:2332858420901494.

Chen, C., Chen, S., Wen, P., and Snow, C. E. (2020). Are screen devices soothing children or soothing parents? Investigating the relationships among children's exposure to different types of screen media, parental efficacy and home literacy practices. *Comput. Hum. Behav.* 112:106462. doi: 10.1016/j.chb.2020.106462

Coats, K. (2019). Visual conceptual metaphors in picturebooks: implications for social justice. *Child. Lit. Assoc. Q.* 44, 364–380. doi: 10.1353/chq.2019.0045

Comber, B. (2015). *Literacy, Place, and Pedagogies of Possibility*. London: Routledge.

Cremin, T. (2008). "Revisiting reading for pleasure: diversity, delight and desire," in *Understanding Phonics And The Teaching Of Reading: A Critical Perspective. Critical Perspectives*, eds G. Kathy, and L. Andrew, (Berkshire: McGraw Hill), 166–190.

Cruz, S., Lencastre, J. A., Coutinho, C., Clough, G., and Adams, A. (2016). "Threshold concepts Vs. tricky topics-exploring the causes of student's misunderstandings with the problem distiller tool," in *Proceedings of CSEDU 2016, 8th International Conference on Computer Supported Education*, Vol. 1, Rome: SCITEPRESS–Science and Technology Publications, 205–215.

Cunningham, S. J., Brebner, J. L., Quinn, F., and Turk, D. J. (2014). The self-reference effect on memory in early childhood. *Child Dev.* 85, 808–823. doi: 10.1111/cdev.12144

Demoulin, D. F. (1999). A personalized development of self-concept for beginning readers. *Education* 120, 14–14.

Dore, R. A., Hassinger-Das, B., Brezack, N., Valladares, T. L., Paller, A., Vu, L., et al. (2018). The parent advantage in fostering children's e-book comprehension. *Early Childh. Res. Q.* 44, 24–33. doi: 10.1016/j.ecresq.2018.02.002

Esteban-Guitart, M., and Moll, L. C. (2014). Funds of identity: a new concept based on the funds of knowledge approach. *Cult. Psychol.* 20, 31–48. doi: 10.1177/1354067x13515934

Ganea, P. A., Canfield, C. F., Simons-Ghafari, K., and Chou, T. (2014). Do cavies talk? The effect of anthropomorphic picture books on children's knowledge about animals. *Front. Psychol.* 5:283. doi: 10.3389/fpsyg.2014.00283

Garton, A. F. (2008). *Exploring Cognitive Development: The Child as Problem Solver*. London: John Wiley & Sons.

Geerdts, M. S., Van de Walle, G. A., and LoBue, V. (2016). Learning about real animals from anthropomorphic media. *Imagin. Cogni. Personal.* 36, 5–26. doi: 10.1177/0276236615611798

Hackett, A. (2016). Young children as wayfarers: learning about place by moving through it. *Child. Soc.* 30, 169–179. doi: 10.1111/chso.12130

Johnston, R. R. (2002). *A Narrative Chronotope. Children's Literature as Communication, Amsterdam*. Philadelphia: John Benjamins Publishing Company, 137–157.

Korat, O., and Shamir, A. (2012). Direct and indirect teaching: using e-books for supporting vocabulary, word reading, and story comprehension for young children. *J. Educ. Comput. Res.* 46, 135–152. doi: 10.2190/ec.46.2.b

Krogstad, A. (2016). The family house chronotope in three picturebooks by Gro Dahle and Svein Nyhus: idyll, fantasy, and threshold experiences. *Barnelitterært Forskningstidsskrift* 7:26040. doi: 10.3402/blft.v7.26040

Kucirkova, N. (2018). Children's agency and reading with story-apps: considerations of design, behavioural and social dimensions. *Qual. Res. Psychol.* 1–25. doi: 10.1080/14780887.2018.1545065

Kucirkova, N. (2019). Children's reading with digital books: past moving quickly to the future. *Child Dev. Perspect.* 13, 208–214. doi: 10.1111/cdep.12339

Kucirkova, N. (2021). *The Future of the Self*. London: Emerald.

Kucirkova, N., Messer, D., and Sheehy, K. (2014). Reading personalized books with preschool children enhances their word acquisition. *First Lang.* 34, 227–243. doi: 10.1177/0142723714534221

Larson, L. C. (2015). E-books and audiobooks: extending the digital reading experience. *Read. Teach.* 69, 169–177. doi: 10.1002/trtr.1371

Leaton Gray, S. (2017). The social construction of time in contemporary education: implications for technology, equality and Bernstein's 'conditions for democracy'. *Br. J. Sociol. Educ.* 38, 60–71. doi: 10.1080/01425692.2016.1234366

Littleton, K., and Mercer, N. (2013). *Interthinking: Putting talk to work*. London: Routledge.

Livingstone, S., and Helsper, E. J. (2008). Parental mediation of children's internet use. *J. Broadcas. Electron. Media* 52, 581–599.

Love, K., and Hamston, J. (2003). Teenage boys' leisure reading dispositions: juggling male youth culture and family cultural capital. *Educ. Rev.* 55, 161–177. doi: 10.1080/00131910303255

Ludvigsen, K., Ness, I. J., and Timmis, S. (2019). Writing on the wall: how the use of technology can open dialogical spaces in lectures. *Think. Skills Creat.* 34:100559. doi: 10.1016/j.tsc.2019.02.007

Luo, Z. (2017). *A Bakhtinian Reading of Fantasy Chronotopes in Modern Children's Fantasy Literature*. Doctoral dissertation, University of Warwick, Coventry.

Maaninen-Olsson, E., and Müllern, T. (2009). A contextual understanding of projects–The importance of space and time. *Scand. J. Manag.* 25, 327–339. doi: 10.1016/j.scaman.2009.03.011

Marsh, J., Brooks, G., Hughes, J., Ritchie, L., Roberts, S., and Wright, K. (2005). *# Digital Beginnings: Young Children's use of Popular Culture, Media and New Technologies*. Sheffield: University of Sheffield, 2005.

Mercer, N. (1994). "Neo-Vygotskian theory and classroom education," in *Language, Literacy and Learning in Educational Practice*, eds B. Stierer, and J. Maybin, (Clevendon: The Open University), 92–110.

Merleau-Ponty, M. (1982). *Phenomenology of Perception*. New York, NY: Routledge.

Mildenberg, A. (2017). *Modernism and Phenomenology: Literature, Philosophy, Art*. London: Springer.

Moll, L. C., Amanti, C., Neff, D., and Gonzalez, N. (1992). Funds of knowledge for teaching: using a qualitative approach to connect homes and classrooms. *Theory Into Pract.* 31, 132–141. doi: 10.1080/00405849209543534

Nikolajeva, M. (2015). *Children's Literature Comes of Age: Toward a New Aesthetic*. New York, NY: Routledge.

Orvell, A., Kross, E., and Gelman, S. A. (2017). How "you" makes meaning. *Science* 355, 1299–1302. doi: 10.1126/science.aaj2014

Orvell, A., Kross, E., and Gelman, S. A. (2019). Lessons learned: young children's use of generic-you to make meaning from negative experiences. *J. Exp. Psychol.* 148, 184–191. doi: 10.1037/xge0000445

O'Sullivan, E. (2005). *Comparative Children's Literature*. London: Routledge.

O'Toole, K. J., and Kannass, K. N. (2018). Emergent literacy in print and electronic contexts: the influence of book type, narration source, and attention. *J. Exp. Child Psychol.* 173, 100–115. doi: 10.1016/j.jecp.2018.03.013

Ozturk, G., and Hill, S. (2018). Mother–child interactions during shared reading with digital and print books. *Early Child Dev. Care* 190, 1425–1440. doi: 10.1080/03004430.2018.1538977

Pahl, K. (2014). *Materializing Literacies in Communities: The Uses of Literacy Revisited*. London: Bloomsbury Publishing.

Peterson, C., and McCabe, A. (1994). A social interactionist account of developing decontextualized narrative skill. *Dev. Psychol.* 30, 937–948. doi: 10.1037/0012-1649.30.6.937

Piaget, J. (1950). *The Psychology of Intelligence*. London: Routledge.

Przybylski, A. K., and Weinstein, N. (2019). Digital screen time limits and young children's psychological well-being: evidence from a population-based study. *Child Dev.* 90, e56–e65.

Richter, A., and Courage, M. L. (2017). Comparing electronic and paper storybooks for preschoolers: attention, engagement, and recall. *J. Appl. Dev. Psychol.* 48, 92–102. doi: 10.1016/j.appdev.2017.01.002

Rosenblatt, L. M. (1978). *The Reader, the Text, the Poem: The Transactional Theory of the Literary Work*. Carbondale, IL: Southern Illinois University Press.

Ross, J., Anderson, J. R., and Campbell, R. N. (2011). I remember me: mnemonic self-reference effects in preschool children. *Monogr. Soc. Res. Child Dev.* 76, 1–10. doi: 10.1111/j.1540-5834.2011.00613.x

Rowsell, J. (2014). Toward a phenomenology of contemporary reading. *Austr. J. Lang. Lit.* 37, 117–127.

Ryan, M. L. (2009). From narrative games to playable stories: toward a poetics of interactive narrative. *Storyworlds*1, 43–59. doi: 10.1353/stw.0.0003

Scholz, B. F. (1998). "Bakhtin's Concept of "Chronotope": the kantian connection," in *The contexts of Bakhtin: Philosophy, Authorship, Aesthetics*, Vol. 2, ed. D. G. Shepherd, (Hove: Psychology Press), 141–173.

Schwartz, S. J., Luyckx, K., and Vignoles, V. L. (eds) (2011). *Handbook of Identity Theory and Research*. Berlin: Springer Science & Business Media.

Spreng, R. N., Mar, R. A., and Kim, A. S. (2009). The common neural basis of autobiographical memory, prospection, navigation, theory of mind, and the default mode: a quantitative meta-analysis. *J. Cogn. Neurosci.* 21, 489–510. doi: 10.1162/jocn.2008.21029

Sui, J., and Zhu, Y. (2005). Five-year-olds can show the self-reference advantage. *Int. J. Behav. Dev.* 29, 382–387. doi: 10.1177/01650250500172673

Swyt, D. (1992). New concepts in precision dimensional measurement for modern manufacturing. *Control Dyn. Syst.* 45, 111–163. doi: 10.1016/b978-0-12-012745-0.50010-3

Takacs, Z. K., Swart, E. K., and Bus, A. G. (2015). Benefits and pitfalls of multimedia and interactive features in technology-enhanced storybooks: a meta-analysis. *Rev. Educ. Res.* 85, 698–739. doi: 10.3102/0034654314566989

Tattersall Wallin, E., and Nolin, J. (2020). Time to read: exploring the timespaces of subscription-based audiobooks. *New Media Soc.* 22, 470–488. doi: 10.1177/1461444819864691

Turk, D. J., Gillespie-Smith, K., Krigolson, O. E., Havard, C., Conway, M. A., and Cunningham, S. J. (2015). Selfish learning: the impact of self-referential encoding on children's literacy attainment. *Learn. Instr.* 40, 54–60. doi: 10.1016/j.learninstruc.2015.08.001

Turkle, S. (2017). *Alone Together: Why we Expect More From Technology and Less From Each Other*. New York, NY: Hachette UK.

Twenge, J. M. (2017). *iGen: Why Today's Super-Connected Kids are Growing up Less Rebellious, More Tolerant, Less Happy–and Completely Unprepared for Adulthood–and What That Means for the Rest of us*. New York, NY: Atria Books.

Vygotsky, L. (1978a). Interaction between learning and development. *Read. Dev. Child.* 23, 34–41.

Vygotsky, L. S. (1978b). *Mind in Society: the Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.

Wegerif, R. (2007). *Dialogic Education and Technology: Expanding the Space of Learning*, Vol. 7. London: Springer Science & Business Media.

Wegerif, R. (2011). Towards a dialogic theory of how children learn to think. *Think. Skills Creat.* 6, 179–190. doi: 10.1016/j.tsc.2011.08.002

Wegerif, R. (2013). *Dialogic: Education for the Internet age*. London: Routledge.

Welsh, T. (2013). *The Child as Natural Phenomenologist: Primal and Primary Experience in Merleau-Ponty's Psychology*. Evanston, IL: Northwestern University Press.

Zhao, S., and Unsworth, L. (2016). "Touch design and narrative interpretation," in *Apps, Technology and Younger Learners: International Evidence for Teaching*, eds N. Kucirkova, and G. Falloon, (London: Routledge), 89–102.

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 02 November 2020
doi: 10.3389/fpsyg.2020.569222

# Longitudinal Links Between Media Use and Focused Attention Through Toddlerhood: A Cumulative Risk Approach

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Previous studies that examined the links between media use and children's attention abilities have yielded inconclusive findings. In the current study, we aimed to move beyond the focus on isolated aspects of media use to a comprehensive assessment of both direct and indirect media use and practices in early childhood. Drawing from the cumulative risk literature, we examined whether cumulative media use is related to children's subsequent attention abilities. Participants were 199 mothers of toddlers (60% male) who completed questionnaires assessing various aspects of children's media use, as well as children's focused attention abilities at three time points: 18 months (T1), 22 months (T2), and 26 months (T3) of age. Cumulative media use scores were computed based on four indicators: (1) child average daily screen time; (2) household background television; (3) maternal use of media to regulate child distress; and (4) maternal use of mobile devices while spending time with the child. An autoregressive cross-lagged (ARCL) path model controlling for child sex, maternal education, and general parenting practices showed that cumulative media use at 18 months negatively predicted children's focused attention at 22 months. Moreover, there was a significant negative indirect effect from cumulative media use at 18 months to focused attention at 26 months via focused attention at 22 months. Finally, the cumulative media index appeared to be a better predictor of focused attention than any of the singular media use indicators. Children's focused attention did not predict subsequent cumulative media use across time, providing no evidence for bidirectional links. Findings suggest that exposure to multiple (rather than single) aspects of media use is related to decreased subsequent focused attention abilities during toddlerhood. Family media plans that designate media-free time and increase parental awareness to media use habits in the household should therefore be encouraged.

**Keywords: media use, early childhood, focused attention, cumulative risk, background television, screen time, parental media use**

OPEN ACCESS

***Edited by:***
*Rachel Barr,*
*Georgetown University, United States*

***Reviewed by:***
*Mary Courage,*
*Memorial University of Newfoundland, Canada*
*Matthew A. Lapierre,*
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***Specialty section:***
*This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology*

***Received:*** *03 June 2020*
***Accepted:*** *05 October 2020*
***Published:*** *02 November 2020*

***Citation:***
*Gueron-Sela N and Gordon-Hacker A (2020) Longitudinal Links Between Media Use and Focused Attention Through Toddlerhood: A Cumulative Risk Approach.*
*Front. Psychol. 11:569222.*
*doi: 10.3389/fpsyg.2020.569222*

The relationship between children's use of screen-based media and attention abilities has been a primary focus of research for over four decades (Nikkelen et al., 2014; Kostyrka-Allchorne et al., 2017). During this period, children's media content has become more fast-paced, arousing, and easily accessible to very young children, leading to the development of several hypotheses regarding how these aspects of media use could hamper children's developing attentional skills (Nikkelen et al., 2014). However, despite the accumulation of research on this topic, the extent to which screen media use and attention abilities are linked remains unclear due to a considerable amount of mixed findings (Landhuis et al., 2007; Foster and Watkins, 2010). Notably, the vast majority of these studies have focused on isolated aspects of media use, mainly the *amount* of exposure to screen media, overlooking the importance of contextual factors of media use (Barr, 2019). Family media ecology refers to the way media are used by all members of the household, including children's direct and indirect exposure, and how media are used in children's daily routines such as play, discipline, meals, and bedtime (Barr, 2019). Guided by this contextual framework, in the current study we applied a comprehensive assessment of media use and practices in early childhood. Drawing from the cumulative risk literature suggesting that multiple risk factor exposure exceeds the adverse developmental impacts of singular exposures (Evans et al., 2013), we examined whether cumulative media use is related to children's emerging focused attention abilities. We specifically focused on four indicators of media use and exposure that were selected based on recommendations of the American Academy of Pediatrics (AAP) for media use in early childhood (Council on Communications, and Media, 2016) and previous research linking these indicators to attention abilities directly or indirectly (Kirkorian et al., 2009; Radesky et al., 2016; Kildare and Middlemiss, 2017; Kostyrka-Allchorne et al., 2017), including daily screen time, household background television, use of media to regulate child distress, and parental use of mobile devices while spending time with the child.

## FOCUSED ATTENTION ACROSS TODDLERHOOD

Focused attention, defined as the ability to sustain attention during active engagement with a stimulus or task, is one of the primary attentional skills that enable response persistence, cognitive information processing, and goal-directed behavior (Ruff and Rothbart, 1996; Garon et al., 2008). A substantial body of literature has addressed the role of focused attention in learning and cognitive development, finding that focused attention abilities during infancy and toddlerhood are predictive of later general cognitive abilities and executive function (Lawson and Ruff, 2004; Johansson et al., 2015). The development of sustained attention during early childhood is attributed in part to the development of two attention subsystems: the orienting system, which allows children to attend to stimuli in the external environment, and the executive attention network, which enables more volitional control of attention and the ability to focus attention in the face of potential distractions (Ruff and Rothbart, 1996; Posner et al., 2014). The gradually increasing dominance of the executive attention network toward the end of the first year of life supports children's emerging ability to sustain attention for prolonged periods of time (Colombo and Cheatham, 2007). Indeed, research has shown significant increases in children's duration and frequency of sustained attention during free play and structured situations from late infancy to early childhood (Ruff and Lawson, 1990; Ruff and Capozzoli, 2003; Kannass et al., 2006).

The development of attention abilities has strong biological underpinnings that are considered constitutional and genetic in origin but is also shaped by children's environmental experiences (Colombo and Salley, 2015). The increase in young children's screen media exposure over the past two decades has led to concern about the impact of screen media exposure on the development of the attention networks (Nikkelen et al., 2014; Courage, 2017). Consequently, a substantial body of literature has focused on the links between screen media use and two main aspects of attention measured in the preschool period: attention problems (e.g., distractibility, inability to focus) and executive function (EF; i.e., inhibitory control, working memory, and cognitive set shifting). However, little is known about the potential impact of screen media in toddlerhood, a period when children may be particularly susceptible to environmental experiences that support or hinder the development of attention networks (Comas et al., 2014; Gueron-Sela et al., 2018). Due to the recent increases in screen media exposure in this developmental time period (Rideout, 2017), the current study focused on three time points across toddlerhood: 18, 22, and 26 months. We chose focused attention as our main outcome because it is considered the foundation for the development of EF abilities in later childhood (Garon et al., 2008) and is also predictive of later attention problems (Miller et al., 2018).

## CUMULATIVE MEDIA EXPOSURE AND FOCUSED ATTENTION

The concept of cumulative risk has gained considerable attention within developmental science, mainly due to the robust finding that children who experience multiple and cumulative risk factors in early life show more adverse developmental outcomes than those who experience singular risk factors (Evans et al., 2013; Gach et al., 2018). Traditionally, cumulative risk approaches have been used to assess socioeconomic risk, including financial factors (e.g., low income), family resources (e.g., poor total family functioning), and parental personal resources (e.g., poor mental health; Evans et al., 2013). In the current study, we aimed to apply a similar approach to assess media use in early childhood while considering multiple aspects of exposure to media. In the following paragraph, we describe the individual factors that comprised the cumulative media use (CMU) index and explain how they are related to children's attention abilities. Our choice of indicators was informed by recommendations provided by the AAP regarding media use in early childhood (Council on Communications, and Media, 2016) and by previous literature linking screen media exposure and attention abilities either directly (Kostyrka-Allchorne et al., 2017) or indirectly through parent–child interactions (Kirkorian et al., 2009) and children's self-regulation abilities (e.g., Radesky et al., 2016).

### Screen Time

Based on studies showing associations between excessive television viewing in early childhood and cognitive, language, and social–emotional delays, the 2016 AAP guidelines recommend that screen media exposure be limited to no more than 1 h per day for 2–5-year-old children to allow sufficient time to engage in other activities important to their development (Council on Communications, and Media, 2016). However, nationally representative data from the United States indicate that 2–4-year-old children are exposed to more than 2 h per day on average (Rideout, 2017). These numbers have raised concerns regarding the effects of excessive exposure to screen media on children's cognitive development, and particularly their attention abilities (Anderson and Subrahmanyam, 2017; Courage, 2017). Indeed, the vast majority of empirical studies that examined the associations between media use and attention have used the total amount of direct exposure to screen media as an indicator of children's media use and focused mainly on attention problems as an outcome (see Kostyrka-Allchorne et al., 2017 for review). Overall, whereas there is some evidence for positive cross-sectional links between screen time and attention problems in early childhood (Tamana et al., 2019), longitudinal studies that considered the bidirectional links between screen time and attention problems over time have generally found no support for such links (Stevens et al., 2009; Foster and Watkins, 2010).

Other studies have focused on the links between screen media use and children's EF. Findings from these studies suggest overall that higher screen time may be related to poorer EF abilities in the preschool period (Barr et al., 2010; Nathanson et al., 2014). However, the nature of this association is complex and depends on factors such as children's age, parenting practices, type of programming watched, and demographic factors (Barr et al., 2010). For example, Barr et al. (2010) found that only high levels of exposure to adult-directed (but not child-directed) media content were associated with poorer EF at age 4. Linebarger et al. (2014) further demonstrated that for children at high demographic risk, increased exposure to educational media content was associated with better EF. Finally, in one study the amount of television viewing was negatively related to EF at age 5, but this association was no longer significant when controlling for the home learning environment and parental scaffolding (Blankson et al., 2015).

## Household Background Television

The AAP advises parents to reduce young children's exposure to background television (i.e., adult-directed content to which children pay little active attention; Anderson and Evans, 2001) in the household, as it can be distracting and interfere in experiences such as toy play and social interactions that are essential for children's cognitive development (Anderson and Pempek, 2005; Council on Communications, and Media, 2016). Indeed, experimental research directly assessing the impact of background television indicates that it disrupts children's attention during play (Schmidt et al., 2008; Setliff and Courage, 2011). For example, in the presence of background television, young children (ages 12, 24, and 36 months) showed less solitary toy play overall and shorter bouts of focused attention than in play situations in which the television was off (Schmidt et al., 2008).

An additional body of research focused on correlational links between background television and children's EF (Barr et al., 2010; Linebarger et al., 2014). For example, Barr et al. (2010) showed that children's high levels of exposure to household television during infancy and at age four were associated with poorer EF at age four (Barr et al., 2010). Similarly, Linebarger et al. (2014) showed that greater exposure to background television was associated with lower EF for preschool children at high demographic risk, and low-risk primary school children. Parenting style further moderated the latter relationship, with high levels of inconsistent parenting behaviors exacerbating the negative effects of background television on EF. Findings from this study showed that the associations between background television and EF are complex and may depend on additional factors such as demographic risk and parenting (Linebarger et al., 2014).

The impact of background television on parental behavior can also be a mechanism through which background television can impede children's attention skills. During infancy and toddlerhood, dyadic social interactions serve as a primary socialization mechanism in which parents engage to support their infants' attention abilities (Yu and Smith, 2016). Through time, continuous shared attentional states between the parent and the child can facilitate children's ability to sustain attention toward objects on their own for increasingly longer stretches of time (Yu and Smith, 2016). The distractions caused by the presence of background television can disrupt this process. For example, in the presence of background television, parents were found to be less verbally interactive with their children and less responsive to their children's bids for attention than when the television was off (Kirkorian et al., 2009).

## Use of Media to Regulate Child Distress

Parents often report using screens to soothe their children (Kabali et al., 2015; Radesky et al., 2016; Gordon-Hacker and Gueron-Sela, 2020). However, the AAP recommends not relying heavily on screen media devices to regulate children's distress, as excessive use of this strategy could interfere with the development of children's self-regulation abilities (Council on Communications, and Media, 2016). During early childhood, self-regulatory abilities are limited and children largely depend on external regulation provided by their parents in modulating their arousal (Sameroff, 2010). When parents respond to children's negative emotions in unsupportive ways, such as punitive reactions, personal distress, or minimizing the child's distress, children may experience hyperarousal, which can interfere with their ability to focus and shift attention in response to environmental demands (Spinrad et al., 2007). Indeed, unsupportive maternal responses to children's negative emotions were negatively related to children's later attentional control (Spinrad et al., 2007). The use of media to soothe negative emotions may establish passive and ineffective regulatory strategies in young children, resulting in increased arousal and difficulties in regulating and focusing attention for prolonged periods of time.

## Parental Mobile Device Use

Finally, based on research showing that heavy parental use of mobile devices is associated with fewer verbal and non-verbal interactions between parents and children (e.g., Radesky et al., 2015), which are essential for children's cognitive and social–emotional development, the AAP recommends reducing parental media use while parenting and enhancing parent–child "media free" interactions (Council on Communications, and Media, 2016). Accumulating evidence suggests that when parents are occupied with mobile devices, their ability to respond to their children's cues is limited (see Kildare and Middlemiss, 2017 for a review). Similar to background television, parental use of mobile devices may interfere with parent–child reciprocal social interactions that serve as a primary socialization mechanism for the development of attention skills. For example, research has found that mothers distracted by mobile devices exhibited less verbal and non-verbal communication with their children, were slower to respond to their children's engagement attempts, and were less sensitive in their eventual responses than were mothers who were not engaged with a device (Radesky et al., 2014a; Hiniker et al., 2015). On the child's side, children showed less toy engagement when their mothers were occupied with a mobile device than during free play with no mobile device (Myruski et al., 2018). Thus, excessive parental mobile device can result in continuous disruptions in parent–child social interactions that prevent children from practicing their emerging focused attention skills.

# THE CURRENT STUDY

Given the increase in screen media use in the past decade by both parents and young children, understanding the potentially harmful implications for children's cognitive abilities is critical (Anderson and Subrahmanyam, 2017; Courage, 2017). The current study addressed this issue by examining the links between a cumulative index of media use and children's focused attention abilities at three time points in toddlerhood: 18 (T1), 22 (T2), and 26 (T3) months of children's age. We aimed to expand extant literature in three main ways. First, guided by a family media ecology framework and the recent call to broaden the examination of media effects beyond screen time (Barr, 2019), we examined four different aspects of media use in early childhood that can be related to children's attention abilities, including overall screen time (Nikkelen et al., 2014), background television (Anderson and Pempek, 2005; Schmidt et al., 2008; Courage, 2017), use of media to regulate child distress (Radesky et al., 2016), and mobile device use while parenting (Kildare and Middlemiss, 2017). Second, we applied a cumulative risk approach that can be especially helpful in assessing the additive impact of multiple sources of exposure that span a variety of children's daily experiences. Finally, acknowledging the potential bidirectional links between media use and child characteristics (Radesky et al., 2014b; Kostyrka-Allchorne et al., 2017; Cliff et al., 2018), we used a short-term longitudinal design that enabled us to disentangle the transactional links between media use and attention abilities. Importantly, because these indicators of media use may tap into general parenting practices, we controlled for maternal supportive and unsupportive parenting behaviors in order to elucidate the unique implications of media use for children's attention abilities.

We hypothesized that CMU and child-focused attention would show both prospective and longitudinal negative associations between T1, T2, and T3. We also examined whether the CMU index is a more powerful predictor of focused attention than any of the singular factors that comprise the risk index.

# MATERIALS AND METHODS

## Participants and Procedure

The study protocol was reviewed and approved by the Human Subjects Research Committee at (Ben Gurion University) University. Data were collected from January 2018 to January 2019 through Prolific, an online research platform (Palan and Schitter, 2018). Mothers of children aged 17–19 months were initially approached via Prolific and invited to participate in the study. Mothers who were willing to participate signed online consent forms. The initial sample at T1 consisted of 207 mothers of children (*M* child age in months = 17.71, *SD* = 0.83; 60% male). Eight participants were excluded from the study due to child health or developmental problems ($n = 3$), maternal health problems ($n = 4$), or answering the attention-verifying items wrongly ("If you read this please mark 4"; $n = 1$). Thus, 199 participants comprised the final sample at T1. Demographic information is reported in **Table 1**. Participants were re-approached via Prolific 4 and 8 months later to participate at T2 ($n = 149$; *M* child age in months = 21.11, *SD* = 1.04) and T3 ($n = 119$; *M* child age in months = 25.21, *SD* = 1.04). Mothers were requested to complete a set of questionnaires at all three time points. Participants received 1.3 GBP for participating in T1 and 3 GBP for participating in T2 and T3.

## Measures

### Cumulative Media Use (CMU)

The CMU measure was constructed from four indicators that were selected based on the recommendations of the AAP for media use in early childhood (Council on Communications, and Media, 2016):

#### *Child Average Daily Screen Time*

Screen time was assessed using maternal report of average child screen time (i.e., watching television, watching videos/playing games on a handled device) during a typical weekday and weekend day. Weighted average scores for total screen time across time (weekdays and weekends) were calculated for all three time points. Screen time data at specific time points were not used for participants who reported aberrantly high child screen time (+ 2 *SD* above the mean) due to concerns regarding the reliability of these reports. These included nine participants at T1 (above 447.62 min per day), seven participants at T2 (above 379.62 min per day), and four participants at T3 (above 412.72 min a day).

#### *Household Background Television*

Mothers were asked to rate how often the television is on, if ever, in their household when someone is at home, even if no one

**TABLE 1 |** Sample demographic characteristics.

| | *M* | *SD* | Range |
|---|---|---|---|
| Maternal age (years) | 31.33 | 4.96 | 19–45 |
| **Maternal education (percent)** | | | |
| > 12 | 1.5% | | |
| Full high-school Diploma | 50% | | |
| Academic | 48% | | |
| **Current country or nationality (percent)** | | | |
| United Kingdom | 79.2% | | |
| United States | 13.6% | | |
| Europe | 7.2% | | |
| **Ethnicity (percent)** | | | |
| European White | 92.5% | | |
| African American | 2.5% | | |
| Asian | 3.5% | | |
| Other ethnicity | 1.5% | | |
| Number of children | 1.84 | 0.95 | 1–6 |
| **Family status (percent)** | | | |
| In a relationship or married | 87% | | |
| Separated or divorced | 3.5% | | |
| Single | 9.5% | | |
| **Employment status (percent)** | | | |
| Full-time | 25.6% | | |
| Part-time | 44.7% | | |
| Unemployed/homemaker | 29.6% | | |

is actually watching it, on a scale ranging from 0 (*Never*) to 5 (*Always*).

### *Use of Media to Regulate Child Distress*

Mothers completed a version of the Coping with Toddlers' Negative Emotion Scale (CTNES; Spinrad et al., 2007) that was modified for the current study. The CTNES consists of 12 different scenarios in which children exhibit distress (e.g., parent prohibits an activity). Mothers are asked to rate the likelihood to respond in seven different ways to children's distress (i.e., distress reactions, minimizing the child's distress, encouraging emotional expressiveness, punitive reactions, emotion focused, problem focused, and granting the child's wish) that were rated on a scale ranging from 1 (*Very unlikely*) to 7 (*Very likely*). In the current study, four distress scenarios were presented to mothers to reduce participant burden, and an additional strategy was added: the likelihood of responding with the provision media to reduce the child's distress (e.g., "If my child becomes angry because s/he is not allowed to have a snack when s/he wants it, I would offer to let my child play or watch something on my phone/tablet/computer/television"), which was the scale for the current variable. Items on this scale were averaged, and a higher score on this scale indicates a higher likelihood of using media to regulate child distress (α = 0.78, 0.79, and 0.80 for T1, T2, and T3, respectively).

### *Maternal Mobile Device Use*

Mothers were asked to rate how often, if ever, they use media (for example, a mobile phone or tablet) to keep themselves occupied while spending time with their children on a scale ranging from 0 (*Never*) to 3 (*Often*).

### *Calculating the CMU Scores*

CMU scores were calculated using a proportion-score approach (Moran et al., 2017). For each indicator, a proportion score is computed by dividing each individual score by the maximum score, yielding a proportion score with a maximum value of one. The composite score is then the mean of all proportion scores. This method is appropriate when risk factors are continuous, as it maintains the relative rank ordering of individuals, which is lost in dichotomization. Thus, this approach assumes that risk occurs on a continuum with varying degrees of severity (Ettekal et al., 2019).

For each time point, a CMU score was calculated by first dividing each individual risk indicator score by the maximum score within the current sample (yielding a proportion score with a maximum value of one) and then computing the mean of all four indicators to estimate a total score for each time point. Higher scores represent higher exposure to problematic media use. CMU scores ranged between 0.04 and 0.78 at T1, 0.08 and 0.83 at T2, and 0.12 and 0.76 at T3.

## Child Focused Attention

Children's focused attention abilities were measured using the Attentional Focusing subscale from the Early Childhood Behavior Questionnaire Short Form (ECBQ-SF; Putnam et al., 2006). The Attentional Focusing subscale includes six items that assess children's ability to sustain duration of orienting on an object of attention and resist distractions (e.g., "When engaged in play with his/her favorite toy, how often did your child play for more than 10 min?"; "When engaged in an activity requiring attention, such as building with blocks, how often did your child move quickly to another activity?"; "While looking at picture books on his/her own, how often did your child become easily distracted?"). Mothers were asked to rate each item on a scale ranging from 1 (*Never*) to 7 (*Always*). Higher scores on this scale indicate better focused attention abilities (α = 0.70, 0.69, and 0.73 for T1, T2, and T3, respectively).

## Covariates

Maternal education and child sex were included as covariates in all analyses, based on previous studies linking child media use to maternal education level (Vijakkhana et al., 2015) and indicating sex differences in attention abilities (Groot et al., 2004). Maternal education was rated on a scale from 1 (*Less than a high-school diploma*) to 6 (*Graduate degree*). In order to examine the unique role of media use above and beyond general parenting approaches, we also included two measures that reflect supportive and unsupportive parenting behaviors that were derived from the CTNES (Spinrad et al., 2007). The items on each scale of the CTNES were averaged to create the supportive (problem-focused, emotion-focused, and expressive encouragement; α = 0.83) and unsupportive (minimizing and punitive reaction; α = 0.76) subscales.

## Missing Data and Attrition

Of the 199 participants who composed the final sample at T1, 149 participated in T2 and 119 at T3. No significant differences were found between participants who did not participate at T2 and T3 and those who participated at all three time points in maternal education level, child sex, and the study variables. In addition, participants who wrongly answered the attention-verifying items at T2 ($n = 6$) and T3 ($n = 2$) were excluded from those specific time points. To account for missing data, we utilized a full maximum likelihood (FIML) estimator for all analyses. FIML is well recognized as an effective method for analyzing longitudinal data with moderate to large amounts of missing data and has been demonstrated to provide less biased parameter estimates than other commonly used techniques, such as listwise deletion (Enders, 2013). Because FIML procedures allow for the use of all available data from each participant, the full sample of $n = 199$ was retained in all primary analyses.

### Statistical Analysis

An autoregressive cross-lagged (ARCL) model was applied to test the main study hypothesis. The ARCL model represents a path model that simultaneously estimates the autoregressive relations (i.e., stability) of two or more variables that unfold over time, along with the cross-lagged relations between these variables (i.e., the time-lagged regressions across time points). The cross-lagged parameters are typically interpreted as the between-person effect of X at time 1 on Y at time 2, controlling for Y at time 1 (and vice versa). Thus, this model is particularly suitable for examining bidirectional relations between variables across several time points.

CMU and child-focused attention were estimated at all three time points. Autoregressive paths were specified within measurements of CMU and focused attention at T1, T2, and T3, and cross-lagged paths were specified between measures of CMU and focused attention across time points. Concurrent associations between variables within time points were estimated. All focal variables in the model were regressed on the selected covariates (i.e., maternal education, child sex, supportive and unsupportive parenting). Bootstrapping (with 10,000 resamples) was used to derive 95% confidence intervals for the direct and indirect effects. Model fit was determined using the root mean square error of approximation (RMSEA), standardized root mean square residual (SRMR), and comparative fit index (CFI). Adequate fit was defined as CFI values $\geq$ 0.95, RMSEA value $\leq$ 0.06, and SRMR values $\leq$ 0.08.

## RESULTS

### Descriptive Statistics

**Table 2** presents the bivariate correlations, means, and standard deviations for the study variables and covariates. Both the CMU and FA measures were significantly and positively correlated across time points. In addition, the CMU measures at all three time points were significantly negatively correlated with FA at T2 and T3. FA at T1 was also negatively correlated with CMU at T3. As for the study covariates, unsupportive parenting practices were positively linked with CMU at all-time points, and supportive parenting practices were negatively correlated with CMU at T1. In addition, maternal education was significantly negatively correlated with CMU at T2, and child sex was related to FA at T1 such that girls tended to have higher FA than boys.

### ARCL Model: Longitudinal Links Between CMU and FA

We first estimated a model in which autoregressive paths were specified within measurements of CMU and FA and cross-lagged paths were specified between measures of CMU and FA across the three time points. In addition, concurrent associations between variables within time points were estimated, and all focal variables in the model were regressed on the selected covariates. However, model fit was unsatisfactory, $\chi^2(4) = 21.99$, $p = 0.01$, CFI = 0.96, RMSEA = 0.07, SRMR = 0.03. Analysis of modification indices suggested that the addition of a path between CMU at T1 and CMU at T3 would improve model fit. Thus, this path was added to the final model (**Figure 1**). Path coefficients remained similar to the previous model, and model fit was improved: $\chi^2(3) = 9.28$, $p = 0.41$, CFI = 0.99, RMSEA = 0.01, SRMR = 0.02.

All autoregressive paths were significant, indicating stability in CMU and FA over time. In addition, CMU at T1 negatively predicted FA at T2 ($\beta = -0.22$, $p = 0.001$, [95% CI, −0.35 to −0.08]), indicating that higher exposure to CMU was longitudinally related to lower FA. Moreover, there was a significant negative indirect path between CMU at T1 and FA at T3 via FA at T2 ($\beta = -0.12$, $p = 0.003$, [95% CI, −0.20 to −0.04]). Notably, the path between FA at T2 and CMU at T3 showed a non-significant trend ($\beta = -0.13$, $p = 0.079$, [95% CI, −0.28 to 0.01]).

### Testing the Predictive Efficacy of the CMU Measure

We first examined whether the singular factors that composed the CMU score were predictive of FA. To that aim, we estimated an ARCL model in which autoregressive and crossed-lagged paths were specified within and between measurements of child screen time, background television, use of media to regulate distress, maternal mobile device use, and FA across the three time points. All focal variables in the model were also regressed on the selected covariates. None of the singular variables significantly predicted FA at T2 and T3 (see **Table 3**).

We next analyzed the efficacy of the CMU score at T1 in predicting FA at T2 compared to each of the singular factors that composed the CMU. We estimated four models, each including the original ARCL model with the addition of one of the individual factors (i.e., child screen time, background television, use of media to regulate distress, and maternal mobile device use) at all three time points. In all four models, while T1 CMU was a significant predictor of T2 FA, the singular factors were not (see **Supplementary Figures 1–4**).

## DISCUSSION

The goal of the current study was to develop a cumulative media use index that includes multiple aspects of young

**TABLE 2 |** Unweighted means, standard deviations, and correlations among all study variables.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. CMU T1 | – | | | | | | | | | | | | | | | | | | | | | |
| 2. CMU T2 | 0.71*** | – | | | | | | | | | | | | | | | | | | | | |
| 3. CMU T3 | 0.61*** | 0.63*** | – | | | | | | | | | | | | | | | | | | | |
| 4. FA T1 | −0.13 | −0.13 | −0.20* | – | | | | | | | | | | | | | | | | | | |
| 5. FA T2 | −0.30*** | −0.37*** | −0.41*** | 0.50*** | – | | | | | | | | | | | | | | | | | |
| 6. FA T3 | −0.18* | −0.34*** | −0.35*** | 0.33*** | 0.59*** | – | | | | | | | | | | | | | | | | |
| 7. ST T1 | 0.70*** | 0.53*** | 0.49*** | −0.00 | −0.17* | −0.10 | – | | | | | | | | | | | | | | | |
| 8. ST T2 | 0.36*** | 0.61*** | 0.34*** | 0.03 | −0.15 | −0.19* | 0.49*** | – | | | | | | | | | | | | | | |
| 9. ST T3 | 0.38*** | 0.46*** | 0.68*** | −0.10 | −0.23* | −0.20* | 0.49*** | 0.62*** | – | | | | | | | | | | | | | |
| 10. BTV T1 | 0.48*** | 0.63*** | 0.46*** | −0.02 | −0.19* | −0.13 | 0.34*** | 0.29** | 0.27** | – | | | | | | | | | | | | |
| 11. BTV T2 | 0.63*** | 0.55*** | 0.48*** | −0.07 | −0.22** | −0.20* | 0.36*** | 0.34*** | 0.38*** | 0.64*** | – | | | | | | | | | | | |
| 12. BTV T3 | 0.41*** | 0.49*** | 0.62*** | −0.03 | −0.26** | −0.11 | 0.41*** | 0.31** | 0.37*** | 0.73*** | 0.64*** | – | | | | | | | | | | |
| 13. MREG T1 | 0.62*** | 0.42*** | 0.47*** | −0.10 | −0.25** | −0.11 | 0.41*** | 0.20* | 0.36*** | 0.15 | 0.24** | 0.13 | – | | | | | | | | | |
| 14. MREG T2 | 0.36*** | 0.52*** | 0.44*** | −0.20* | −0.25** | −0.25** | 0.34*** | 0.25** | 0.43*** | 0.19* | 0.23** | 0.19* | 0.61*** | – | | | | | | | | |
| 15. MREG T3 | 0.40*** | 0.38*** | 0.58*** | −0.21* | −0.35*** | −0.39*** | 0.39*** | 0.19* | 0.40*** | 0.15 | 0.25** | 0.18 | 0.58*** | 0.63*** | – | | | | | | | |
| 16. PMU T1 | 0.63*** | 0.37*** | 0.18* | −0.15* | −0.16* | −0.06 | 0.11 | −0.02 | −0.11 | 0.20* | 0.14* | 0.01 | 0.10 | −0.07 | −0.06 | – | | | | | | |
| 17. PMU T2 | 0.44*** | 0.58*** | 0.28** | −0.11 | −0.28* | −0.22* | 0.16 | 0.01 | −0.06 | 0.10 | 0.13 | −0.00 | 0.12 | −0.02 | 0.03 | 0.60*** | – | | | | | |
| 18. PMU T3 | 0.30*** | 0.23* | 0.54*** | −0.12 | −0.16 | −0.15 | −0.00 | −0.12 | 0.04 | 0.02 | −0.02 | 0.04 | 0.12 | −0.05 | −0.02 | 0.48*** | 0.56*** | – | | | | |
| 19. MEDU | −0.05 | −0.17* | −0.15 | −0.08 | 0.05 | 0.11 | −0.12 | −0.08 | −0.22* | −0.26** | −0.21** | −0.36*** | 0.05 | −0.20* | −0.07 | 0.06* | 0.07 | 0.18* | – | | | |
| 20. Child sex | −0.02 | 0.00 | −0.00 | 0.18* | 0.05 | 0.02 | −0.04 | 0.00 | −0.01 | 0.04 | 0.09 | 0.06 | 0.05 | 0.08 | 0.08 | −0.13 | −0.09 | −0.11 | −0.04 | – | | |
| 21. SUPP | −0.15* | 0.01 | −0.01 | 0.08 | −0.03 | −0.09 | −0.20** | −0.12 | −0.19* | 0.05 | −0.12 | −0.03 | −0.02 | 0.06 | 0.02 | −0.06 | 0.02 | 0.12 | 0.06 | 0.12 | – | |
| 22. UNSUPP | 0.25*** | 0.21* | 0.25** | −0.04 | −0.15 | −0.13 | 0.31*** | 0.19* | 0.22* | 0.11 | 0.18* | 0.15 | 0.26*** | 0.22** | 0.27** | −0.04 | 0.00 | 0.00 | −0.10 | 0.06 | −0.06 | – |
| Mean | 0.40 | 0.41 | 0.41 | 4.25 | 4.42 | 4.73 | 132.40 | 131.22 | 150.33 | 2.41 | 2.45 | 2.49 | 2.62 | 2.73 | 2.97 | 1.28 | 1.18 | 1.12 | NA | NA | 5.16 | 3.19 |
| *SD* | 0.15 | 0.14 | 0.13 | 0.96 | 0.87 | 0.83 | 100.64 | 80.05 | 83.35 | 1.08 | 1.05 | 1.09 | 1.32 | 1.35 | 1.44 | 0.91 | 0.94 | 0.84 | NA | NA | 0.85 | 1.17 |

*T1, age 18 months; T2, age 22 months; T3, age 26 months; CMU, cumulative media use; FA, focused attention; ST, screen time; BTV, background television; MREG, use of media to regulate child distress; PMU, maternal mobile device use; MEDU, maternal education; SUPP, supportive parenting; UNSUPP, unsupportive parenting; *p < 0.05, **p < 0.01, ***p < 0.001.*

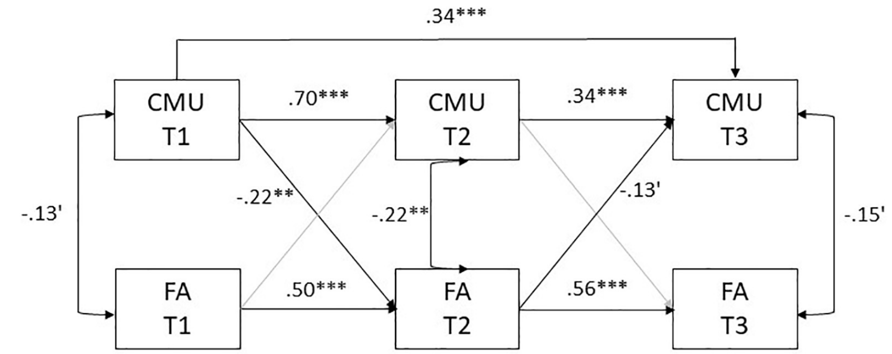


**FIGURE 1 |** An ARCL model estimating autoregressive and cross-lagged paths between repeated measures of CMU and FA between T1 to T3. Notes: For ease of presentation only significant paths are included in the figure; The following covariates were included in the model, but are not depicted in this figure: maternal education, child sex, supportive and unsupportive parenting behaviors; CVTU, cumulative media use; FA, focused attention; $'p < 0.1$, $^{**}p < 0.01$, $^{***}p < 0.001$.

children's direct and indirect media use (CMU) and examine its predictive associations with children's later focused attention abilities. Consistent with our hypothesis, higher levels of CMU predicted lower consecutive attention abilities during toddlerhood. Moreover, the CMU score appeared to be a better predictor of attention abilities than any of the singular measures of media use. Our findings demonstrate the possible implications that extensive media use may have for children's focused attention abilities and indicate the importance of including multiple contextual factors of media use in studies of media and child development.

Previous research on the link between media use and attention in early childhood is limited in three main ways. First, although there is some evidence that excessive screen viewing time in early childhood predicts subsequent attention problems (Christakis et al., 2004; Cheng et al., 2010), these studies assessed attention abilities only as an outcome, precluding the ability to consider the bidirectional links between media use and attention. While it is possible that excessive exposure to screen media interferes with the development of attention skills, it is also plausible that children with limited attention spans are more drawn to screen media, and as a result parents often expose them to screens to occupy or soothe them (Kostyrka-Allchorne et al., 2017). Second, previous research did not consider the broader family context of children's exposure to media, such as how the media are used by all member of the household, including children's direct and indirect exposures (Barr et al., 2010). Addressing these contextual factors is particularly important in early childhood because during this period children's self-regulatory and attention abilities are limited, and the home environment plays a vital role in fostering these emerging abilities (Kopp, 1989). Finally, the majority of previous research focused on attention abilities (e.g., EF) or attention problems in the preschool period, and therefore little is known about the potential impact of screen media in early childhood.

To our knowledge, this study is the first to address these aforementioned limitations by applying a repeated-measure longitudinal design and examining media use from an ecological perspective that includes, in addition to direct media exposure, indirect exposure to media and media use practices. Drawing from the cumulative risk literature (Evans et al., 2013), we created a cumulative media use index that included four aspects of media use. Results show that higher CMU at age 18 months directly predicted lower FA at age 22 months. In addition, CMU at 18 months indirectly predicted lower FA at age 26 months via FA at 22 months. However, CMU at 22 months was not a significant predictor of FA at 26 months. These findings suggest that elevated media use in early toddlerhood (age 18 months) can initiate a cascade of attention difficulties that persist across toddlerhood.

Why would exposure to media at 18 months of age be critical for the development of FA? The attentional network framework (Posner et al., 2014) suggests that the orienting network exerts much of the control over other attention networks during infancy and toddlerhood, while the executive attention network becomes increasingly dominant during the second year of life. The time period between 18 and 24 months represents a developmental period in which both of these attention systems are still developing rapidly. After age 24 months, the orienting system reaches a plateau and individual differences in orienting abilities stabilize (Posner et al., 2014). Thus, 18 months may be a time period in which children are particularly susceptible to environmental experiences, such as excessive media use, that support or hinder the development of both the orienting and the executive attention networks.

Contrary to previous research on media use and child outcomes (Magee et al., 2014; Kostyrka-Allchorne et al., 2017; Cliff et al., 2018), we only found unidirectional paths between CMU and FA, with the reverse associations being non-significant. Although there was a negative link between FA at 22 and CMU at 26 months, this path did not reach significance ($p = 0.08$) and therefore cannot be interpreted. These discrepant findings may be related to the different age groups between samples. Two studies that found significant links between children's self-regulation and sleep and consecutive media use used samples of 4–6-years-old children (Magee et al., 2014; Cliff et al., 2018), who are able to use media independently, whereas in our younger sample (ages 18–26 months) media use may be mainly determined by parents and less driven by child

**TABLE 3 |** Standardized path coefficients for the ARCL model with the singular CMU factors.

| | Estimate | SE | *p*-value |
|---|---|---|---|
| ST T1 → FA T2 | −0.00 | 0.09 | 0.974 |
| MREG T1 → FA T2 | −0.12 | 0.07 | 0.111 |
| BTV T1 → FA T2 | −01 | 0.08 | 0.106 |
| PMU T1 → FA T2 | 0.07 | 0.06 | 0.273 |
| SUPP → FA T2 | −0.05 | 0.07 | 0.455 |
| UNSUPP → FA T2 | −0.07 | 0.07 | 0.315 |
| FA T1 → FA T2 | 0.48 | 0.06 | 0.000 |
| Maternal education → FA T2 | 0.08 | 0.07 | 0.220 |
| Child sex → FA T2 | 0.04 | 0.07 | 0.542 |
| ST T1 → ST T2 | 0.43 | 0.03 | 0.000 |
| MREG T1 → ST T2 | −0.03 | 0.03 | 0.702 |
| BTV T1 → ST T2 | 0.17 | 0.04 | 0.037 |
| PMU T1 → ST T2 | −0.07 | 0.04 | 0.295 |
| SUPP → ST T2 | −0.03 | 0.03 | 0.649 |
| UNSUPP → ST T2 | 0.07 | 0.03 | 0.322 |
| FA T1 → ST T2 | −0.01 | 0.03 | 0.850 |
| Maternal education → ST T2 | 0.04 | 0.03 | 0.898 |
| Child sex → ST T2 | 0.04 | 0.07 | 0.542 |
| ST T1 → MREG T2 | 0.08 | 0.08 | 0.280 |
| MREG T1 → MREG T2 | 0.56 | 0.06 | 0.000 |
| BTV T1 → MREG T2 | 0.01 | 0.07 | 0.802 |
| PMU T1 → MREG T2 | −0.11 | 0.06 | 0.061 |
| SUPP → MREG T2 | 0.08 | 0.06 | 0.205 |
| UNSUPP → MREG T2 | 0.02 | 0.06 | 0.690 |
| FA T1 → MREG T2 | −0.11 | 0.06 | 0.008 |
| Maternal education → MREG T2 | −0.23 | 0.06 | 0.000 |
| Child sex → MREG T2 | 0.08 | 0.06 | 0.192 |
| ST T1 → BTV T2 | 0.04 | 0.08 | 0.617 |
| MREG T1 →BTV T2 | 0.00 | 0.07 | 0.967 |
| BTV T1 → BTV T2 | 0.59 | 0.06 | 0.000 |
| PMU T1 → BTV T2 | 0.09 | 0.06 | 0.132 |
| SUPP → BTV T2 | 0.17 | 0.06 | 0.007 |
| UNSUPP → BTV T2 | −0.01 | 0.06 | 0.852 |
| FA T1 → BTV T2 | 0.02 | 0.06 | 0.726 |
| Maternal education → BTV T2 | −0.14 | 0.06 | 0.036 |
| Child sex → BTV T2 | 0.01 | 0.06 | 0.856 |
| ST T1 → PMU T2 | 0.16 | 0.08 | 0.059 |
| MREG T1 → PMU T2 | 0.00 | 0.07 | 0.992 |
| BTV T1 → PMU T2 | −0.02 | 0.07 | 0.717 |
| PMU T1 → PMU T2 | 0.57 | 0.05 | 0.000 |
| SUPP → PMU T2 | 0.05 | 0.07 | 0.413 |
| UNSUPP → PMU T2 | −0.02 | 0.07 | 0.765 |
| FA T1 → PMU T2 | −0.05 | 0.07 | 0.437 |
| Maternal education → BTV T2 | 0.05 | 0.07 | 0.462 |
| Child sex → BTV T2 | −0.02 | 0.06 | 0.774 |
| ST T2 → FA T3 | −0.08 | 0.08 | 0.333 |
| MREG T2 → FA T3 | −0.03 | 0.08 | 0.703 |
| BTV T2 → FA T3 | 0.04 | 0.08 | 0.591 |
| PMU T2 → FA T3 | −0.03 | 0.08 | 0.663 |
| FA T2 → FA T3 | 0.51 | 0.08 | 0.000 |
| SUPP → FA T3 | −0.06 | 0.07 | 0.389 |
| UNSUPP → FA T3 | −0.03 | 0.07 | 0.610 |

*(Continued)*

**TABLE 3 |** Continued

| | Estimate | SE | *p*-value |
|---|---|---|---|
| FA T1 → FA T3 | 0.09 | 0.09 | 0.297 |
| Maternal education → FA T3 | 0.09 | 0.08 | 0.238 |
| Child sex → FA T3 | 0.00 | 0.07 | 0.933 |
| ST T2 → ST T3 | 0.52 | 0.07 | 0.000 |
| MREG T2 → ST T3 | 0.24 | 0.07 | 0.002 |
| BTV T2 → ST T3 | 0.00 | 0.07 | 0.906 |
| PMU T2 → ST T3 | −0.04 | 0.07 | 0.564 |
| FA T2 → ST T3 | −0.05 | 0.08 | 0.521 |
| SUPP → ST T3 | −0.12 | 0.06 | 0.080 |
| UNSUPP → ST T3 | 0.03 | 0.06 | 0.628 |
| FA T1 → ST T3 | −0.04 | 0.08 | 0.563 |
| Maternal education → ST T3 | −0.10 | 0.07 | 0.151 |
| Child sex → ST T3 | −0.06 | 0.06 | 0.364 |
| ST T2 → MREG T3 | 0.07 | 0.07 | 0.831 |
| MREG T2 → MREG T3 | 0.38 | 0.09 | 0.000 |
| BTV T2 → MREG T3 | −0.07 | 0.07 | 0.306 |
| PMU T2 → MREG T3 | −0.06 | 0.07 | 0.359 |
| FA T2 → MREG T3 | −0.17 | 0.08 | 0.037 |
| SUPP → MREG T3 | 0.00 | 0.07 | 0.987 |
| UNSUPP → MREG T3 | 0.07 | 0.07 | 0.280 |
| FA T1 → MREG T3 | −0.03 | 0.08 | 0.656 |
| Maternal education → MREG T3 | −0.04 | 0.07 | 0.540 |
| Child sex → MREG T3 | 0.02 | 0.06 | 0.739 |
| MREG T1 → MREG T3 | 0.29 | 0.08 | 0.001 |
| ST T2 → BTV T3 | 0.06 | 0.07 | 0.355 |
| MREG T2 → BTV T3 | −0.08 | 0.07 | 0.204 |
| BTV T2 → BTV T3 | 0.50 | 0.07 | 0.000 |
| PMU T2 → BTV T3 | −0.04 | 0.06 | 0.540 |
| FA T2 → BTV T3 | −0.06 | 0.07 | 0.428 |
| SUPP → BTV T3 | 0.00 | 0.06 | 0.951 |
| UNSUPP → BTV T3 | 0.05 | 0.06 | 0.370 |
| FA T1 → BTV T3 | −0.03 | 0.07 | 0.661 |
| Maternal education → BTV T3 | −0.12 | 0.06 | 0.072 |
| Child sex → BTV T3 | 0.02 | 0.05 | 0.678 |
| BTV T1 → BTV T3 | 0.27 | 0.07 | 0.000 |
| ST T2 → PMU T3 | −0.10 | 0.09 | 0.244 |
| MREG T2 → PMU T3 | −0.02 | 0.09 | 0.775 |
| BTV T2 → PMU T3 | 0.09 | 0.08 | 0.787 |
| PMU T2 → PMU T3 | 0.54 | 0.07 | 0.000 |
| FA T2 → PMU T3 | −0.01 | 0.09 | 0.910 |
| SUPP → PMU T3 | 0.03 | 0.08 | 0.666 |
| UNSUPP → PMU T3 | 0.04 | 0.07 | 0.602 |
| FA T1 → PMU T3 | 0.01 | 0.09 | 0.860 |
| Maternal education → PMU T3 | 0.14 | 0.08 | 0.081 |
| Child sex → PMU T3 | −0.07 | 0.07 | 0.341 |

*Model fit: $\chi^2(18) = 26.72$, $p = 0.08$, CFI = 0.98, RMSEA = 0.04, SRMR = 0.02; T1, age 18 months; T2, age 22 months; T3, age 26 months; CMU, cumulative media use; FA, focused attention; ST, screen time; BTV, background television; MREG, use of media to regulate child distress; PMU, maternal mobile device use; MEDU, maternal education; SUPP, supportive parenting; UNSUPP, unsupportive parenting.*

characteristics. It is also possible that the current study did not have sufficient statistical power to detect small effect sizes due to our modest sample size.

To our knowledge, this study is the first to apply the cumulative risk approach to media exposure. Thus, an additional goal of this study was to examine the predictive utility of the CMU index compared to the singular aspects of media use. Our results indicate that CMU at age 18 months was a better predictor of FA at 22 than any of the singular measures. This finding coincides with the cumulative risk literature that has consistently demonstrated that children exposed to cumulative risk factors in early life show more adverse outcomes than those exposed to singular risk factors (Evans et al., 2013). The CMU index may confer increased risk for attention problems because it exerts continuous interference to the attentional system spanning the child's day, rather than segmented periods of interference, such as daily screen viewing time. Children with high CMU are at risk for experiencing distractions in toy play and social interactions caused by background television and parental mobile phone use, as well as increased arousal and difficulties in regulating attention due to parental use of media to regulate their distress. Moreover, elevated screen viewing time often includes prolonged exposure to fast-paced content that is hypothesized to prompt a scanning–shifting attentional style that may hinder the ability to focus attention in natural settings such as toy play (Nikkelen et al., 2014). Cumulative exposure to these distracting and arousing experiences throughout the day also denies children opportunities to participate in environmental experiences that are crucial for fostering their emerging FA skills, such as contingent social interactions, mutual joint attention during play, and parent–child reading interactions (Zimmerman and Christakis, 2007). Moreover, a recent study suggests that increased use of screen-based media (as measured by access to screens, frequency of use, content, and co-viewing) may alter children's cognitive abilities through neural pathways, such as decreased microstructural integrity of the brain white matter tracts that support language, executive functions, and language abilities (Hutton et al., 2020a).

The CMU index may tap into general parenting practices, and there is therefore reason to suspect that the link between CMU and FA is actually driven by the link between parenting practices and CMU. Children's screen-based media use has been previously correlated with less stimulating home cognitive environments, and higher use of authoritarian and permissive parenting styles (Howe et al., 2017; Hutton et al., 2020b). Indeed, consistent with previous literature, in the current study unsupportive parenting practices were positively related with the CMU index, implying that children of mothers who frequently use parenting practices such as punishment and minimizing children's distress may also be exposed to multiple aspects of media use in the household. However, the CMU index was a significant predictor of children's FA even when controlling for both supportive and unsupportive parenting practices. These findings highlight the unique implications of media use for children's attention abilities, beyond the potential contribution of general parenting practices.

## LIMITATIONS

The findings of the current study should be considered in light of several limitations. First, our assessment of media exposure did not include the type of content (e.g., fast/slow-paced, entertainment/educational) that children are exposed to. There is evidence that the links between children's overall screen time and attention problems are only evident when watching entertainment or adult-directed content, but not when watching educational content (Zimmerman and Christakis, 2007; Barr et al., 2010; Kostyrka-Allchorne et al., 2017). In fact, viewing educational media content was linked to increased EFs in children at high demographic risk (Linebarger et al., 2014). Second, our indicators of media use and attention are based exclusively on maternal reports, which may result in report bias or inaccurate estimates. Applying a multi-method assessment of media use that also includes daily time-use diaries and passive sensing applications that detect media use on mobile devices can reduce parents' report bias and yield more accurate estimates (Barr, 2019). Similarly, using observational tasks of children's FA abilities in naturalistic setting such as toy play (Lansink et al., 2000) could further increase measurement validity. Finally, the correlational nature of this study precludes the inference of causal relations between media use and attention skills. Because our focus was on cumulative exposure to media and the examination of associations over time, it is not possible to examine our research questions in a controlled experimental design. However, an important next step could be to examine the immediate impact of exposure to increasing levels of our four media use indictors on children's attention abilities in an experimental design (e.g., Lillard et al., 2015).

## CONCLUSION

Our findings demonstrate that elevated exposure to media predicts lower subsequent focused attention abilities during toddlerhood. In this study, we addressed two key limitations of previous research by applying a repeated-measure longitudinal design that considers concurrent and cross-lagged associations between media use and attention, and by broadening the measurement of media use from the *amount* of direct exposure to include contextual factors reflecting *how* the media are used in the household. Our work adds to the extant literature by documenting that a broad and cumulative approach to assess media use is effective for understanding the potential implications of media use on children's cognitive development.

The findings of this study can inform family-based prevention initiatives designed to promote balanced household media use. Increasing parental awareness of the possible implications of indirect media use such as background television, parental mobile phone use, and the use of media to regulate distress, along with encouraging "media-free" time slots and the use of alternative regulatory strategies, can help families use media in a thoughtful and appropriate manner.

## DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because the ethics approval does not permit sharing the dataset. Requests to access the datasets should be directed to NG-S, gueron@post.bgu.ac.il.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Human Subjects Research Committee, Ben-Gurion University of the Negev. The patients/participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

NG-S designed and conceptualized the study, conceived the ideas for the manuscript, and performed data analysis and interpretation. AG-H designed and conceptualized the study, performed data collection and analysis, and provided revisions to scientific content of the manuscript. Both authors contributed to the article and approved the submitted version.

## FUNDING

Publication fees will be funded by the Ben-Gurion University of the Negev. The research was not funded by any internal or external funding agencies.

## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.569222/full#supplementary-material

## REFERENCES

Anderson, D. R., and Evans, M. K. (2001). Peril and potential of media for infants and toddlers. *Zero Three* 22, 10–16.

Anderson, D. R., and Pempek, T. A. (2005). Television and very young children. *Am. Behav. Sci.* 48, 505–522. doi: 10.1177/0002764204271506

Anderson, D. R., and Subrahmanyam, K. (2017). Digital screen media and cognitive development. *Pediatrics* 140, S57–S61. doi: 10.1542/peds.2016-1758C

Barr, R. (2019). growing up in the digital age: early learning and family media ecology. *Curr. Dir. Psychol. Sci.* 28, 341–346. doi: 10.1177/0963721419838245

Barr, R., Lauricella, A., Zack, E., and Calvert, S. L. (2010). Infant and early childhood exposure to adult-directed and child-directed television programming: relations with cognitive skills at age four. *Merrill Palmer Q.* 56, 21–48. doi: 10.1353/mpq.0.0038

Blankson, A. N., O'Brien, M., Leerkes, E. M., Calkins, S. D., and Marcovitch, S. (2015). Do hours spent viewing television at ages 3 and 4 predict vocabulary and executive functioning at age 5? *Merrill Palmer Q.* 61, 264–289. doi: 10.13110/merrpalmquar1982.61.2.0264

Cheng, S., Maeda, T., Yoichi, S., Yamagata, Z., and Tomiwa, K. (2010). Early television exposure and children's behavioral and social outcomes at age 30 months. *J. Epidemiol.* 20(Suppl.2), 1–2. doi: 10.2188/jea.JE20090179

Christakis, D. A., Zimmerman, F. J., DiGiuseppe, D. L., and McCarty, C. A. (2004). Early television exposure and subsequent attentional problems in children. *Pediatrics* 113, 708–713. doi: 10.1542/peds.113.4.708

Cliff, D. P., Howard, S. J., Radesky, J. S., McNeill, J., and Vella, S. A. (2018). Early childhood media exposure and self-regulation: bidirectional longitudinal associations. *Acad. Pediatr.* 18, 813–819. doi: 10.1016/j.acap.2018.04.012

Colombo, J., and Cheatham, C. (2007). "The emergence of endogenous attention in infancy and early childhoodNo Title," in *Advances in Child Development and Behavior*, ed. R. Kail, (New York, NY: Elsevier), 283–322. doi: 10.1016/s0065-2407(06)80010-8

Colombo, J., and Salley, B. (2015). "Biopsychosocial perspectives on the development of attention in infancy," in *Handbook of Infant Biopsychosocial Development*, ed. S. D. Calkins, (New York, NY: Guilford Press), 71–96.

Comas, M., Valentino, K., and Borkowski, J. G. (2014). Maternal depressive symptoms and child temperament: longitudinal associations with executive functioning. *J. Appl. Dev. Psychol.* 35, 156–167. doi: 10.1016/j.appdev.2014.03.005

Council on Communications, and Media, (2016). Media and young minds. *Pediatrics* 138:e20162591. doi: 10.1542/peds.2016-2591

Courage, M. L. (2017). "Screen media and the youngest viewers: implications for attention and learning," in *Cognitive Development in Digital Contexts*, eds F. C. Blumberg, and P. J. Brooks, (Amsterdam: Elsevier Inc), doi: 10.1016/B978-0-12-809481-5.00001-8

Enders, C. K. (2013). Dealing with missing data in developmental research. *Child Dev. Perspect.* 7, 27–31. doi: 10.1111/cdep.12008

Ettekal, I., Eiden, R. D., Nickerson, A. B., and Schuetze, P. (2019). Comparing alternative methods of measuring cumulative risk based on multiple risk indicators: are there differential effects on children's externalizing problems? *PLoS One* 14:e0219134. doi: 10.1371/journal.pone.0219134

Evans, G. W., Li, D., and Whipple, S. S. (2013). Cumulative risk and child development. *Psychol. Bull.* 139, 1342–1396. doi: 10.1037/a0031808

Foster, E. M., and Watkins, S. (2010). The value of reanalysis: TV viewing and attention problems. *Child Dev.* 81, 368–375. doi: 10.1111/j.1467-8624.2009.01400.x

Gach, E. J., Ip, K. I., Sameroff, A. J., and Olson, S. L. (2018). Early cumulative risk predicts externalizing behavior at age 10: the mediating role of adverse parenting. *J. Fam. Psychol.* 32, 92–102. doi: 10.1037/fam0000360

Garon, N., Bryson, S. E., and Smith, I. M. (2008). Executive function in preschoolers: a review using an integrative framework. *Psychol. Bull.* 134, 31–60. doi: 10.1037/0033-2909.134.1.31

Gordon-Hacker, A., and Gueron-Sela, N. (2020). Maternal use of media to regulate child distress: a double-edged sword? Longitudinal links to toddlers' negative emotionality. *Cyberpsychol. Behav. Soc. Network.* 23, 400–405. doi: 10.1089/cyber.2019.0487

Groot, A. S., de Sonneville, L. M. J., Stins, J. F., and Boomsma, D. I. (2004). Familial influences on sustained attention and inhibition in preschoolers. *J. Child Psychol. Psychiatry Allied Disciplines* 45, 306–314. doi: 10.1111/j.1469-7610.2004.00222.x

Gueron-Sela, N., Camerota, M., Willoughby, M. T., Vernon-Feagans, L., and Cox, M. J. (2018). Maternal depressive symptoms, mother-child interactions, and children's executive function. *Dev. Psychol.* 54, 71–82. doi: 10.1037/dev0000389

Hiniker, A., Sobel, K., Suh, H., Sung, Y. C., Lee, C. P., and Kientz, J. A. (2015). "Texting while parenting: how adults use mobile phones while caring for children at the playground," in *Conference on Human Factors in Computing Systems - Proceedings*, Seoul, 727–736. doi: 10.1145/2702123.2702199

Howe, A. S., Heath, A. L. M., Lawrence, J., Galland, B. C., Gray, A. R., Taylor, B. J., et al. (2017). Parenting style and family type, but not child temperament, are associated with television viewing time in children at two years of age. *PLoS One* 12:e0188558. doi: 10.1371/journal.pone.0188558

Hutton, J. S., Dudley, J., Horowitz-Kraus, T., Dewitt, T., and Holland, S. K. (2020a). Associations between screen-based media use and brain white matter integrity in preschool-aged children. *JAMA Pediatr.* 174, 1–10. doi: 10.1001/jamapediatrics.2019.3869

Hutton, J. S., Huang, G., Sahay, R. D., DeWitt, T., and Ittenbach, R. F. (2020b). A novel, composite measure of screen-based media use in young children (ScreenQ) and associations with parenting practices and cognitive abilities. *Pediatr. Res.* 87, 1211–1218. doi: 10.1038/s41390-020-0765-1

Johansson, M., Marciszko, C., Gredebäck, G., Nyström, P., and Bohlin, G. (2015). Sustained attention in infancy as a longitudinal predictor of self-regulatory functions. *Infant Behav. Dev.* 41, 1–11. doi: 10.1016/j.infbeh.2015.07.001

Kabali, H. K., Irigoyen, M. M., Nunez-Davis, R., Budacki, J. G., Mohanty, S. H., Leister, K. P., et al. (2015). Exposure and use of mobile media devices by young children. *Pediatrics* 136, 1044–1050. doi: 10.1542/peds.2015-2151

Kannass, K. N., Oakes, L. M., and Shaddy, D. J. (2006). A longitudinal investigation of the development of attention and distractibility. *J. Cogn. Dev.* 7, 381–409. doi: 10.1207/s15327647jcd0703_8

Kildare, C. A., and Middlemiss, W. (2017). Impact of parents mobile device use on parent-child interaction: a literature review. *Comput. Hum. Behav.* 75, 579–593. doi: 10.1016/j.chb.2017.06.003

Kirkorian, H. L., Pempek, T. A., Murphy, L. A., Schmidt, M. E., and Anderson, D. R. (2009). The impact of background television on parent-child interaction. *Child Dev.* 80, 1350–1359. doi: 10.1111/j.1467-8624.2009.01337.x

Kopp, C. B. (1989). Regulation of distress and negative emotions: a developmental view. *Dev. Psychol.* 25, 343–354. doi: 10.1037/0012-1649.25.3.343

Kostyrka-Allchorne, K., Cooper, N. R., and Simpson, A. (2017). The relationship between television exposure and children's cognition and behaviour: a systematic review. *Dev. Rev.* 44, 19–58. doi: 10.1016/j.dr.2016.12.002

Landhuis, C. E., Poulton, R., Welch, D., and Hancox, R. J. (2007). Does childhood television viewing lead to attention problems in adolescence? Results from a prospective longitudinal study. *Pediatrics* 120, 532–537. doi: 10.1542/peds.2007-0978

Lansink, J. M., Mintz, S., and Richards, J. E. (2000). The distribution of infant attention during object examination. *Dev. Sci.* 3, 163–170. doi: 10.1111/1467-7687.00109

Lawson, K. R., and Ruff, H. A. (2004). Early focused attention predicts outcome for children born prematurely. *J. Dev. Behav. Pediat.* 25, 399–406. doi: 10.1097/00004703-200412000-00003

Lillard, A. S., Drell, M. B., Richey, E. M., Boguszewski, K., and Smith, E. D. (2015). Further examination of the immediate impact of television on children's executive function. *Dev. Psychol.* 51, 792–805. doi: 10.1037/a0039097

Linebarger, D. L., Barr, R., Lapierre, M. A., and Piotrowski, J. T. (2014). Associations between parenting, media use, cumulative risk, and children's executive functioning. *J. Dev. Behav. Pediatr.* 35, 367–377. doi: 10.1097/dbp.0000000000000069

Magee, C. A., Lee, J. K., and Vella, S. A. (2014). Bidirectional relationships between sleep duration and screen time in early childhood. *JAMA Pediatr.* 168, 465–470. doi: 10.1001/jamapediatrics.2013.4183

Miller, M., Iosif, A. M., Young, G. S., Hill, M. M., and Ozonoff, S. (2018). Early detection of ADHD: insights from infant siblings of children with autism. *J. Clin. Child Adolesc. Psychol.* 47, 737–744. doi: 10.1080/15374416.2016.1220314

Moran, L., Lengua, L. J., Zalewski, M., Ruberry, E., Klein, M., Thompson, S., and Kiff, C. (2017). Variable- and person-centered approaches to examining temperament vulnerability and resilience to the effects of contextual risk. *J. Res. Personal.* 67, 61–74. doi: 10.1016/j.jrp.2016.03.003

Myruski, S., Gulyayeva, O., Birk, S., Pérez-Edgar, K., Buss, K. A., and Dennis-Tiwary, T. A. (2018). Digital disruption? Maternal mobile device use is related to infant social-emotional functioning. *Dev. Sci.* 21, 1–9. doi: 10.1111/desc.12610

Nathanson, A. I., Aladé, F., Sharp, M. L., Rasmussen, E. E., and Christy, K. (2014). The relation between television exposure and executive function among preschoolers. *Dev. Psychol.* 50, 1497–1506. doi: 10.1037/a0035714

Nikkelen, S. W. C., Valkenburg, P. M., Huizinga, M., and Bushman, B. J. (2014). Media use and ADHD-related behaviors in children and adolescents: a meta-analysis. *Dev. Psychol.* 50, 2228–2241. doi: 10.1037/a0037318

Palan, S., and Schitter, C. (2018). Prolific.ac—A subject pool for online experiments. *J. Behav. Exp. Finance* 17, 22–27. doi: 10.1016/j.jbef.2017.12.004

Posner, M. I., Rothbart, M. K., Sheese, B. E., and Voelker, P. (2014). Developing attention: behavioral and brain mechanisms. *Adv. Neurosci.* 2014:405094. doi: 10.1155/2014/405094

Putnam, S. P., Gartstein, M. A., and Rothbart, M. K. (2006). Measurement of fine-grained aspects of toddler temperament: the early childhood behavior questionnaire. *Infant Behav. Dev.* 29, 386–401. doi: 10.1016/j.infbeh.2006.01.004

Radesky, J., Miller, A. L., Rosenblum, K. L., Appugliese, D., Kaciroti, N., and Lumeng, J. C. (2015). Maternal mobile device use during a structured parent–child interaction task. *Acad. Pediatr.* 15, 238–244. doi: 10.1016/j.acap.2014.10.001

Radesky, J. S., Kistin, C. J., Zuckerman, B., Nitzberg, K., Gross, J., Kaplan-Sanoff, M., et al. (2014a). Patterns of mobile device use by caregivers and children during meals in fast food restaurants. *Pediatrics* 133, e843–e849. doi: 10.1542/peds.2013-3703

Radesky, J. S., Silverstein, M., Zuckerman, B., and Christakis, D. A. (2014b). Infant self-regulation and early childhood media exposure. *Pediatrics* 133, e1172–e1178. doi: 10.1542/peds.2013-2367

Radesky, J. S., Peacock-Chambers, E., Zuckerman, B., and Silverstein, M. (2016). Use of mobile technology to calm upset children: associations with social-emotional development. *JAMA Pediatr.* 170, 397–399. doi: 10.1001/jamapediatrics.2015.4260

Rideout, V. (2017). *The Common Sense Census: Media use by kids Age Zero to Eight.* San Francisco, CA: Common Sense Media.

Ruff, H. A., and Capozzoli, M. C. (2003). Development of attention and distractibility in the first 4 years of life. *Dev. Psychol.* 39, 877–890. doi: 10.1037/0012-1649.39.5.877

Ruff, H. A., and Lawson, K. R. (1990). Development of sustained, focused attention in \bung. *Child. During Free Play* 26, 85–93. doi: 10.1037/0012-1649.26.1.85

Ruff, H. A., and Rothbart, M. K. (1996). *Attention in Early Development: Themes and Variations.* New York, NY: Oxford University Press.

Sameroff, A. (2010). A unified theory of development: a dialectic integration of nature and nurture. *Child Dev.* 81, 6–22. doi: 10.1111/j.1467-8624.2009.01378.x

Schmidt, M. E., Pempek, T. A., Kirkorian, H. L., Lund, A. F., and Anderson, D. R. (2008). The effects of background television on the toy play behavior of very young children. *Child Dev.* 79, 1137–1151. doi: 10.1111/j.1467-8624.2008.01180.x

Setliff, A. E., and Courage, M. L. (2011). Background television and infants' allocation of their attention during toy play. *Infancy* 16, 611–639. doi: 10.1111/j.1532-7078.2011.00070.x

Spinrad, T. L., Eisenberg, N., Gaertner, B., Popp, T., Smith, C. L., Kupfer, A., et al. (2007). Relations of maternal socialization and toddlers' effortful control to children's adjustment and social competence. *Dev. Psychol.* 43, 1170–1186. doi: 10.1037/0012-1649.43.5.1170

Stevens, T., Barnard-Brak, L., and To, Y. (2009). Television viewing and symptoms of inattention and hyperactivity across time: the importance of research questions. *J. Early Intervent.* 31, 215–226. doi: 10.1177/1053815109338562

Tamana, S. K., Ezeugwu, V., Chikuma, J., Lefebvre, D. L., Azad, M. B., Moraes, T. J., et al. (2019). Screen-time is associated with inattention problems in preschoolers: results from the CHILD birth cohort study. *PLoS One* 14:e0213995. doi: 10.1371/journal.pone.0213995

Vijakkhana, N., Wilaisakditipakorn, T., Ruedeekhajorn, K., Pruksananonda, C., and Chonchaiya, W. (2015). Evening media exposure reduces night-time sleep. *Acta Paediat. Int. J. Paediatr.* 104, 306–312. doi: 10.1111/apa.12904

Yu, C., and Smith, L. B. (2016). The social origins of sustained attention in one-year-old human infants. *Curr. Biol.* 26, 1235–1240. doi: 10.1016/j.cub.2016.03.026

Zimmerman, F. J., and Christakis, D. A. (2007). Associations between content types of early media exposure and subsequent attentional problems. *Pediatrics* 120, 986–992. doi: 10.1542/peds.2006-3322


**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

ORIGINAL RESEARCH
published: 22 October 2020
doi: 10.3389/fpsyg.2020.570392

# Screen Time and Executive Function in Toddlerhood: A Longitudinal Study

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Technology is pervasive in homes with young children. Emerging evidence that electronic screen-based media use has adverse effects on executive functions may help explain negative relations between media use and early academic skills. However, longitudinal investigations are needed to test this idea. In a sample of 193 British toddlers tracked from age 2 to 3 years, we test concurrent and predictive relations between screen use and children's executive function. We find no concurrent association between screen use and executive function; however, screen time at age 2 is negatively associated with the development of executive functions in toddlerhood from age 2 to 3, controlling for a range of covariates including verbal ability. Implications for parenting, education, and pediatric recommendations are discussed.

**Keywords: screen time, executive function, inhibition, working memory, toddler, longitudinal**

OPEN ACCESS

***Edited by:***
*Adriana Bus,*
*University of Stavanger, Norway*

***Reviewed by:***
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***Specialty section:***
*This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology*

***Received:*** *07 June 2020*
***Accepted:*** *28 September 2020*
***Published:*** *22 October 2020*

***Citation:***
*McHarg G, Ribner AD, Devine RT and Hughes C (2020) Screen Time and Executive Function in Toddlerhood: A Longitudinal Study. Front. Psychol. 11:570392. doi: 10.3389/fpsyg.2020.570392*

## INTRODUCTION

Parents around the globe have, since the advent of the television, been questioning the effects of screens on children's development – leading to a "moral panic" surrounding children's electronic screen-time (Drotner, 2013). This debate has, in part, been fueled by reports of negative consequences of screen time during childhood and adolescence. For example, screen viewing has been associated with reduced sleep in infancy and toddlerhood (e.g., Cheung et al., 2017; Ribner and McHarg, 2019) and in adolescence (e.g., Hisler et al., 2020; Magee and Blunden, 2020). In addition, increased screen time is associated with increased sedentary behavior and obesity (e.g., Robinson et al., 2017); and television has been negatively correlated with both parental engagement (e.g., Mendelsohn et al., 2008; Christakis et al., 2009; Kirkorian et al., 2009) and children's language and literacy skills (Ribner et al., 2020). Each of these associations is important for parents and clinicians to consider when addressing questions about the potential risks of screen time. Understanding digital media's impacts on cognition is therefore vital to support those who care for children. However, few studies have applied longitudinal designs to explore how screen time might affect toddlers' cognitive development. Addressing this gap, the current study investigates variation in children's executive functions at 36-months of age in relation to ratings of screen use gathered both concurrently and 12-months earlier (i.e., at 24-months).

Executive functions (EF) are a multidimensional set of skills comprised of inhibitory control, working memory, and cognitive flexibility. These skills are implicated in classroom behavior and learning, and in the pursuit of goal-directed cognitions, actions, and behavior more broadly

(Diamond, 2013). EF and its component parts develop from very early childhood through early adulthood, with substantial individual differences in the pace of development (e.g., Diamond, 2013). While the factor structure of EF—particularly in infancy and toddlerhood—is unclear (e.g., Willoughby et al., 2010, 2012; Lerner and Lonigan, 2014; Miller and Marcovitch, 2015; Holmboe et al., 2018; Devine et al., 2019; Fiske and Holmboe, 2019), it is evident that individual differences in very early EF (regardless of how it is operationalized) are associated with children's ability to regulate their behavior (Vernon-Feagans et al., 2016; Hughes et al., 2020), engage in goal-directed behavior (e.g., Hendry et al., 2016), understand others' thoughts and feelings (Hughes et al., 2009; Devine and Hughes, 2014), and successfully transition to school settings (Hughes et al., 2009; Mulder et al., 2017; Willoughby et al., 2017).

Several factors portend individual differences in EF including neurological differences (e.g., Short et al., 2019), early attention (e.g., Blankenship et al., 2019; Devine et al., 2019), and cognitive training (Scionti et al., 2020). Furthermore, several environmental factors including aspects of parenting (e.g., Hughes et al., 2013; Fay-Stammbach et al., 2014; Hughes and Devine, 2019), child care (e.g., Duncan et al., 2019), and stress (Blair, 2010) are associated with the development of young children's EF. While many of these factors might be outside parents' locus of control, screen exposure may be a more controllable environmental factor related to EF development.

Prior research has established that increased screen time is typically associated with lower EF (e.g., Barr et al., 2010; Lillard and Peterson, 2011; Nathanson et al., 2014; Cliff et al., 2018); notably, this association is evident as early as infancy. Specifically, McHarg et al. (2020) used a propensity score matching approach and found that, all things being equal, having regular screen exposure of any amount at 4 months was related to worse inhibitory control, though there was no association of screen exposure with working memory or cognitive flexibility. However, it is important to note that screen exposure in infancy is fundamentally different than later screen exposure. Infants do not begin to process information presented on screens for more than 3–5 s (for summary, see Kirkorian et al., 2017), and young children do not begin to understand even child-directed content until age 2 (Anderson and Subrahmanyam, 2017; Hipp et al., 2017), suggesting that all screen time in infancy might be effectively treated as adult-directed content and/or background media.

Importantly, though, longitudinal associations between screen time and EF appear to extend beyond infancy. One study showed that viewing less television and less overall media exposure at age 2-years were related to higher self-regulation at 4-years (Cliff et al., 2018). Another found that higher levels of exposure to non-child-directed screen content at 12 to 14 months of age were related to lower inhibitory self-control and metacognition skills at age four (Barr et al., 2010). Experimental findings bolster these correlational results. Lillard and Peterson (2011) found that 4-year-old children who watched a fast-paced cartoon, rather than either an educational cartoon or no television, performed significantly worse on EF tasks immediately after watching. Separately, Huber et al. (2018) found that children were less likely to delay gratification after viewing a cartoon than after playing an educational app. Collectively, these findings suggest temporary "state" effects on EF—that is, effects that are short lasting and might be associated with a third variable such as mood or attention and will fade out over a brief period—but say nothing about effects on individual differences in chronic or lasting "traits"—that is, effects that are longer lasting that might have negative downstream consequences.

For parents, educators, and clinicians, "screen time" is a loaded term and may reflect a number of different definitions for parents and researchers. Technological advance and the growing availability of mobile technologies far outpace research, making it difficult to know what is "right" for children, particularly in an era when screens are increasingly used for educational purposes. In addition, large immobile screens that pervade the everyday landscape (e.g., on the street, in shop windows, in restaurants) and mobile devices are fundamentally different, as one can be carried around and used on buses and trains and one must be watched from one location, adding to the difficulty of making recommendations. Indeed, mobile devices offer opportunities for interactive use (e.g., playing games or taking photographs) that offer opportunities to practice working memory, planning and inhibition, and so may even improve executive functions (e.g., Huber et al., 2018).

Many international health organizations (e.g., the American Academy of Pediatrics, as stated in Chassiakos et al., 2016; World Health Organization, 2019) recommend a daily limit of less than 1 h of screen time for children between the ages of 2 and 4. Importantly—in part due to the correlational nature of most extant research and the rapidly evolving landscape of technology—the consequences of extended screen viewing are still unclear, inconclusive, and misunderstood, leading some health organizations (e.g., Royal College of Pediatrics and Child Health, as stated in Viner et al., 2019) to avoid making any recommendation about screen viewing limits for young children.

The present study contributes to two major gaps in the literature. First, the majority of extant research has used cross-sectional data, making it impossible to disentangle directionality in the relations between media use and EF. Those few studies that have investigated longitudinal associations have found that screen time predicts worse EF—or at least components thereof—at later time points (e.g., McHarg et al., 2020). However, it is also important to note that much of the work examining relations between media use and EF has been limited to either infants (e.g., McHarg et al., 2020) or preschool-aged children (e.g., Barr et al., 2010). There has been little exploration of these relations in toddlerhood, particularly in recent years when screen time has become increasingly mobile. Filling in this developmental gap is key for understanding how executive function develops, especially as digital media use increases with age (e.g., Madigan et al., 2019). Though executive function may begin to develop in infancy (e.g., Hughes et al., 2020), development does not stop until adulthood (e.g., Friedman et al., 2016) and toddlerhood may be a key period for establishing EF skills. As such, in the first study of its kind, our second aim is to extend prior investigations to better understand consequences of extended screen use in toddlerhood using a large prospective longitudinal study in the United Kingdom. We expect that increased digital media use will be associated with lower executive function, both concurrently and longitudinally, at 36-months of age.

# MATERIALS AND METHODS

## Participants

Participants were recruited as a part of a larger longitudinal study of parents and their first-born children. To be eligible for the current study, potential participants had to: (1) be first-time parents, (2) be expecting to deliver a healthy singleton baby, (3) be planning to speak the English as the child's primary language, and (4) have no history of severe mental illness (e.g., psychosis) or substance misuse. We recruited 213 couples expecting their first child attending prenatal classes and appointments at local hospitals in the East of England. All parents were co-habiting, first-time parents planning to speak English as a primary language with their child. All remaining participants were born full term (after 36 weeks) and without birth complications. Of families recruited, 194 families agreed to participate in a home visit when their children were 24 months old and 170 children were visited when they were 36 months old. Families who completed all data collection when children were 24 months of age ($n = 179$) were included in analyses; participants who completed data collection at 36 months of age but not 24 months ($n = 7$) were excluded. Participants who completed data collection at 24 months but not 36 months of age were included in all inferential analyses and missing data were accounted for using Full Information Maximum Likelihood estimation; however, sample sizes for descriptive analyses vary as the number of participants who completed each task or for whom parents provided data may differ from one task to another.

All procedures performed were in accordance with the Ethical standards of the Institutional and/or National Research Committees involved and were acceptable according to the 1964 Helsinki declaration and its later amendments or comparable Ethical standards. The National Health Service (NHS, United Kingdom) Research Ethics Committee approved the study protocol (REF: 14/LO/1113).

## Procedure

Data collection occurred at five timepoints: the third trimester of pregnancy, and when the children were 4, 14, 24, and 36 months of age; for the present investigation however, only data from the 24-, and 36-month timepoints are used. Data collection took place in children's homes when children were 24 months of age [T1, $M_{age}(179) = 24.29$ months, $SD = 0.85$]; when children were 36 months of age [T2, $M_{age}(163) = 36.24$ months, $SD = 1.09$], 109 children were seen at their nursery, 56 children were seen at home, and five children were seen with their childminder/nanny at the childminder's house. All protocols were administered in a standardized order by trained graduate students or postdoctoral researchers.

## Measures

### Screen Exposure

Both mothers and fathers completed separate similar online questionnaires which included questions about their children's technology use when their children were approximately 24-months old and 36-months old. Parents reported the amount of time children watched television and used other technology (e.g., touchscreens and computers) on weekdays and weekends in response to an item that asked "Thinking about your child how much time does your child spend doing each of the following activities at home on a typical WEEKDAY/WEEKEND DAY." Parents responded to four items, one each asked the amount of time their child spent engaging with TV or DVDs, computers, books, and touch screen devices (e.g., tablet, phone). Each item was rated on the same scale in which parents were asked to respond with how much time (choosing from "not used", "less than or equal to 30 min," "30 min to an hour," "1 to 2 h," "3 to 4 h," or "greater than or equal to 5 h") their child spent engaging with TV or DVDs, computers, books, and touch screen devices per day. These answers were transformed to the numerical value in the middle of the range in minutes (i.e., corresponding to the above options, transformed values were 0, 15, 45, 90, 330, and 600 min) and values for screen-based devices were summed. Time spent engaging with books was not included in the constructed variables because, though it is considered a type of media, it was impossible to disaggregate whether parents were reporting on paper or digital books; in addition, book sharing in both physical and electronic forms is fundamentally different from viewing media (e.g., Lillard et al., 2015; Ribner et al., 2020).

Wherever possible, an average of mother- and father-reported child media use was used as the variable of interest; if only one parent responded, that parent's values were used. I total, there were data available for $n = 179$ children at T1 and for $n = 149$ children at T2. At T1, 170 mothers and 171 fathers completed questionnaires; at T2, 145 mothers and 128 fathers completed questionnaires. Mother and father reports on the resulting aggregates comprising screen time on TV/DVD, computers, and touchscreen devices were quite similar [T1, $r(160) = 0.471$, $p < 0.001$; T2, $r(122) = 0.628$, $p < 0.001$].

Importantly, for the current project, screen time was considered to be non-interactive and mostly involved viewing television content (as opposed to being interactive and contingent). Parent interviews completed with families from this sample (180 mothers and 179 fathers) for a separate study revealed that mobile device screen usage, in addition to television viewing, in toddlerhood mainly involved children viewing television content in the vast majority of cases—most children were not using applications. Therefore, a decision was taken to combine parents' answers to questions about all devices (i.e., TV or DVDs, computers, touchscreen devices) into one screen time variable by averaging values for each that is understood to be mostly non-interactive.

### Executive Function

Executive function was measured using a series of direct assessment tasks administered in a standardized order.

Administration of tasks and scoring at each time point are detailed below. At T1, children completed three EF tasks: A multi-location search task, followed an A-not-B-style shifting task, then a Stroop task; this battery of assessments is described in greater detail elsewhere (Hughes et al., 2020) and is reviewed below. At T2 months, children completed four EF tasks: A multi-location search task, a Dimensional Change Card Sorting task, a Stroop task, and a self-ordered pointing task. Scoring for T1 was the same as prior investigations using this same assessment battery (i.e., Hughes et al., 2020); scoring conventions for T2 was designed to be as similar to T1 as possible while still maintaining an adequate distribution of scores and providing equal weight in the resulting aggregate score to each assessment. Assessment took approximately 10 min at each time point.

#### *EF at 24 months*

Children first completed a Multi-Location Search Task as a measure of working memory (Miller and Marcovitch, 2015). Children searched for five cars hidden in five toy garages (one in each garage) that were distinct in both color and size after a delay of 5 s between each search. The task continued until the child retrieved all cars or made three consecutive errors. Children passed, and thus received a score of "1," if they retrieved all of the hidden cars ($n = 107$). If they did not find all five cars, they received a score of "0" ($n = 75$).

Children then completed the Ball Run Task (Devine et al., 2019) as a measure of cognitive flexibility. In the learning phase, the examiner demonstrated how to activate a musical switch by placing a colored ball (e.g., red) into one of two colored holes (e.g., red hole). The other hole (e.g., green) was sealed from beneath and could not be used to activate the switch. Children completed 6 learning trials with feedback. In the reversal phase, the examiner demonstrated how to activate the toy by placing a different colored ball (e.g., green) into the previously unused hole (e.g., green); the color of the ball always matched the color of its intended hole in an effort to test cognitive flexibility rather than inhibition. The original hole was sealed from beneath and could no longer be used to activate the switch. Children completed 6 reversal trials with feedback. Children passed a phase if they performed correctly on 4 or more trials, such that they could receive a score of "0" ($n = 30$) if they passed neither the learning nor reversal phase; "1" ($n = 66$) if they passed only the learning phase; or "2" ($n = 89$) if they passed both the learning and reversal phase. Order of administration (red vs. green hole and ball first) was counterbalanced across children.

Finally, children completed the Baby Stroop Task (Hughes and Ensor, 2005). Children participated in a "silly game" in which they pointed to a large spoon when the examiner said "Baby" and a small spoon when the examiner said "Mummy." Children completed 6 trials (with feedback) and passed (earning a score of "1") if they performed correctly on 4 or more trials ($n = 43$); children who performed correctly on fewer than 4 trials received a score of 0 ($n = 124$).

We created an EF score by summing together the number of tasks each child passed, such that children could receive a score between 0 and 4 (Hughes et al., 2020).

#### *EF at 36 months*

Children first completed the Spin the Pots task, a different multi-location search task designed to test children's working memory (Hughes and Ensor, 2005). Six raisins were hidden beneath eight paper cups on a lazy Susan tray (two cups were empty). Each of the eight cups was a different color. After raisins were hidden, the entire display was covered by a cloth and the tray was rotated 180 degrees. The cloth was then removed and children were instructed to "show me which cup you want to open". If the child chose a cup with a raisin in it, the child was told "Good job! Well done. You got a raisin! Let's put your raisin in here for later" after which the raisin was visibly and obviously removed from the cup and placed in an envelope. If the child chose a cup with no raisin, the child was told "Oh no. There's no raisin there. Let's try another." Testing was discontinued either when the child had received all six raisins or when 12 trials had been administered. Children received a score of "1" ($n = 63$) if they found five of six raisins, "2" ($n = 73$) if they found all six raisins, and a score of "0" ($n = 29$) if they found fewer than five raisins.

Children then completed a version of the Dimensional Change Card Sorting task (Zelazo, 2006), wherein they were counterbalanced across a color-first or shape-first condition. Children were first familiarized with the cards (a blue rabbit and a red boat), then saw one example trial and received one training trial with feedback. In the "color game" children were asked to place all the cards of a given color in the appropriate pile. Children received six test trials with no feedback in a standardized order with a reminder of the rule at the beginning of each ("Remember, if it's blue it goes here and if it's red it goes there. Here's a red/blue one. Where does it go?"). In the shape game, children were asked to place all the cards of a given shape in the appropriate pile. Again, children received six test trials with no feedback in a standardized order with a reminder of the rule at the beginning of each ("Remember, if it's a rabbit it goes here, and if it's a boat it goes there. Here's a rabbit/boat, where does it go?"). If a child was incorrect on four or more trials of the first test condition, testing was discontinued; if the child was correct on three or more trials, they moved to other game. Children passed a phase if they performed correctly on 4 or more trials, such that they could receive a score of "0" ($n = 17$), "1" ($n = 96$), or "2" ($n = 45$).

Next, children completed the *Baby Stroop Task* described above (Hughes and Ensor, 2005). In the version administered when children were 36 months, children received a total of 16 test trials. To avoid fatigue, half the trials were completed with spoons as at 24 month, and half were completed with cups. Again, children played a "silly game" in which they pointed to a large spoon/cup when the examiner said "Baby" and a small spoon/cup when the examiner said "Mummy." Assessment was discontinued if children were incorrect on three trials in either the spoon or cup condition. For the purpose of analysis, the two different conditions (spoons and cups) were treated as separate tasks and children passed each trial (and thus received a score of "1" if they performed correctly on 6 or more trials, such that they could receive a score of "0" ($n = 37$), "1" ($n = 36$), or "2" ($n = 72$).

Finally, children completed a self-ordered pointing task (Cragg and Nation, 2007; Devine et al., 2016). Children were shown a flipbook with an increasing number of pictures of single-syllable objects (ranging from 2 to 6) in 1 of 16 locations on a page. For example, the first page depicted two objects (e.g., doll and belt) and the next page had the same two objects in two different locations. Children were required to point to a new picture on each page and were told to not select the same picture twice. The task began with two practice trials with experimenter feedback. All children completed two test trials for each number of objects (3, 4, 5, and 6 objects) for a total of eight test trials. A span score was assigned based on the highest number of objects for which the child made zero errors on at least one of the two test trials. Children received a score of "0" if their span score was below 3 ($n = 47$), "1" if their span score was 3 or 4 ($n = 83$), and a score of "2" if their span score was 5 or 6 ($n = 24$).

An EF score was again created by summing together the number of tasks each child passed, such that children could receive a score between 0 and 8. In addition to reducing the number of variables in our models, we opted for a single aggregate score for EF because these scores exhibit greater stability over time than individual task scores (Miller and Marcovitch, 2015). Both EF aggregates were adequately reliable; reliability coefficient (i.e., ordinal alpha based on tetrachoric correlations) was modest at both 14 months ($\alpha = 0.58$) and 24 months ($\alpha = 0.49$). These results were consistent with the modest EF task correlations in this age range (Kochanska and Knaack, 2003; Miller and Marcovitch, 2015; Johansson et al., 2016).

## Covariates

A series of covariates was included in analyses to ensure inferences are not due to level of understanding or other child characteristics. In addition to EF at T1, covariates included child age at each time point (thereby also effectively controlling for length of time between testing time points), child sex, and receptive vocabulary at both T1 and T2. In addition, covariates describing parent age at time of child birth, parents' subjective social status ("This ladder represents where people stand in society. Where would you be on this ladder?" On a range from "1" = "The worst off people are at the bottom of the ladder–these people have the least education and money and the worst jobs" to "10" = "The best off people are at the top of the ladder–these people have the most education and money and the best jobs.") and whether or not parent had received higher than a bachelor's degree were included in analyses. Receptive vocabulary was measured using the receptive vocabulary subtest of the Wechsler Preschool and Primary Scales of Intelligence. Children were asked to point to one of four images that corresponded to word read aloud by the experimenter; participants completed up to 38 trials of increasing difficulty. Testing was discontinued after children were incorrect on 5 consecutive trials. The total score was used to provide an index for verbal ability.

# RESULTS

## Descriptive Statistics

Descriptive statistics are displayed in **Table 1**, and bivariate correlations among all variables are displayed in **Table 2**. Most children engaged in screen time at both 24- and 36-month time points, and screen time increased as children got older. Individual differences were stable across timepoints, $r(147) = 0.579$, $p < 0.001$. Mean screen time usage increased significantly from T1 ($M_{T1} = 86.86$, $SD = 64.99$) to T2 ($M_{T2} = 116.18$, $SD = 52.53$), paired-sample $t(148) = 6.53$, $p < 0.001$. There were no gender differences in screen use at either timepoint [T1: $t(177) = -0.80$, $p = 0.423$; T2: $t(147) = 0.50$, $p = 0.617$]. Individual differences in EF were modestly stable from 24- to 36-months, $r_s(168) = 0.15$, $p = 0.050$, consistent with prior findings on stability in EF (Carlson et al., 2004; Miller and Marcovitch, 2015; Hughes et al., 2020).

## Regression Analysis

We next ran an OLS regression model to test the hypothesis that screen time is negatively associated with children's EF at 36 months of age. We tested the association of both concurrent and prior screen use; results are shown in **Table 3**. Concurrent screen time was not significantly associated with children's EF such that there appeared to be no direct relation between screen use and EF when children were 36 months of age ($p = 0.069$); however, screen time from T1 (when children were 24 months) was negatively associated with children's EF at 36 months, suggesting longitudinal implications for screen use. Screen time at T1 was negatively associated with EF at T2, $\beta = -0.20$, $p = 0.035$, such that an increase in one standard deviation of

**TABLE 1** | Descriptive statistics and frequencies for all study variables.

| | N | Min. | Max. | Mean | SD |
|---|---|---|---|---|---|
| EF 24 months | 179 | 0 | 4 | 2.15 | 1.05 |
| EF 36 months | 163 | 0 | 8 | 4.14 | 1.79 |
| Screen time 24 months | 179 | 0 | 384.64 | 84.95 | 61.79 |
| Screen time 36 months | 149 | 34 | 372.5 | 116.18 | 52.53 |
| WPPSI 24 months | 140 | 0 | 23 | 10.34 | 5.02 |
| WPPSI 36 months | 160 | 0 | 29 | 18.12 | 5.67 |
| Age 24 months | 179 | 20.34 | 26.97 | 24.29 | 0.85 |
| Age 36 months | 163 | 34.79 | 40.15 | 36.73 | 1.06 |
| Mother age at child birth | 177 | 25.10 | 43.15 | 32.68 | 3.68 |
| Father age at child birth | 174 | 23.76 | 49.63 | 34.17 | 4.45 |
| Mother subjective social status | 179 | 3.67 | 10 | 7.37 | 1.18 |
| Father subjective social status | 179 | 4.33 | 10 | 7.34 | 1.10 |
| Child gender | 179 | | | | |
| Male | 100 | | | | |
| Female | 79 | | | | |
| Mother more than bachelor degree | 177 | | | | |
| Yes | 75 | | | | |
| No | 102 | | | | |
| Father more than bachelor degree | 176 | | | | |
| Yes | 68 | | | | |
| No | 108 | | | | |

**TABLE 2 |** Bivariate Pearson correlations among study variables.

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Executive Function 24mo | – | | | | | | | | | | | | | | |
| 2 | Executive Function 36mo | 0.15 | – | | | | | | | | | | | | | |
| 3 | Screen Time 24mo | −0.05 | −0.12 | – | | | | | | | | | | | | |
| 4 | Screen Time 36mo | 0.03 | 0.06 | 0.56*** | – | | | | | | | | | | | |
| 5 | WPPSI 24mo | 0.15 | 0.27** | 0.03 | 0.07 | – | | | | | | | | | | |
| 6 | WPPSI 36mo | 0.10 | 0.29*** | −0.10 | −0.07 | 0.28** | – | | | | | | | | | |
| 7 | Child Age 24mo | 0.16* | 0.03 | 0.09 | −0.11 | 0.24** | 0.04 | – | | | | | | | | |
| 8 | Child Age 36mo | 0.06 | 0.08 | −0.01 | −0.09 | 0.15 | 0.10 | 0.49*** | – | | | | | | | |
| 9 | Child Female | 0.16* | 0.20* | 0.06 | −0.04 | 0.04 | 0.14 | −0.11 | −0.15 | – | | | | | | |
| 10 | Mother >Bach. Deg. | 0.08 | −0.04 | −0.24** | −0.31*** | 0.05 | 0.03 | −0.02 | 0.05 | 0.07 | – | | | | | |
| 11 | Father >Bach. Deg. | 0.07 | 0.07 | −0.34*** | −0.32*** | 0.12 | 0.03 | 0.02 | −0.01 | −0.03 | 0.29*** | – | | | | |
| 12 | Mother Age at Child Birth | 0.00 | −0.04 | −0.01 | −0.16* | 0.08 | 0.05 | 0.01 | −0.07 | 0.01 | 0.18* | 0.08 | – | | | |
| 13 | Father Age at Child Birth | −0.06 | −0.06 | −0.05 | −0.23** | 0.03 | 0.06 | 0.02 | −0.07 | 0.02 | 0.10 | 0.11 | 0.67*** | – | | |
| 14 | Mother Subj. Social Status | 0.03 | 0.06 | −0.19* | −0.25** | −0.05 | 0.08 | −0.03 | −0.02 | 0.10 | 0.26*** | 0.20** | 0.15* | 0.14 | – | |
| 15 | Father Subj. Social Status | 0.07 | 0.06 | −0.24** | −0.18* | −0.12 | 0.14 | −0.11 | 0.05 | −0.02 | 0.17* | 0.34*** | 0.00 | −0.01 | 0.39*** | – |

****p< 0.001, **p< 0.01, *p< 0.05; > Bach. Deg.—More than Bachelor's Degree; Subj. Social Status—Subjective Social Status; WPPSI—Wechsler Preschool and Primary Scales of Intelligence Receptive Vocabulary Score.*

**TABLE 3 |** Linear regression predicting EF at 36 months.

| | β | *SE* | *p-value* |
|---|---|---|---|
| Executive function 24 months | 0.05 | 0.08 | 0.500 |
| Screen time 24 months | −0.20 | 0.09 | 0.032 |
| Screen time 36 months | 0.18 | 0.10 | 0.071 |
| WPPSI 24 months | 0.15 | 0.09 | 0.115 |
| WPPSI 36 months | 0.20 | 0.08 | 0.018 |
| Child age 24 months | 0.00 | 0.09 | 0.961 |
| Child age 36 months | 0.09 | 0.09 | 0.303 |
| Child female | 0.17 | 0.08 | 0.022 |
| Mother more than bachelor degree | −0.09 | 0.08 | 0.243 |
| Father more than bachelor degree | 0.06 | 0.08 | 0.502 |
| Mother age at child birth | 0.01 | 0.10 | 0.959 |
| Father age at child birth | −0.04 | 0.10 | 0.678 |
| Mother subjective social status | 0.05 | 0.08 | 0.560 |
| Father subjective social status | 0.02 | 0.08 | 0.855 |

*WPPSI, Wechsler preschool and primary scales of intelligence receptive vocabulary score.*

screen time (64.99 min) was associated with nearly a quarter standard deviation (0.48 of eight possible points) in EF.

To better understand the direction of these associations, we tested an alternative hypothesis whereby children with worse EF spend more time engaged with digital media. To test this alternate direction of association, a sensitivity test was run wherein EF at T1 and T2, as well as screen time at T1, were used to predict screen time at T2. The same covariates (i.e., receptive vocabulary, gender, and age) were included. The only significant predictor of screen use at T2 was screen use at T1: $\beta = 0.48$, $p < 0.001$.

## DISCUSSION

As expected, the current study found that, controlling for receptive vocabulary, gender, age, and prior EF, there was a linear relation between screen time at 24 months and EF 1 year later, such that increased screen time was associated with worse EF. Contrary to expectations, however, concurrent screen time was not associated with EF when children were 36 months of age.

The longitudinal findings of the current study are concordant with prior longitudinal findings (e.g., Barr et al., 2010; McHarg et al., 2020). This association may be due to increased screen use replacing activities that are important for cognitive development, such as playing with manipulatives and engaging in imaginative play. When these activities are replaced by screen time, executive function development may be permanently and negatively impacted. Indeed, the current findings suggest digital media use is implicated in EF development longitudinally in a "trait" fashion, rather than simply in a short-term "state" effect which might be suggested by concurrent relations. This impact is critical – if early television exposure is impacting executive function in a long-term manner, seemingly innocuous media exposure may have detrimental effects on academic achievement, socioemotional learning, and more. Thus, the current findings suggest that the WHO and AAP guidelines are justifiable.

Alternatively, children who are more inclined to view television more often, or parents who may be more likely to use television as everyday entertainment for their children, may have lower executive functioning due to genetic or other environmental factors. Indeed, Cliff et al. (2018) found that more screen time at 2-years was associated with lower self-regulation at 4-years. This association was strongest for children with highly educated parents, and may be child-driven (e.g., parents using more screen time to cope with children with self-regulation difficulties). Future research should investigate the potential mediating factor of parental EF on these associations.

Notably, concurrent screen time and EF were unrelated. This may be due to children viewing more child-directed content as they get older, as opposed to most television viewing in infancy and toddlerhood consisting of exposure to adult-directed content. Indeed, one study by Barr et al. (2010) found negative associations between specific aspects of screen exposure and EF. Using a longitudinal study, the authors reported that while exposure to adult-directed content was associated with lower EF, exposure to child-directed screen content was unrelated to EF. It is well-established that parent-child interactions are impaired when adult-directed content is on in the background (Kirkorian et al., 2009). It could be that children who are exposed to more adult-directed content miss out on important interactions with parents, or other exploration that is important for EF development. In contrast, child-directed content often includes information that is helpful for EF development, or at least incorporates enough of these things that development is not impaired by screen viewing. Importantly, however, it could be that longitudinal associations are significant because the negative impacts on development might be cumulative rather than immediate; concurrent associations might not be as easily detected as negative impacts of digital media use over time. The differences between the concurrent and longitudinal effects are important examples of the complex relation between executive function and screen time longitudinally, and highlight the need for caution in interpretation.

Another important consideration is the varied elements of EF. Some prior research has suggested that screen time may influence different executive functions differently. For example, Huber et al. (2018) found in a sample of 96 2- and 3-year-old children, those who engaged in tablet play were more likely to delay gratification than children who watched a cartoon; working memory increased after tablet play. Similarly, McHarg et al. (2020) found that screen exposure at 4-months was associated with decreased inhibition at 14-months, but was not significantly associated with working memory or set-shifting. However, due to the strong association between different elements of EF and the different test batteries at different time points, a composite score of EF was used in the current study. Future work should develop robust task batteries that include several measures of each element of EF and investigate these longitudinally.

### Strengths and Limitations

Strengths of the current work include the robust measurement of both EF and screen exposure across time-points in an age group that is understudied with respect to longitudinal trends in digital media usage. In addition, our regression analyses included vocabulary to ensure effects were specific to EF.

Three key limitations also deserve note. First, while this longitudinal investigation offers a unique opportunity to test and understand long-run implications of early media use on *gains* in EF over time, the study lacked the experimental design needed to infer causality. In particular, another unmeasured variable may account for the development of both children's EF and screen viewing. Second, to minimize participant burden, reflective surveys rather than a screen time diary or device monitoring system were used to assess digital media use. Though the survey included the opportunity to note which devices children were exposed to over time, it did not record specific information about what children were doing on each device, such as playing an interactive game or viewing a film. In addition, the current study did not account for background television and context of viewing (e.g., while eating, co-viewing with a parent, viewing to calm a child down vs. to allow a parent to accomplish a task, etc.). Further work is needed to identify fine-grained associations between digital media and EF development. Third, to avoid lengthy assessments we included just 3–4 EF tasks at each time-point and so were limited in our ability to investigate individual EF components in detail. Future work should establish research designs that allow for longitudinal investigations that can test the factor structure of EF within the dataset and, if appropriate, test the predictive value of screen time for different aspects of EF.

### Conclusion

Overall, the current longitudinal findings strengthen a growing body of literature on associations between screen-based digital media exposure and EF in toddlerhood. The findings discussed here highlight the potentially detrimental impacts of increased digital media exposure in toddlerhood on cognitive development. EF is a complex construct, and is influenced by several environmental and heritable factors, some of which cannot be controlled. However, though digital media exposure is ubiquitous in a modern childhood, parents, educators, and caretakers should exercise caution when exposing young children to large amounts of screen time.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of Cambridge Ethics Committee and National Health Service (NHS, United Kingdom) Research Ethics Committee approved the study protocol (REF: 14/LO/1113). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

GM, RD, and CH were involved in data collection. All authors were involved in study design, data analysis, and manuscript preparation.

## FUNDING

Support for this research was provided by ESRC ES/L010648/1 to CH. In addition, funding for the 36-month wave of the study was provided by a doctoral studentship to GM at the University of Cambridge.

## ACKNOWLEDGMENTS

We would like to thank the families for allowing us into their lives and their homes.

## REFERENCES


Anderson, D. R., and Subrahmanyam, K. (2017). Digital screen media and cognitive development. *Pediatrics* 140(Suppl. 2), S57-S61. doi: 10.1542/peds.2016-1758C

Barr, R., Lauricella, A., Zack, E., and Calvert, S. L. (2010). Infant and early childhood exposure to adult-directed and child-directed television programming: relations with cognitive skills at age four. *Merrill Palmer Q.* 56, 21–48. doi: 10.1353/mpq.0.0038

Blair, C. (2010). Stress and the development of self-regulation in context. *Child Dev. Perspect.* 4, 181–188. doi: 10.1111/j.1750-8606.2010.00145.x

Blankenship, T. L., Slough, M. A., Calkins, S. D., Deater-Deckard, K., Kim-Spoon, J., and Bell, M. A. (2019). Attention and executive functioning in infancy: links to childhood executive funciton and reading achievement. *Dev. Sci.* 22:e12824. doi: 10.1111/desc.12824

Carlson, S. M., Mandell, D. J., and Williams, L. (2004). Executive function and theory of mind: stability and prediction from ages 2 to 3. *Dev. Psychol.* 40, 1105–1122. doi: 10.1037/0012-1649.40.6.1105

Chassiakos, Y. L. R., Radesky, J., Christakis, D., Moreno, M. A., and Cross, C. (2016). Children and adolescents and digital media. *Pediatrics* 138:e20162593. doi: 10.1542/peds.2016-2593

Cheung, C. H. M., Bedford, R., Saez de Urabain, I. R., Karmiloff-Smith, A., and Smith, T. J. (2017). Daily touchscreen use in infants and toddlers is associated with reduced sleep and delayed sleep onset. *Sci. Rep.* 7:46104. doi: 10.1038/srep46104

Christakis, D. A., Gilkerson, J., Richards, J. A., Zimmerman, F. J., Garrison, M. M., Xu, D., et al. (2009). Audible television and decreased adult words, infant vocalizations, and conversational turns: a population-based study. *Arch. Pediatr. Adolesc. Med.* 163, 554–558. doi: 10.1001/archpediatrics.2009.61

Cliff, D. P., Howard, S. J., Radesky, J. S., McNeill, J., and Vella, S. A. (2018). Early childhood media exposure and self-regulation: bidirectional longitudinal associations. *Acad. Pediatr.* 18, 813–819. doi: 10.1016/j.acap.2018.04.012

Cragg, L., and Nation, K. (2007). Self-ordered pointing as a test of working memory in typically developing children. *Memory* 15, 526–535. doi: 10.1080/09658210701390750

Devine, R. T., Bignardi, G., and Hughes, C. (2016). Executive function mediates the relations between parental behaviors and children's early academic ability. *Front. Psychol.* 7:1902. doi: 10.3389/fpsyg.2016.01902

Devine, R. T., and Hughes, C. (2014). Relations between false belief understanding and executive function in early childhood: a meta-analysis. *Child Dev.* 85, 1777–1794. doi: 10.1111/cdev.12237

Devine, R. T., Ribner, A., and Hughes, C. (2019). Measuring and predicting individual differences in executive functions at 14 months: a longitudinal study. *Child Dev.* 90:e618–e636. doi: 10.1111/cdev.13217

Diamond, A. (2013). Executive functions. *Annu. Rev. Psychol.* 64, 135–168.

Drotner, K. (2013). "The co-construction of media and childhood," in *The Routledge International Handbook of Children, Adolescents and Media*, ed. D. Lemish (Abingdon: Routledge), 15–22.

Duncan, R. J., Schmitt, S. A., and Vandell, D. L. (2019). Additive and synergistic relations of early mother–child and caregiver–child interactions for predicting later achievement. *Dev. Psychol.* 55, 2522-2533. doi: 10.1037/dev0000824

Fay-Stammbach, T., Hawes, D. J., and Meredith, P. (2014). Parenting influences on executive function in ealry childhood: a review. *Child Dev. Perspect.* 8, 258–264. doi: 10.1111/cdep.12095

Fiske, A., and Holmboe, K. (2019). Neural substrates of early executive function development. *Dev. Rev.* 52, 42–62. doi: 10.1016/j.dr.2019.100866

Friedman, N. P., Miyake, A., Altamirano, L. J., Corley, R. P., Young, S. E., Rhea, S. A., et al. (2016). Stability and change in executive function abilities from late adolescence to early adulthood: a longitudinal twin study. *Dev. Psychol.* 52, 326-340. doi: 10.1037/dev0000075

Hendry, A., Jones, E. J. H., and Charman, T. (2016). Executive function in the first three years of life: precursors, predictors and patterns. *Dev. Rev.* 42, 1–33. doi: 10.1016/j.dr.2016.06.005

Hipp, D., Gerhardstein, P., Zimmermann, L., Moser, A., Taylor, G., and Barr, R. (2017). "The dimensional divide: learning from TV and touchscreens during early childhood," in *Media Exposure During Infancy and Early Childhood*. eds R. Barr and D. N. Linebarger (Cham: Springer), 33–54. doi: 10.1007/978-3-319-45102-2_3

Hisler, G., Twenge, J. M., and Krizan, Z. (2020). Associations between screen time and short sleep duration among adolescents varies by media type: evidence from a cohort study. *Sleep Med.* 66, 92–102. doi: 10.1016/j.sleep.2019.08.007

Holmboe, K., Bonneville-Roussy, A., Csibra, G., and Johnson, M. H. (2018). Longitudinal development of attention and inhibitory control during the first year of life. *Dev. Sci.* 21:e12690. doi: 10.1111/desc.12690

Huber, B., Yeates, M., Meyer, D., Fleckhammer, L., and Kaufman, J. (2018). The effects of screen media content on young children's executive functioning. *J. Exp. Child Psychol.* 170, 72–85. doi: 10.1016/j.jecp.2018.01.006

Hughes, C., and Devine, R. T. (2019). For better or for worse? Positive and negative parental influences on young children's executive function. *Child Dev.* 90, 593–609. doi: 10.1111/cdev.12915

Hughes, C., Devine, R. T., Mesman, J., and Blair, C. (2020). Understanding the terrible twos: a longitudinal investigation of the impact of early executive function and parent-child interactions. *Dev. Sci.* e12979. doi: 10.1111/desc.12979 [Epub ahead of print].

Hughes, C., and Ensor, R. (2005). Executive function and theory of mind in 2 year olds: a family affair? *Dev. Neuropsychol.* 28, 645–668. doi: 10.1207/s15326942dn2802_5

Hughes, C., Ensor, R., Wilson, A., and Graham, A. (2009). Tracking executive function across the transition to school: a latent variable approach. *Dev. Neuropsychol.* 35, 20–36. doi: 10.1080/87565640903325691

Hughes, C., Roman, G., Hart, M. J., and Ensor, R. (2013). Does maternal depression predict young children's executive function?–a 4-year longitudinal study. *J. Child Psychol. Psychiatry* 54, 169–177. doi: 10.1111/jcpp.12014

Johansson, M., Marciszko, C., Brocki, K., and Bohlin, G. (2016). Individual differences in early executive functions: a longitudinal study from 12 to 36 months. *Infant Child Dev.* 25, 533–549. doi: 10.1002/icd.1952

Kirkorian, H., Pempek, T., and Choi, K. (2017). "The role of online processing in young children's learning from interactive and noninteractive digital media," in *Media Exposure During Infancy and Early Childhood*, eds R. Barr and D. N. Linebarger (Cham: Springer), 65–89. doi: 10.1007/978-3-319-45102-2_5

Kirkorian, H. L., Pempek, T. A., Murphy, L. A., Schmidt, M. E., and Anderson, D. R. (2009). The impact of background television on parent-child interaction. *Child Dev.* 80, 1350–1359. doi: 10.1111/j.1467-8624.2009.01337.x

Kochanska, G., and Knaack, A. (2003). Effortful control as a personality characteristic of young children: antecedents, correlates, and consequences. *J. Pers.* 71, 1087–1112. doi: 10.1111/1467-6494.7106008

Lerner, M. D., and Lonigan, C. J. (2014). Executive function among preschool children: unitary versus distinct abilities. *J. Psychopathol. Behav. Assess.* 36, 626–639. doi: 10.1007/s10862-014-9424-3

Lillard, A. S., Drell, M. B., Richey, E. M., Boguszewski, K., and Smith, E. D. (2015). Further examination of the immediate impact of television on children's executive function. *Dev. Psychol.* 51, 792–805. doi: 10.1037/a0039097

Lillard, A. S., and Peterson, J. (2011). The immediate impact of different types of television on young children's executive function. *Pediatrics* 128, 644–649. doi: 10.1542/peds.2010-1919

Madigan, S., Browne, D., Racine, N., Mori, C., and Tough, S. (2019). Association between screen time and children's performance on a developmental screening test. *JAMA Pediat*. doi: 10.1001/jamapediatrics.2018.5056

Magee, C. A., and Blunden, S. (2020). Sleep timing during adolescence: a latent transition analysis approach. *Behav. Sleep Med.* 18, 131–146. doi: 10.1080/15402002.2018.1546180

McHarg, G., Ribner, A. D., Devine, R. T., Hughes, C., and NewFAMS Study Team (2020). Infant screen exposure links to toddlers' inhibition, but not other EF constructs: a propensity score study. *Infancy* 25, 205–222. doi: 10.1111/infa.12325

Mendelsohn, A. L., Berkule, S. B., Tomopoulos, S., Tamis-LeMonda, C. S., Huberman, H. S., Alvir, J., et al. (2008). Infant television and video exposure associated with limited parent-child verbal interactions in low socioeconomic status households. *Arch. Pediatr. Adolesc. Med.* 162, 411–417. doi: 10.1001/archpedi.162.5.411

Miller, S. E., and Marcovitch, S. (2015). Examining executive function in the second year of life: coherence, stability, and relations to joint attention and language. *Dev. Psychol.* 51, 101-114. doi: 10.1037/a0038359

Mulder, H., Verhagen, J., Van der Ven, S. H., Slot, P. L., and Leseman, P. P. (2017). Early executive function at age two predicts emergent mathematics and literacy at age five. *Front. Psychol.* 8:1706. doi: 10.3389/fpsyg.2017.01706

Nathanson, A. I., Aladé, F., Sharp, M. L., Rasmussen, E. E., and Christy, K. (2014). The relation between television exposure and executive function among preschoolers. *Dev. Psychol.* 50, 1497–1506. doi: 10.1037/a0035714

Ribner, A., Barr, R. F., and Nichols, D. L. (2020). Media use and school readiness skills: indirect effects of self-regulation. *Pediatr. Res.*

Ribner, A., and McHarg, G. (2019). Why won't she sleep? Screen expsoure and sleep patterns in young infants. *Infant Behav. Dev.* 57:101334. doi: 10.1016/j.infbeh.2019.101334

Robinson, T. N., Banda, J. A., Hale, L., Lu, A. S., Fleming-Milici, F., Calvert, S. L., et al. (2017). Screen media exposure and obesity in children and adolescents. *Pediatrics* 140, S97–S101. doi: 10.1542/peds.2016-1758K

Scionti, N., Cavallero, M., Zogmaister, C., and Marzocchi, G. M. (2020). Is cognitive training effective for improving executive functions in preschoolers? A systematic review and meta-analysis. *Front. Psychol.* 10:2812. doi: 10.3389/fpsyg.2019.02812

Short, S. J., Willoughby, M. T., Camerota, M., Stephens, R. L., Steiner, R. J., Styner, M., et al. (2019). Individual differences in neonatal white matter are associated with executive function at 3 years of age. *Brain Struct. Funct.* 224, 3159–3169. doi: 10.1007/s00429-019-01955-0

Vernon-Feagans, L., Willoughby, M., and Garrett-Peters, P. (2016). Predictors of behavioral regulation in kindergarten: household chaos, parenting, and early executive functions. *Dev. Psychol.* 52, 430–441. doi: 10.1037/dev0000087

Viner, R., Davie, M., and Firth, A. (2019). *The Health Impacts of Screen Time: A Guide for Clinicians and Parents*. Available online at: https://www.rcpch.ac.uk/sites/default/files/2018-12/rcpch_screen_time_guide_-_final.pdf (accessed January 30, 2019).

Willoughby, M. T., Blair, C. B., Wirth, R. J., and Greenberg, M. (2010). The measurement of executive function at age 3 years: psychometric properties and criterion validity of a new battery of tasks. *Psychol. Assess.* 22, 306-317. doi: 10.1037/a0018708

Willoughby, M. T., Magnus, B., Vernon-Feagans, L., Blair, C. B., Family Life, and Project Investigators. (2017). Developmental delays in executive function from 3 to 5 years of age predict kindergarten academic readiness. *J. Learn. Disabil.* 50, 359–372. doi: 10.1177/0022219415619754

Willoughby, M. T., Wirth, R. J., and Blair, C. B. (2012). Executive function in early childhood: longitudinal measurement invariance and developmental change. *Psychol. Assess.* 24, 418-431. doi: 10.1037/a0025779

World Health Organization (2019). *Guidelines on Physical Activity, Sedentary Behaviour and Sleep for Children under 5 Years of Age*. Available online at: https://apps.who.int/iris/handle/10665/311664 (accessed April 2, 2019).

Zelazo, P. D. (2006). The dimensional change card sort (DCCS): a method of assessing executive function in children. *Nat. Protoc.* 1, 297–301. doi: 10.1038/nprot.2006.46

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

PERSPECTIVE
published: 10 July 2020
doi: 10.3389/fpsyg.2020.01283

# Beyond Screen Time: A Synergistic Approach to a More Comprehensive Assessment of Family Media Exposure During Early Childhood

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**Specialty section:**
*This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology*

**Received:** *16 December 2019*
**Accepted:** *15 May 2020*
**Published:** *10 July 2020*

**Citation:**
*Barr R, Kirkorian H, Radesky J, Coyne S, Nichols D, Blanchfield O, Rusnak S, Stockdale L, Ribner A, Durnez J, Epstein M, Heimann M, Koch F-S, Sundqvist A, Birberg-Thornberg U, Konrad C, Slussareff M, Bus A, Bellagamba F and Fitzpatrick C (2020) Beyond Screen Time: A Synergistic Approach to a More Comprehensive Assessment of Family Media Exposure During Early Childhood. Front. Psychol. 11:1283. doi: 10.3389/fpsyg.2020.01283*

Digital media availability has surged over the past decade. Because of a lack of comprehensive measurement tools, this rapid growth in access to digital media is accompanied by a scarcity of research examining the family media context and sociocognitive outcomes. There is also little cross-cultural research in families with young children. Modern media are mobile, interactive, and often short in duration, making them difficult to remember when caregivers respond to surveys about media use. The Comprehensive Assessment of Family Media Exposure (CAFE) Consortium has developed a novel tool to measure household media use through a web-based questionnaire, time-use diary, and passive-sensing app installed on family mobile devices. The goal of developing a comprehensive assessment of family media exposure was to take into account the contextual factors of media use and improve upon the limitations of existing self-report measures, while creating a consistent, scalable, and cost-effective tool. The CAFE tool captures the content and context of early media exposure and addresses the limitations of prior media measurement approaches. Preliminary data collected using this measure have been integrated into a shared visualization platform. In this perspective article, we take a tools-of-the-trade approach (Oakes, 2010) to describe four challenges associated with measuring household media exposure in families with young children: measuring attitudes and practices; capturing content and context; measuring short bursts of mobile device usage; and integrating data to capture the complexity of household media usage. We illustrate how each of these challenges can be addressed with preliminary data collected with the CAFE tool and visualized on our dashboard. We conclude with future directions including plans to test reliability, validity, and generalizability of these measures.

**Keywords: joint media engagement, digital media, technoference, early childhood, passive sensing, time use activity data, household usage patterns**

## INTRODUCTION

Young children are immersed in the digital world. In the United States, Rideout (2017) used what was widely considered the standard approach to measure media usage, conducting a nationally representative survey of retrospective parent-reported screen time (i.e., the time children are intentionally exposed to screens per day). Rideout reported that, on average, children from birth to 23 months old spend 42 min with screens per day, and 2- to 4-year-olds spend 2 h and 39 min per day. Most of this screen time (72%) is spent viewing video content. However, actual exposure to screen media is likely much higher than traditionally reported given that 42% of parents report the TV is on "always" or "most of the time" in their home, whether anyone is watching or not. The context of media exposure is often underreported as well. For example, 24% of children younger than 2 years often or sometimes use screen media in the hour before bedtime. This rate is twice as high (49%) for 2- to 4-year-olds. Despite the prevalence of screen use immediately before sleep, the impact of this exposure is not well understood. Moreover, the media landscape is rapidly evolving; 98% of all homes in the United States have a mobile device, a number that has steadily increased to saturation levels since 2013 (Rideout, 2017). This pattern is similar across the globe (Pew Research Center, 2019). The evolving media landscape presents many challenges to researchers attempting to assess media exposure and effects in young children. Researchers need new tools to meet these challenges. The purpose of this perspective article is to describe current challenges in measuring media use and introduce state-of-the-art digital media assessment tools.

### Why Do We Care About Media Measurement?

High levels of screen time (duration of intentional screen media exposure) have been associated with a number of developmental outcomes. Many researchers have reported associations between early media exposure and outcomes as wide ranging as sleep (Cheung et al., 2017), obesity (Jackson et al., 2009), antisocial behavior (Zimmerman and Christakis, 2007), attention problems (Christakis et al., 2004), and language delays (Zimmerman et al., 2007). Higher screen time has been identified as a key predictor of poorer outcomes in many nations, including Turkey (Dinleyici et al., 2016), Canada (Madigan et al., 2019), and Hong Kong (Fu et al., 2017) and in a recent series of qualitative studies across seven European countries (Chaudron, 2015). Despite multiple studies reporting negative associations between media use and child outcomes, mixed findings abound. For example, the link between attention and media usage is unclear, with some studies reporting no association (e.g., Acevedo-Polakovich et al., 2006; Foster and Watkins, 2010) and others reporting a positive association, at least for certain types of content (e.g., Friedrich and Stein, 1973). Such mixed findings may be accounted for by factors such as developmental constraints, demographics, environmental characteristics, and media content. Nonetheless, many studies continue to adopt a single, unitary, global estimate of children's screen time, ignoring the moderating effects of individual-, household-, and media-level characteristics.

Contextual theorists (Vygotsky, 1978; Bronfenbrenner and Morris, 2006) argue that it is imperative to measure the interaction between the individual and the changing contexts within which children develop. Despite widespread debate in both popular and academic circles regarding how traditional and newer forms of digital media influence development, very few studies have examined the confluence of the family social context, digital media use by the parent and child, and early learning and language skills (Troseth et al., 2016). Thus, for a more complete understanding of media use and child development, researchers must investigate not only the duration of media use, but also the developing child within different contexts (e.g., shared use with parents, use during different family routines). However, methods available to collect such contextual knowledge are typically limited. Few studies have included assessments of mobile and interactive media use, particularly among families of very young children. As technology evolves, researchers need to develop measures to complement surveys often focused on screen time. A comprehensive and systematic set of media assessment tools is therefore needed to assess usage in a rapidly changing media landscape.

Furthermore, conclusions are plagued by multiple measurement problems (see Vandewater and Lee, 2009; Barr and Linebarger, 2017 for a review and critique of methods). Observational methods are critical in child- and family-focused research because they reflect the typical behavior of participants in naturalistic settings and because they are capable of chronicling the complex and changing processes that occur daily in young children's lives. Yet such methods are time-consuming and expensive. Observational methods also require highly trained staff. For these reasons, most studies use imprecise survey methods (e.g., global estimates with only one question asking parents to estimate TV in a "typical" day) to quantify media use (Vandewater and Lee, 2009; Barr and Linebarger, 2017). Such total time estimates ignore content, despite multiple studies that document content as a critical moderator of media effects, as summarized later. Moreover, survey methods vary widely, precluding comparisons across studies. Finally, few studies consider the overall household usage, despite a growing literature on the extent to which media effects are moderated by contextual factors (e.g., parent coviewing and mediation, parents' own technology use and "technoference," timing of use such as television viewing immediately before or during sleep, meals, and play).

### The Role of Media Content and Context

For roughly half a century, researchers have documented the critical importance of media content in determining media effects (for reviews, see Fisch, 2004; Anderson and Kirkorian, 2015; Barr and Linebarger, 2017; Lauricella et al., 2017). Relatively less attention has been given to contextual influences, including household characteristics, parental mediation of child media use, and parents' own media use. Nonetheless, there is a growing body of evidence demonstrating that these factors moderate children's access to, use of, and effects from media. For instance, lower parent education, lower household income, and racial/ethnic minority status are associated with higher media use (Anand and Krosnick, 2005; Calvert et al., 2005; Wartella et al., 2014; Goh et al., 2016; Przybylski and Weinstein, 2017; Rideout, 2017). Context is also associated with specific media practices. For example, the extent to which parents coview or discuss TV content with children differs by race and ethnicity (Lauricella et al., 2017). Parents' coviewing and active mediation in turn relate to how children comprehend, respond to, and learn from media (Valkenburg et al., 1999; Rasmussen et al., 2016; Piotrowski, 2017).

Media effects might be best understood through a family system lens. For instance, parent media use and child media use are correlated: higher parental media usage is associated with higher media usage by their young children (St.Peters et al., 1991; Bleakley et al., 2013; Connell et al., 2015; Nikken and Schols, 2015; Goh et al., 2016; Pempek and McDaniel, 2016; Anderson and Hanson, 2017; Lauricella et al., 2017). Parents' own media use not only predicts their children's media use, but it may also have an indirect effect on children via technoference (i.e., reduction in the quality of parent–child interactions when parents are engaged in their own media use) (McDaniel and Radesky, 2018). Parents are less actively engaged in their children's play in the presence of adult-directed television (versus no television), resulting in lower levels of play (Kirkorian et al., 2019). Furthermore, parents' use of mobile media during shared activities is associated with lower-quality interactions (Radesky et al., 2014, 2015a,b) and reduced learning (Reed et al., 2017).

While relatively few studies consider the impact of either content or context during early childhood, even fewer studies have investigated the interaction between these factors. This is illustrated in a 2017 systematic review of research on screen time and cognitive outcomes (Kostyrka-Allchorne et al., 2017), which included 39 cross-sectional and longitudinal studies of screen time during early childhood (0–5 years). After reexamining the articles in the review, we confirmed that two-thirds (62%) of these studies were based on a global estimate of screen time. Fewer than half (44%) considered content in any way. Among those that did consider content, 24% only distinguished between adult- and child-directed content, without measuring variations within child-directed programs (e.g., educational vs. entertainment).

Even fewer studies included in Kostyrka-Allchorne et al. (2017) systematic review considered the context of media use. For instance, we found that while 62% of the studies collected some type of data on parent–child interaction (e.g., parental warmth, parenting style, emotional, and cognitive stimulation), only 10% of the studies considered parent–child interaction as a potential *moderator* of media effects. Similarly, while nearly all of the studies (95%) reported data on one or more parent/child demographic characteristics (e.g., household income, parent education, child race, child ethnicity), only 10% considered these characteristics as potential moderators of media effects.

None of the studies reviewed by Kostyrka-Allchorne et al. (2017) examined interaction effects between media content and context. Although few studies consider such interactions (for exceptions during adolescence, see Linder and Werner, 2012; Fikkers et al., 2017), there is some evidence that individual children may be more or less susceptible to certain content effects–for good or ill–depending on individual- and family-level characteristics (Valkenburg and Peter, 2013). For example, there are fewer associations between media content and outcomes for children living in high-income homes; conversely, for children growing up in low-income homes, educational television is associated with better concurrent executive functioning, whereas background television predicts worse concurrent executive functioning (Wright et al., 2001; Linebarger et al., 2014). In lower-resourced families, educational media (e.g., television, apps, e-books) may be providing cognitive stimulation to children, which may have less impact in higher-resourced families (Linebarger et al., 2014).

In summary, it is critical to examine not only the quantity of media consumed, but also the content and context of early childhood media exposure (Barr and Linebarger, 2017). More precise measurement of the family ecology of early media exposure is needed in order to predict the long-term effects of media exposure on child outcomes. There is currently no standardized, systematic, scalable, and cost-effective measurement tool that comprehensively and accurately captures child and household media exposure, as well as the social context surrounding exposure during the first 5 years of life. The lack of such a tool represents a critical barrier for researchers who aim to describe child and family media use, identify characteristics associated with media use, evaluate associations between media use and concurrent behavior, and assess long-term developmental outcomes associated with early media use–for good or ill.

## DEVELOPING A COMPREHENSIVE ASSESSMENT OF FAMILY EXPOSURE

### A Synergistic Science Approach

The Comprehensive Assessment of Family Media Exposure (CAFE) Consortium is an international group of

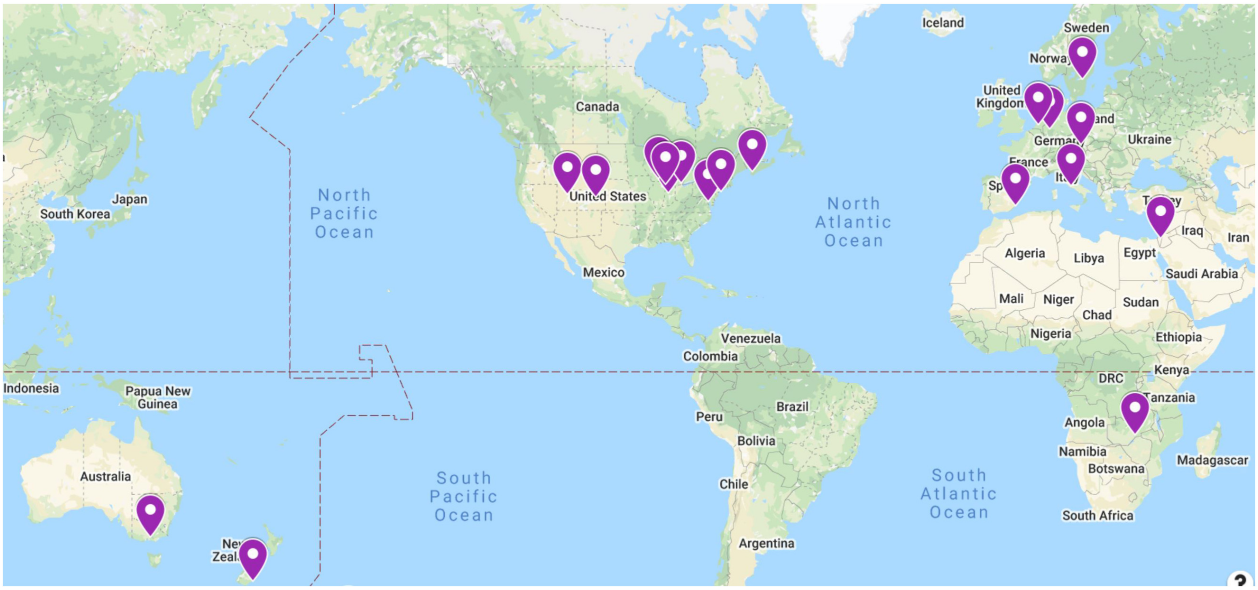


**FIGURE 1 |** CAFE Consortium sites around the globe. Data collection is ongoing or planned at each site.

cross-disciplinary collaborative researchers (**Figure 1**) formed in 2015 based on a shared interest in improving the quality of media measurement tools. So far, data have been collected at five sites across the United States, as well as in Canada, Germany, the Czech Republic, Sweden, Italy, the Netherlands, Australia, New Zealand, and Zambia. Data analysis and integration across these sites are ongoing. Taking a synergistic science approach, the CAFE Consortium developed a comprehensive assessment of family media exposure that included parental report of household usage patterns, attitudes, and practices, accompanied by detailed online time-use diaries and mobile device data collected via passive-sensing applications. Such a multipronged, multidisciplinary approach has been taken in the physical sciences to facilitate data integration and comparison across different sources and collection methods (Yip, 2003) and has recently extended to the field of developmental science (Gilmore and Adolph, 2017).

The purpose of the current article is to describe current challenges in measuring media use and introduce the state-of-the-art CAFE tools to demonstrate the feasibility of a synergistic data collection and analysis approach. The flagship journal of the Cognitive Development Society described tools in the field of developmental science using a tools-of-the-trade approach (e.g., Oakes, 2010). We have adopted a similar approach describing four primary challenges in the field and potential solutions that are offered by different CAFE tools. As part of this approach, we describe the development of each of the CAFE tools and consider their strengths and limitations. We also present illustrative preliminary data from our ongoing study for the purpose of demonstrating the utility of different CAFE measures for capturing different family media use constructs. Our synergistic approach will allow us to test the reliability, validity, and generalizability of these measures in future reports.

## The Ongoing CAFE Study

In order to provide preliminary data to illustrate how each of the tools can address a particular measurement challenge, we collected and integrated data from four sites across the United States. For context, we first summarize the protocol for an ongoing study. The rest of the article uses preliminary data from this study to illustrate key challenges to early media exposure assessment and how each of the CAFE tools can independently and collectively address these challenges. In this perspective piece, the preliminary data serve to illustrate key concepts. Validity and reliability testing of these measures is ongoing and will be published in a future report.

As of November 2019, data from 1074 participants were uploaded to a dashboard created and hosted by OpenLattice, Inc. These data were collected at the University of Wisconsin, University of Michigan, Brigham Young University, and Georgetown University. Each site had an independent institutional review board review. Participants provided informed consent to share data with the CAFE Consortium through the OpenLattice dashboard. Data were then subsetted to include only those families with children who were 0 to 72 months old and who responded correctly to at least 50% of quality assurance questions, resulting in $n$ = 914 parents. Child participants were 431 girls (47% of sample, $mean_{age}$ = 30.9 months, $SD_{age}$ = 13.5 months) and 483 boys (53% of sample, $mean_{age}$ = 29.97 months, $SD_{age}$ = 12.8 months) between 0 and 72 months of age. Participants were drawn from a range of socioeconomic and educational backgrounds, although a majority had at least a 4-year degree: Respondents reported a high school education or less ($n$ = 100, 11%), some college or an associate's degree ($n$ = 248, 27%), a bachelor's degree ($n$ = 272, 30%), and a master's or doctoral degree ($n$ = 294, 32%).

Participants completed one or more of the CAFE tools, described in detail later. Most participants were asked to complete an online questionnaire and an online time-use diary; these tools were developed first. Additionally, participants at some sites were asked to install a passive sensing app on their mobile device to track mobile usage. The app was developed for the Android operating system, so only those families with Android devices were able to utilize the app. Elsewhere we reported data from the CAFE passive-sensing app for Android and similar data collected from iOS devices, revealing few systematic differences between device use in Android and iOS users (Radesky et al., 2020). Most families ($n$ = 624, 68%) provided data for the questionnaire and diary but not the passive-sensing app. Other families provided data for the questionnaire and passive-sensing app but not the diary ($n$ = 27, 3%) and some the questionnaire only ($n$ = 184, 20%). The remaining families ($n$ = 79, 9%) provided data using all three tools.

## CHALLENGES TO MEASUREMENT AND BEST PRACTICES

The primary goals of this perspective article are to describe current challenges in measuring media use and illustrate the feasibility of a synergistic data collection and analysis approach using preliminary data from the CAFE tools. We posit that many studies purporting to examine the relation between early media exposure and developmental outcomes fall short of achieving that goal because almost all ignore the content and context of that early media exposure, focusing predominantly on the total estimated amount of exposure to media. When researchers have examined the relationships between media content and context, they have reported much more nuanced and actionable findings (for review, see Barr and Linebarger, 2017). The rest of this perspective piece highlights four current challenges and how the CAFE Consortium has improved upon existing approaches by developing a comprehensive questionnaire that covers parental attitudes and new digital media (e.g., video chat and smart speakers) (challenge 1), an online time-use diary that emphasizes context (challenge 2), and a passive-sensing app that accurately tracks short bursts of mobile devise use (challenge 3). By combining information across these data streams, we examine how each of these components contributes to the overall household media ecology and index aspects of the content and context of early media exposure (challenge 4).

### Challenge 1: How Can Researchers Measure Attitudes and Practices?

In order to establish the context of media usage, it is important to assess not only the media environment (e.g., how many devices are owned), but also instrumental uses of media for the parent toward the child (e.g., calming or educating the child, occupying the child during travel), attitudes toward media (e.g., concerns about media effects), and household media practices (e.g., coviewing, location of devices, parental digital work demands). Finally, a number of demographic factors have been associated with media usage patterns. A parent-report survey is the method best suited to assess demographics, the general media environment, and parents' attitudes and practices. We therefore developed a comprehensive survey, the Media Assessment Questionnaire (MAQ), to capture parent attitudes and behaviors around media.

#### Questionnaire Description

The 74-item questionnaire covers 10 topics, including household composition and demographics, parent mediation of media use, parent attitudes toward media use, and access to and regularity of use of different devices frequently found in the modern household. The approximate time to complete the entire questionnaire is 20–30 min. The questions were derived from a number of existing surveys (e.g., Lapierre et al., 2012; Rideout, 2017) and were updated to reflect current technologies and research on the content and context of early media exposure. For example, we updated Lapierre et al. (2012) representational survey of early media exposure to include newer devices (e.g., smart speakers, e-books, DVRs, tablet computers), content delivery mechanisms (e.g., streaming content), and newer technology-based activities (e.g., video chat). Quality check questions were embedded in the MAQ to ensure that participants were not responding randomly to questions. The illustrations in this perspective article are based on parents who were accurate on 50% or more of the quality check questions.

We also included established measures of parent media use, behaviors, and attitudes, such as Valkenburg et al. (1999) parent mediation scale. We use the data collected with the established Valkenburg scale to demonstrate our dashboard correlogram function using a measure with an established factor structure (**Figure 2**). In our preliminary data, we see evidence of a similar factor structure, particularly what Valkenburg et al. (1999) called *instructive* and *social* viewing patterns. With sufficiently large samples, such patterns could be analyzed for coherence across strata, such as family characteristics or study sites.

In future reports, we can use this utility to visualize and test factor structure for the newly developed MAQ. For example, we will visualize factor structure in questions about parental technoference (i.e., extent to which technology is seen to disrupt parents' day-to-day activities) and about parents' media-related concerns based on questions used in prior studies (Radesky et al., 2015b). The MAQ can easily be extended to include other questions or scales of interest to individual researchers. For instance, some of our investigators have included standardized parenting stress (Abidin, 1995), sleep (Sadeh, 2004), and language measures (Fenson et al., 2000) at the end of the MAQ.

#### Meeting the Challenge

A comprehensive questionnaire can best capture demographics, attitudes, and practices–factors known to be associated with household media usage patterns.

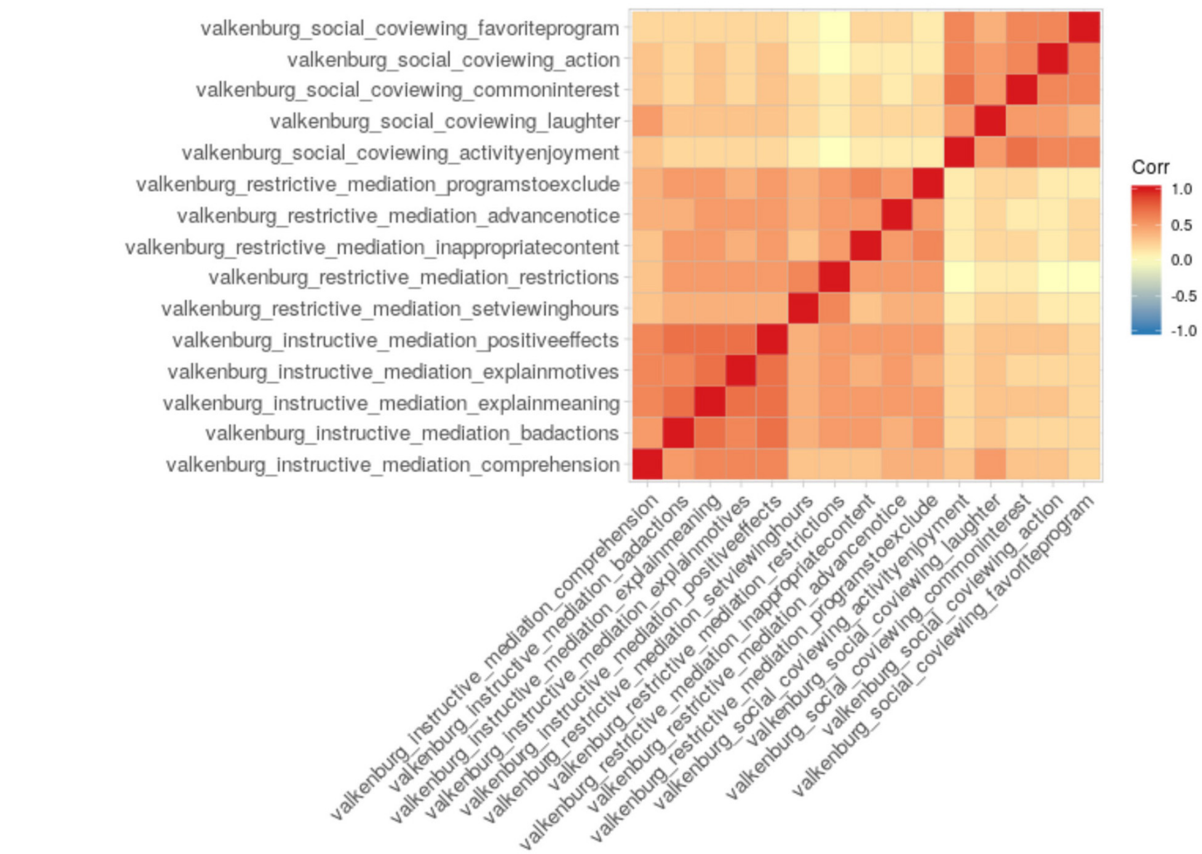


**FIGURE 2 |** A correlogram depicting parents' responses to the Valkenburg et al. (1999) mediation scale.

## Challenge 2: How Can Researchers Capture the Content and Context of Media Usage?

Most prior media exposure research focuses on global estimates of a child's total time spent (Vandewater and Lee, 2009), often ignoring time of day, frequency of use, content, and context. This is true despite robust evidence that both content (Fisch, 2004; Anderson and Kirkorian, 2015) and context (Zack and Barr, 2016; Pempek and Lauricella, 2017) are critical moderators of media effects on learning, behavior, and development. Unlike global estimates, time-use diaries account for every moment in a particular day. Research demonstrates that time-use diaries produce more accurate estimates of actual media use than do global estimates of average media use in a "typical day" (Anderson et al., 1985). Moreover, diaries can be used to index the content and context of media usage within the daily activities of the child and family. Therefore, we developed the CAFE Time-Use Diary (TUD) to more accurately capture not only the amount, but also the content and context of media use.

### Diary Description

The CAFE TUD is a custom-designed, online 24-h time-use diary that details daily activities with follow-up questions about media content and context. The activities were derived from the Panel Study of Income Dynamics Child Supplement time use survey[1] with the addition of a media-use category. There are 10 activity categories (sleep, media use, indoor play, outdoor play, travel, eating, grooming, childcare, household routines, other). Parents fill 15-min blocks of time indicating the target child's primary activities throughout the day. See **Figure 3** for a screenshot of a completed diary. After blocking out primary activities, parents answer follow-up questions that are customized to each primary activity category. For instance, parents answered follow-up questions about background media and parents' own mobile device use for each block pertaining to sleep, eating, and play categories. For all blocks of time in the primary media-use category, parents answered follow-up questions about media content and coviewing patterns. Respondents take approximately 20 min to complete the TUD.

By capturing a high-resolution snapshot of one or more days in a child's life, we can more accurately measure child media use in the context of other activities throughout the day. For instance, we can visualize primary media use and background media use reported in the TUD as a function of family characteristics reported in the MAQ. See **Figure 4** for one illustration examining TV/video viewing as a function of parent education.

[1] https://psidonline.isr.umich.edu/Guide/default.aspx

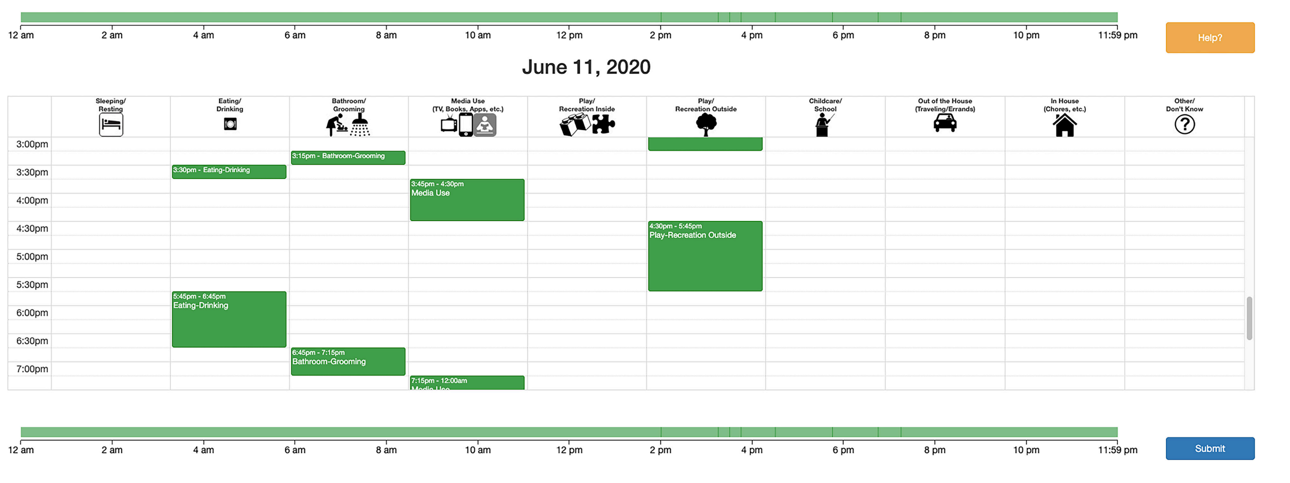


**FIGURE 3 |** Illustration of a completed time-use diary. A help button contains instructional videos describing how to complete the diary, how to delete an activity, and how to know that the diary is complete. Parents click-and-drag to fill 15-min time blocks of child activities across the day. After creating a time block, they click on the time block to complete follow-up questions. The horizontal timeline at the top and the bottom of the diary indicates when each time block is complete by changing color from gray to green.

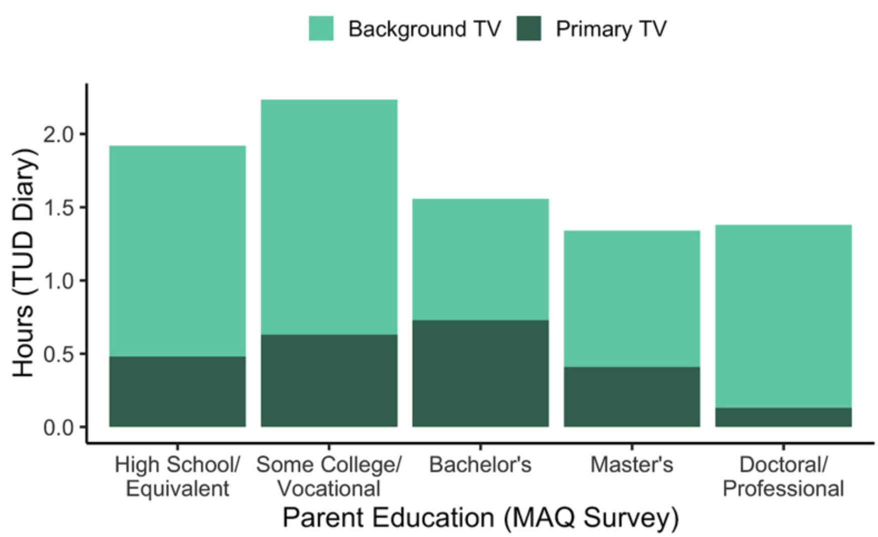


**FIGURE 4 |** Mean parent-reported primary and background TV on the previous day (using the TUD) as a function of parent education (using the MAQ). Primary TV is reported by selecting media use as a primary activity on the time diary grid and indicating that the media type was TV during the follow-up questions about media content and context. Background TV is reported by selecting one of several other primary activities (e.g., sleeping, playing, eating) and indicating that TV was on in the background during the follow-up questions about context. This figure is based on a subset of participants with a TUD ($n$ = 493, 70%) who provided their education level, reported at least 18 h (but not more than 26 h) on the diary and who opened the follow-up questions for at least 90% of the activity blocks in their TUD.

We can similarly capture the extent to which activities such as sleeping, eating, and playing are accompanied by background TV or parents' own mobile device use. Both background media and parent media often disrupt ongoing child activity via a process described as *technoference* (McDaniel and Radesky, 2018). **Figure 5** illustrates times when child activities may be disrupted by either background TV/video or by parent media usage that is unrelated to bedtime routines or mealtimes. Future analyses could examine the content of media use or variations in activities over the course of the day (e.g., the types of media used immediately before vs. during bedtime routines), whether differences in potential technoference are associated with sleep patterns, and many other questions regarding the context of media use.

## Meeting the Challenge

As illustrated, time-use diaries are most useful as descriptions of larger blocks of time and providing context for media use, such as capturing co-occurring activities or determining who (if anyone) is with the child during each activity.

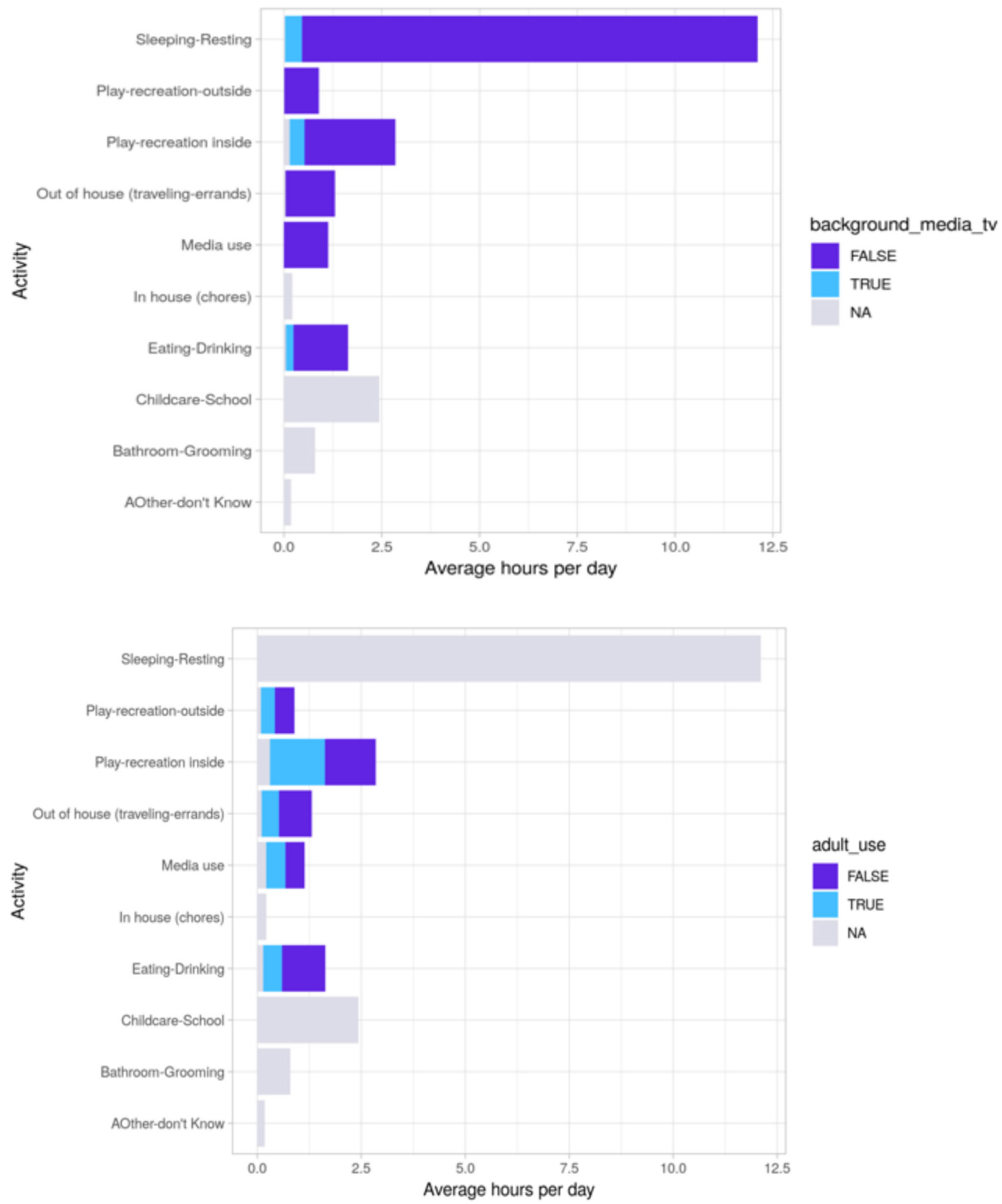


**FIGURE 5 |** Illustration of the amount of time parents reported background TV **(top)** and parent mobile device use **(bottom)** were present (blue/true) or absent (purple/false) during each activity in the TUD. Background TV and parent mobile device use are reported during the follow-up questions about media context for some activities. Gray shading indicates that the follow-up questions did not ask about background TV or parent mobile device use for a particular category (if the entire bar is gray), or the parent did not answer the follow-up question for one or more blocks of time (bars with one small gray segment). This figure is based on a subset of participants with a TUD ($n$ = 500, 71%) who reported at least 18 h (but not more than 26 h) on the diary and who opened the follow-up questions for at least 90% of the activity blocks in their TUD.

## Challenge 3: How Can Researchers Measure Short Bursts of Mobile Device Usage?

One of the goals of the CAFE Consortium is establishing reliable methods for measuring use of newer media (e.g., mobile devices) where exposure occurs in short bursts (Oulasvirta et al., 2005). Short bursts make retrospective assessments problematic (Burns and Anderson, 1993; Vandewater and Lee, 2009). Furthermore, the fact that even young children use handheld devices by themselves (Domoff et al., 2018) limits parents' ability to correctly estimate their children's usage. Moreover, mobile devices are multimodal computers, so measurement of app usage (e.g., video chat vs. YouTube vs. games), as well as the context (e.g., who is using the device), is needed in order to accurately characterize children's media

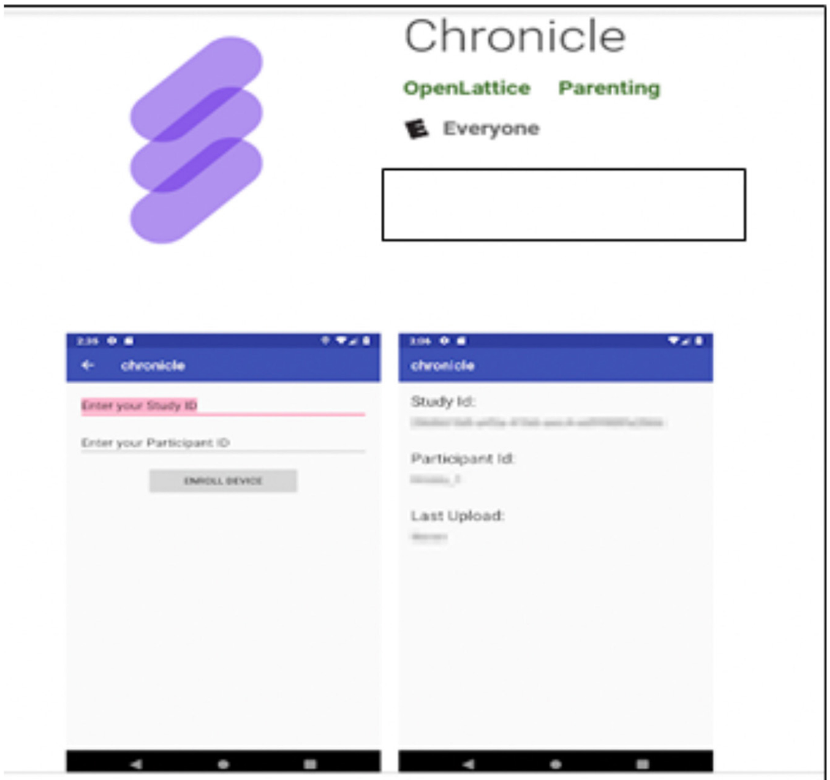


**FIGURE 6 |** The interface that parents receive on downloading the *Chronicle* application from the Google Play Store. Participants receive a unique ID number.

exposure. Although diaries have in the past been validated against direct observation of TV viewing with correlations ranging from 0.70–0.80 (Anderson et al., 1985), there are now many more household devices to track. Therefore, our converging method approach includes mobile device passive sensing.

Mobile device sensing is a methodology that harnesses data that mobile devices already collect, such as location, call logs, app usage logs, or battery usage–in order to study user behavior. User experience researchers have used this method for over 10 years to optimize smartphone design, but it has rarely been utilized as an objective measure of mobile device use (Hiniker et al., 2016; Elhai et al., 2018). The CAFE Consortium developed a mobile device sensing app (*Chronicle*) for Android devices in partnership with OpenLattice, Inc. This app generates accurate data on parent or child mobile media usage.

### Description of *Chronicle* Mobile Device Sensing App

The *Chronicle* app was custom-developed by OpenLattice, Inc., for Android devices (**Figure 6**). The *Chronicle* app and associated findings are described in more detail elsewhere (see Radesky et al., 2020). The *Chronicle* mobile device sensing app tracks the duration, frequency, time of day, general app type (e.g., email, phone, social media, educational), and app status (foreground vs. background, screen on vs. screen off) by querying the Google API every 15 min. Accessing the Google API for app usage statistics reduces computation and storage demands for participants. In addition, the Google API is used by millions of vendors and is closely monitored by Google for security, reliability, and accuracy. That is, participants give specific permission to allow researchers to access data that are already being collected by Google for the duration of the study. A limitation of this methodology is that only Android phone users currently are able to complete this study component. Efforts to expand to other operating systems are ongoing. As a stopgap, some CAFE Consortium investigators have used other methods such as embedded apps (e.g., *ScreenTime* for iOS) or other third-party apps (e.g., *Moment* for iOS). However, data collected by apps other than *Chronicle* are less detailed with respect to content and time intervals.

**Figure 7** illustrates some detailed information that can be obtained from *Chronicle* to address questions of usage across the day. It is possible to see daily fluctuations in usage of different types of content. For example, and perhaps not surprisingly, activity by children on their tablets peaks in the evening and decreases during the night, but some children are still actively using the tablet at that time. Additional reliability and validity testing to evaluate the app is ongoing.

### Meeting the Challenge

Mobile device sampling is a promising method to track short spurts of mobile device usage with high temporal resolution.

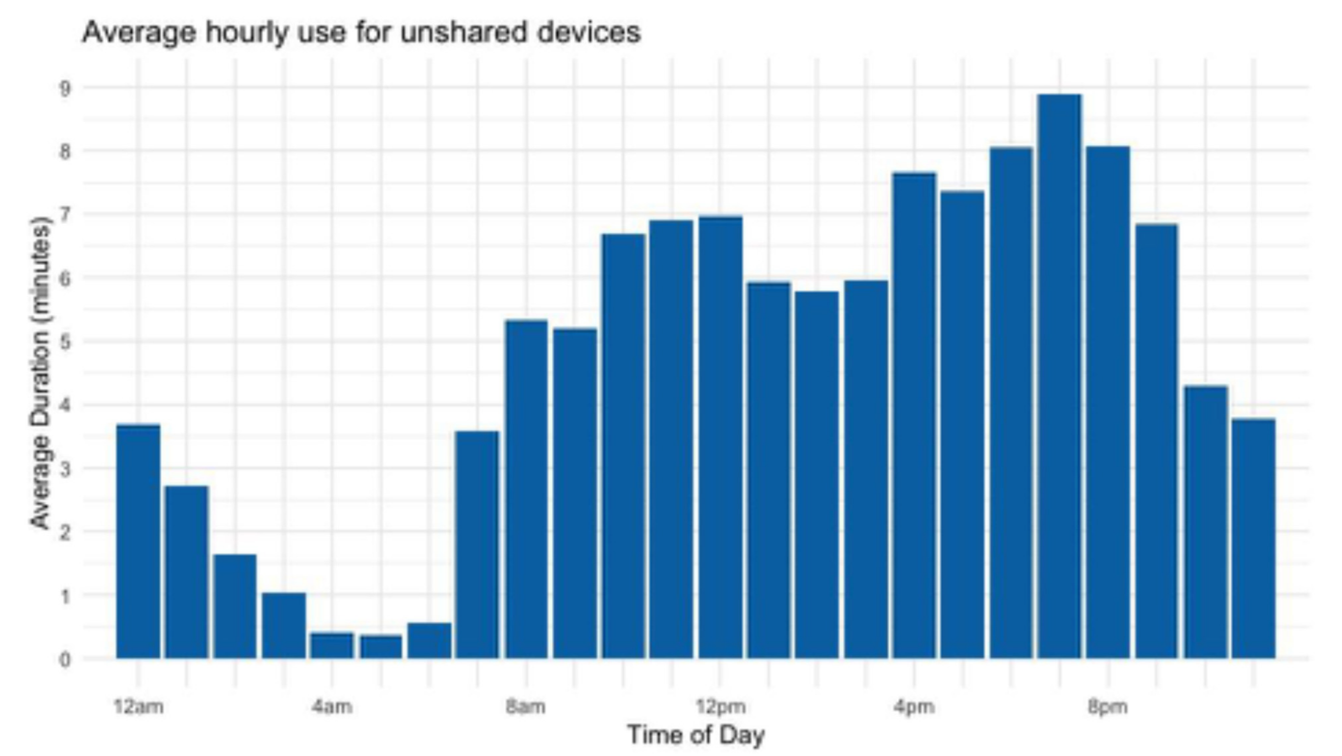


**FIGURE 7 |** Average hourly usage by time of day, aggregated over all children with their own individual tablets as tracked by *Chronicle*. Generated from data collected in Michigan from August 2018 to May 2019. *n* = 37, aged 36–60 months.

## Challenge 4: No Single Tool Captures the Ecology of Household Media Usage

The solution to this challenge is to use a comprehensive assessment of family media exposure using converging methods and data integration across the three CAFE tools (MAQ, TUD, and *Chronicle*). Taking a synergistic approach, the CAFE Consortium is actively recruiting participants to complete the CAFE tools as part of their ongoing research programs. We developed a protocol for de-identifying and sharing data across sites for collation purposes to maintain confidentiality and maximize data sharing.

This suite of tools allows us to leverage the strengths of each methodology to provide the best metrics for parental attitudes via survey methodology (Barr and Linebarger, 2017; Valkenburg et al., 1999), capture the content and context of media use alongside all daily activities via online time use methods (Vandewater and Lee, 2009), and reduce participant bias in recalling small bursts of mobile device usage via passive sensing technology to automatically record digital media usage (Goedhart et al., 2015). This maximizes the pros of each measurement approach while offsetting the cons. For example, media usage does not occur in a vacuum. Continuous, intensive measurement of media use will be most informative when it is integrated with data about important drivers of media use such as participant mood (Bayer et al., 2016), cues (Bayer and Campbell, 2012), behaviors (Fedele et al., 2019), social interactions (Radesky et al., 2016), or other environmental or contextual variables. We posit that mobile device sensing is much more accurate for short bursts of time on mobile devices. Parental attitudes, however, influence how media are used (e.g., Valkenburg et al., 1999). These metrics can be accessed via standardized surveys. Meanwhile, the context of usage in larger chunks of time including who is present can be best captured by the time-use diary. Combining passive sensing of mobile media usage via *Chronicle* with the TUD and MAQ data allows the context of the media usage to be established. *Chronicle* and TUD can also capture aspects of media content (e.g., app or program titles).

### Description of the CAFE-OpenLattice Dashboard

In order to integrate data streams from each of the CAFE tools, we built and tested a dashboard to accommodate use and storage by multiple study teams. We built an automated data pipeline for cleaning and visualizing data, including a customizable dashboard to facilitate standardized summary variable creation and reduction within the OpenLattice platform.

To maximize future utilization, the dashboard was developed in *R* (R Core Team, 2013), a widely used and freely available data analysis language for social sciences and available for collaboration on the code sharing platform GitHub. The dashboard has been built with consideration of international security and privacy regulations including Health Insurance Portability and Accountability Act and General Data Protection Regulation. Specifically, the dashboard requires a secure data login by each researcher. Each team deidentifies data before

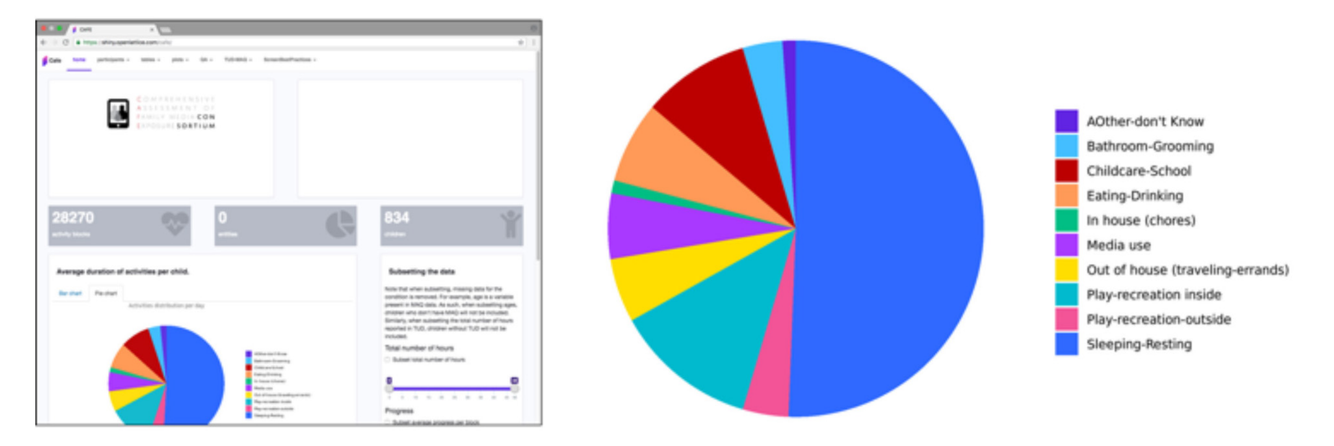


**FIGURE 8 |** Screenshot from the dashboard landing page (left) that provides data visualization of the time use activities (expanded on the right), the number of participants, and options for subsetting the data for further visualization and analysis.

integrating into the platform. For example, each participant has a code number, and no names, dates of birth, or IP information about any participant is stored. The code numbers are recoded within the platform for added protection. Each research team can view tables of their own individual data to ensure accurate data upload and data integrity, but researchers cannot see individual data from other investigators (only aggregated data).

At the time of this writing, the platform integrates data for TUD and MAQ. See **Figure 8** for a screenshot of the dashboard landing page. We are in the process of creating such a dashboard for the *Chronicle* app as well. Ultimately, the dashboard will allow for visualization and analysis of data across all three CAFE tools: MAQ (survey), TUD (diary), and *Chronicle* (mobile device sensing app).

Using the current dashboard, we can examine associations between detailed reports of media use (as reported in the TUD) and a wide range of parent-reported household characteristics, child behavior, and outcomes (as reported in the MAQ). Preset scripts in the dashboard allow investigators to quickly and easily visualize distributions and associations. See **Figure 9** for an illustration. In **Figure 9**, we show the distributions of and correlations between TV, tablet, and book use as the child's primary activity (as opposed to being on in the background) from the TUD and the Valkenburg instructive and restrictive scales from the MAQ. Primary TV hours are associated with primary tablet and book hours. **Figure 9** illustrates how the data distributions and associations between different variables are visualized.

Given concerns about the accuracy of self-report estimates of small bursts of mobile activity, we examined the relation between self-reported mobile usage time [grouped by time estimates (from the MAQ)] and the time tracked by the *Chronicle* app in a group of 37 participants. These data collected with the MAQ and *Chronicle* illustrate that many parents were inaccurate (either overreporting or underreporting) when self-reporting their mobile device usage on the MAQ. Approximately one in three parents (31%) accurately reported mobile device use during weekdays, and only one in four (24%) accurately reported mobile device use during the weekend (**Table 1**). **Figure 10** illustrates the concordance between *Chronicle* and parent report. For example, when parents self-reported 2- to 3-h usage on either the weekday or weekend using MAQ, *Chronicle* recorded 30 min less on the weekend and 1 h less during the weekday overall. In general, parents tended to either underreport or overreport on both weekdays and weekends. *Chronicle* data collection based on the Google API has been tested for accuracy against usage logs. In addition, comparison to parent reports suggests that, as in prior studies, self-report and recollection of cell phone usage are likely to be poor.

We calculated Kendall's tau-b rank correlation coefficient ($p < 0.05$) between the category of parent-reported mobile device use on the MAQ and the *Chronicle* estimate. These correlations were relatively low for weekdays, $\tau(35) = 0.41$, $p < 0.001$, and not significant for weekend days, $\tau(33) = 0.20$, $p < 0.11$. Conversely, the correlation between the two self-reported estimates (weekday and weekend day) was high, $\tau(35) = 0.81$, $p < 0.0001$, suggesting that parent report is consistent within individuals but less consistent with more objective metrics. This finding illustrates that parent-reported mobile device use may not be a reliable measure of actual mobile device use. Passive mobile device sensing is a more reliable and accurate way to measure child mobile phone usage (see also Radesky et al., 2020).

The examples presented here illustrate the utility of combining multiple methods to better capture the family media ecology. Ultimately, we will be able to test reliability and validity by testing for consistency across all three tools. **Figure 11** provides a conceptual overview linking the MAQ, TUD, and *Chronicle* to support future reliability and validity testing.

## Meeting the Challenge

The combination of methods provides a more comprehensive assessment of the family media ecology, creating opportunities for improved validity and reliability testing.

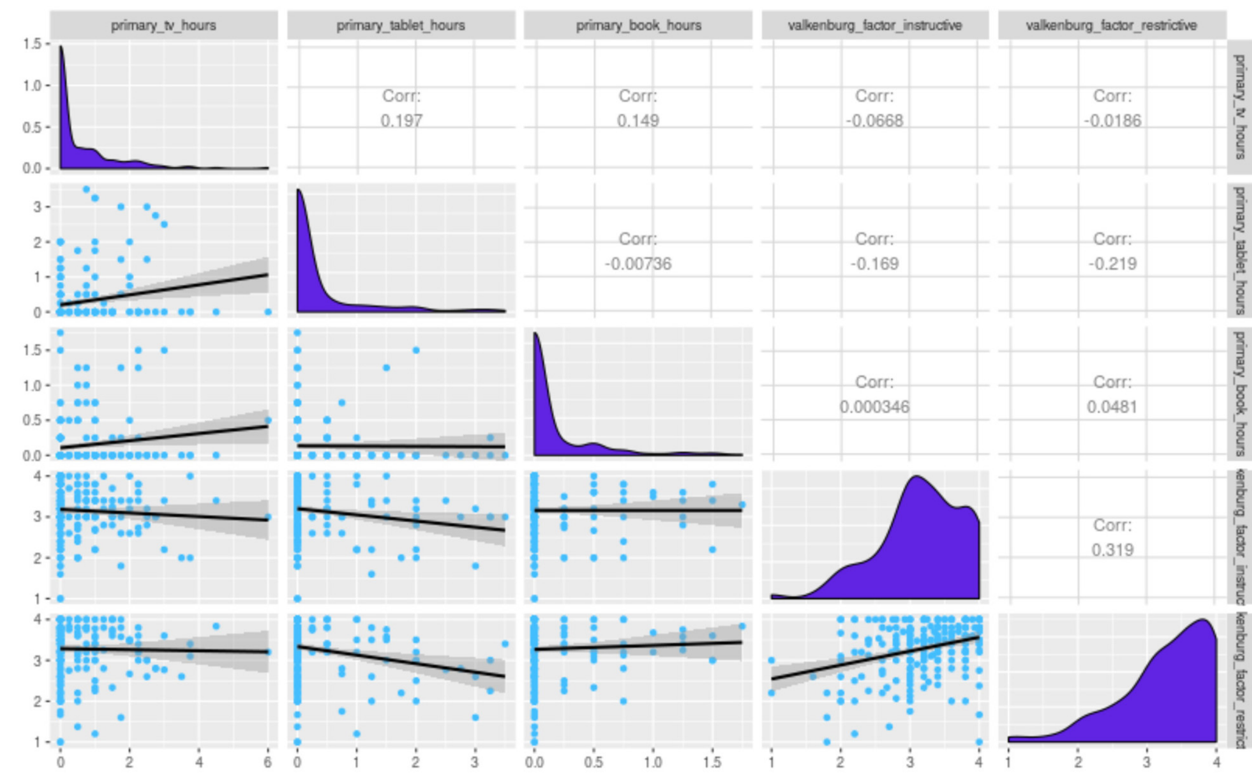


**FIGURE 9 |** Distributions, scatterplots, and correlations between the primary TV hours, tablet hours, and book hours from the TUD and the Valkenburg instructive and restrictive scales from the MAQ. Along the diagonal are distributions of each variable. Above the diagonal are Pearson correlation coefficients. Below the diagonal are scatterplots between the variables. Initial visual inspection of the data suggests associations between tablet use and parental mediation may exist, which can be further tested in the dashboard. This figure is based on a subset of participants with a TUD ($n$ = 231) who were between 30 and 72 months, reported at least 18 h (but not more than 26 h) on the diary, and opened the follow-up questions for at least 90% of the activity blocks in their TUD.

**TABLE 1 |** Proportion of parents who were underreporting, accurate, or overreporting their preschool-aged child's mobile device use, compared to *Chronicle* output, as a function of weekend or weekday estimates.

| | % Underreport | % Accurate | % Overreport |
|---|---|---|---|
| Weekday | 37.14% | 31.43% | 31.43% |
| Weekend | 30.30% | 24.24% | 45.45% |

## DISCUSSION

We have successfully applied a synergistic approach to developing the CAFE tool. There are a number of advantages of the synergistic scientific approach taken by the CAFE Consortium. Consortium members have complementary expertise in different developmental domains (e.g., memory, language, sleep, pediatrics). Each research group contributed to the design of the CAFE tool, collected data using the tool, and also designed and collected data with other specific research questions in mind. That is, all researchers have a shared interest in the measurement of household media ecology, but all have independent research programs. For example, research groups are pursuing links to attachment, mental health, language development, book reading, and language and sleep patterns. Experimental studies are evaluating technoference and physiological responses to media exposure. All researchers collect and collate the data from the CAFE tools in the dashboard. Meanwhile, each researcher can use his/her own data as a metric within individual designs. From the open-science framework perspective, however, it is useful for multiple groups to utilize the same tool and to share data in order to replicate across multiple sites. Data collection time is reduced and optimized. From a data analysis perspective, analytics can be optimized across the datasets for data visualization and analysis. This allows researchers to then develop and test more complex questions based on a larger and more diverse sample. Finally, it is feasible to do cross-site comparisons to assess whether variables that differ across sites (e.g., culture, population density, language) can be directly compared because the same metrics have been developed by and utilized across sites. Thus far, materials have been translated into Spanish, Czech, Swedish, German, and Italian by Consortium members, and data have been collected in the Czech Republic, Italy, Germany, and Sweden, with plans to expand to other languages as needs and resources arise.

The content and context of early media exposure are likely to shape developmental trajectories and to be even more pronounced in the current media landscape than ever before (Barr and Linebarger, 2017). In this time of unprecedented technology expansion, researchers need better tools to track

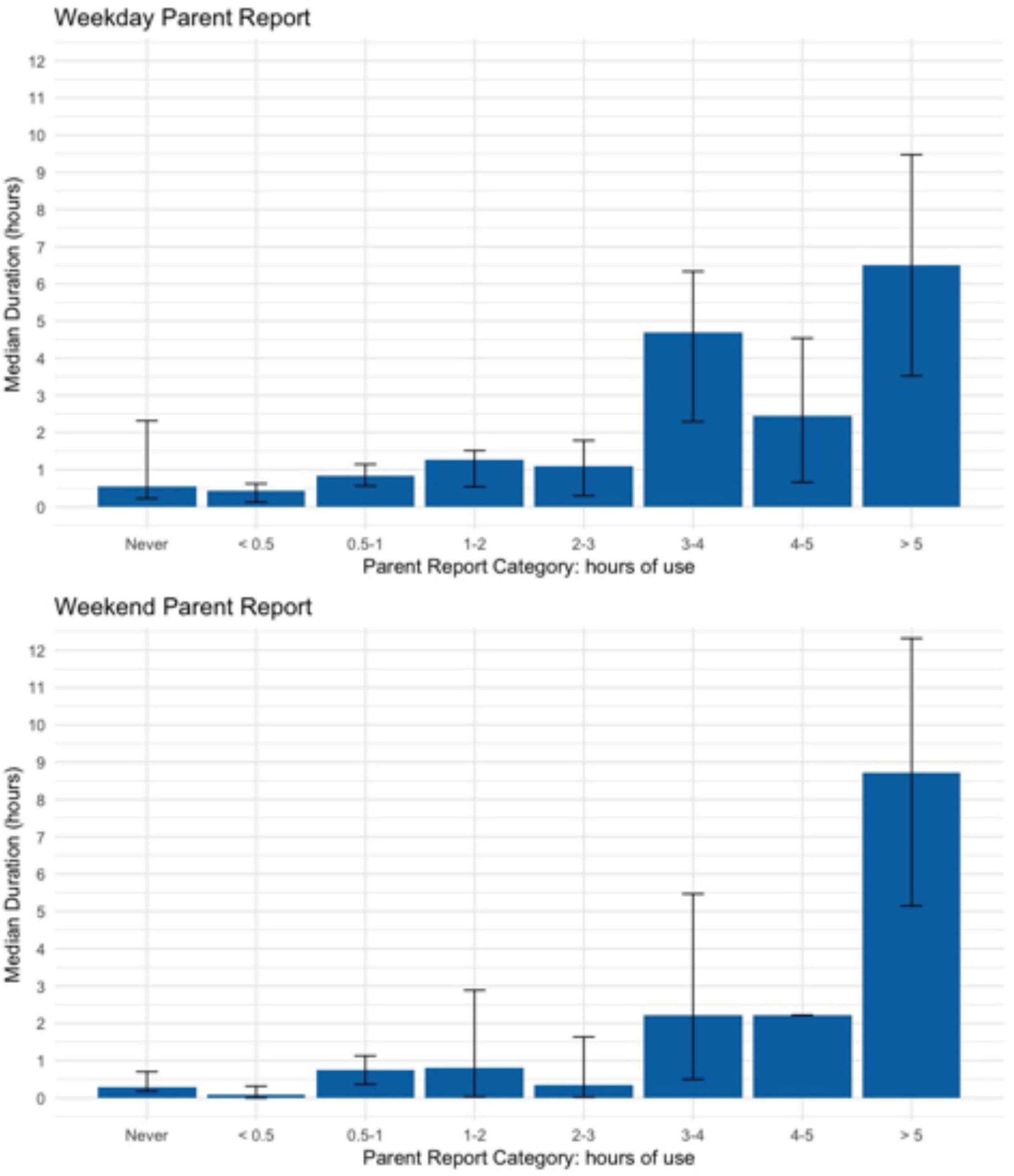


**FIGURE 10 |** Comparison of parent-reported child mobile device use category from the MAQ to median daily usage calculated from *Chronicle* on weekdays (top) and weekends (bottom). This figure is based on a small sample collected in Michigan ($n$ = 37 parents with a child 36–60 months old).

family media ecology and child responses to such exposure. The CAFE Consortium has taken a first step toward developing tools for the greater research community that can be utilized in longitudinal studies to examine how developmental trajectories of media exposure affect child outcomes. The OpenLattice dashboard provides an opportunity for researchers to rapidly integrate, visualize, and compare responses across a suite of complementary tools to establish best practices in measurement

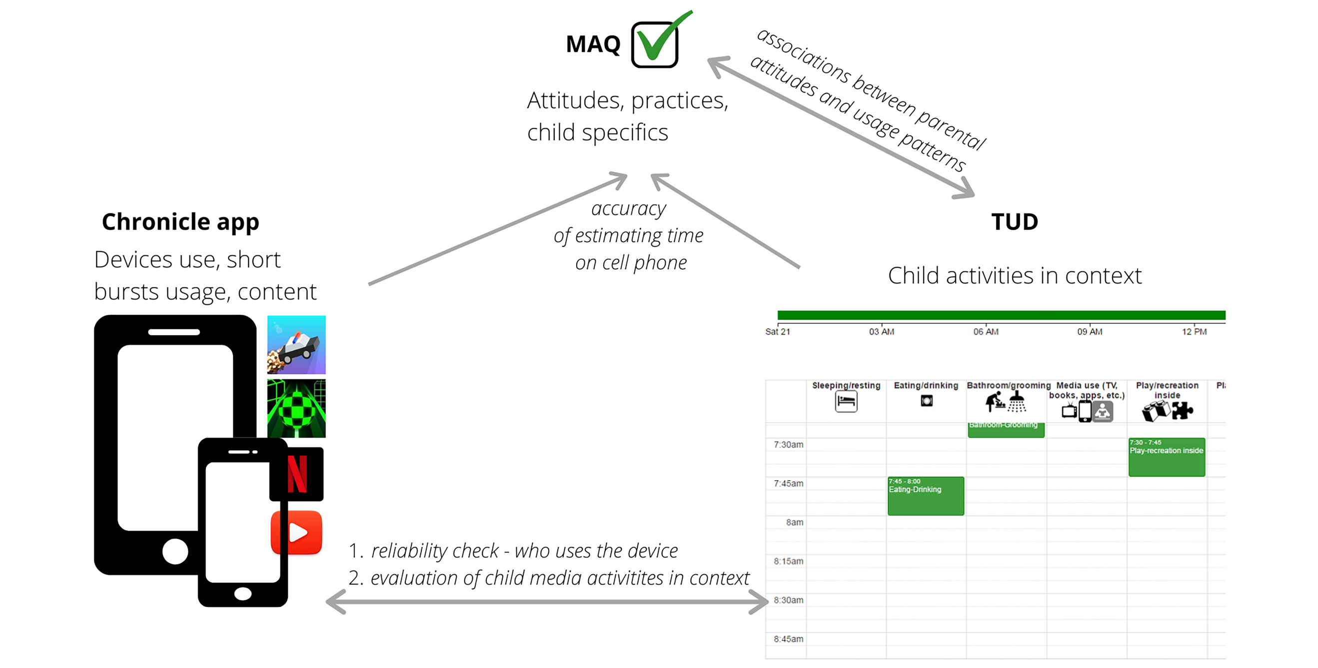


**FIGURE 11 |** Conceptual overview linking the MAQ, TUD, and *Chronicle* to support reliability and validity testing. This work is ongoing.

of family media ecology. As demonstrated here, each tool can meet different challenges. The MAQ can assess parental attitudes, practices, and household characteristics that influence the general household media environment. The TUD characterizes the broad duration of the child's daily activities in the context of media patterns in the household, including follow-up questions about the content and context of media use. Finally, mobile device sampling via *Chronicle* provides a detailed assessment of the short bursts of mobile activity and different content accessed throughout the day. As illustrated here, the CAFE tools can be used to replicate investigations of factors that are likely to be associated with screen time within the family context, such as associations between education and daily duration of media use. Such a replication approach will allow us to further test the reliability and validity of the tools.

## Future Directions

The CAFE tools can be used to extend our knowledge of family media ecology, going beyond the default screen time estimates to test which combination of factors is likely to predict child outcomes. There are a number of exciting directions that the CAFE Consortium hopes to pursue.

### Patterns Across Time of Day

Both TUD and *Chronicle* are time-stamped throughout the day, and we are currently integrating these time-stamped activities. In the future, this degree of time-stamped information will allow us to map blocks of time in different activities from the TUD (e.g., mealtime, play, hour before sleep) to blocks of usage by parents on their devices or children's own tablets. For example, we can plot number of engagements and duration of engagements on mobile devices during outdoor playtime or mealtime.

### New Data Streams and Analytics

Currently, we are building upon our existing dashboard to incorporate additional time-stamped objective measures. For example, different CAFE groups are currently collecting data using a number of wearable devices to track physiological responses, including heart rate variability, actigraphy, LENA audio recordings of the language environment, and ecological momentary assessment (EMA). Specifically, EMA participants receive additional contact during the mobile device sampling and TUD data collection periods to collect contextual data such as a panoramic photo. We would build upon approaches developed to examine adolescent media usage using MYME (e.g., Rich et al., 2015). New assessments also need to capture emerging technologies like video chat, virtual reality, and intelligent agents. The addition of these time-stamped methods would allow researchers to examine cascades of events that shape behavior over minutes, hours, or days–rather than asking for global estimates. Integrating mobile device sampling data with physiologic sensory data would allow us to identify physiologic stress, sleep patterns, or physical activity patterns crucial for understanding associations of media use with these health determinants.

### Scalability and Sharing

We are streamlining the existing tools and integrating them within one interface to facilitate future scalability. We are actively testing reliability and validity. Concurrently, we are expanding our data analytics to address these complex contextual research questions. Simultaneously, we are exploring whether we can use our integrated data to develop a short form of household media usage. A short form might capture key features of the content and context of media exposure utilizing specific aspects of each of the three metrics with high validity, reliability, and relevance to important outcomes. These short-form CAFE tools could then be more easily incorporated into large-scale longitudinal studies. A short form will also be valuable for responding to time-sensitive research needs. For instance, some Consortium members have used CAFE tools to capture family media ecology following a natural disaster. Similarly, the COVID-19 pandemic emerged as we wrote this perspective article, dramatically changing the media landscape for millions of young families and creating a critical need to understand how media may help or hinder as families cope. Ultimately, once the Consortium has completed the dashboard and analytics phases of the CAFE tool development, we will share and scale the tool for broader usage.

### Associations With Cognitive and Behavioral Assessments

We are currently examining associations between media exposure and daily activities with other standardized measures. For instance, many sites added a standard sleep questionnaire (Sadeh, 2004), parenting stress questionnaire (Abidin, 1995), and infant language measures (Fenson et al., 2000). We will therefore examine associations between the content and context of early media exposure with parenting stress, child sleep duration and quality, child language, and changes to routines such as bedtime reading.

### Comparing Attitudes and Activities

Optimizing the three tools, we aim to examine patterns of short bursts of mobile device activity (*Chronicle*) with self-reports of attitudes toward mobile usage (MAQ) and selected child activities (e.g., play and mealtimes from the TUD). We could then test predictions about relations between attitudes, activities, and usage patterns.

### Cross-Cultural Comparisons

We are now integrating data that have been collected at sites outside of the United States to assess global similarity in the adoption and use of technology in the household. We will be able to examine cross-cultural comparisons of attitudes and availability of media in different countries, as well how specific policy (e.g., parental leave policies, income inequity, privacy regulations) may be associated with household media practices.

As shown by the challenges outlined in the current article, the standard approach to media assessment is insufficient. As illustrated by the comprehensive, converging, and complementary nature of the CAFE tools, parent global estimates can be inaccurate or provide an incomplete picture of the context of media exposure. When comparing mobile device sampling to self-report, a majority of parents either overestimated or underestimated their actual device use. More accurate assessment is needed not only for researchers, but also for healthcare, home visitors, and childcare providers in order to develop guidelines for healthy media diets that are based on realistic usage patterns, highlighting both problematic and effective practices. Better feedback can then be provided to parents. Obvious health domains that require further investigation are in the areas of parents' usage, parental stress, child obesity, child emotion regulation, and cognitive outcomes. It is critical that future studies include diverse populations, across race, ethnicity, and income. It is equally important that measures of family media ecology are easy for participants to use. The finalized CAFE tools could be utilized globally to examine child health and welfare, where there is a critical need to incorporate more precise measures of media exposure to go beyond screen time.

## DATA AVAILABILITY STATEMENT

The datasets generated for this study will not be made publicly available. We have built a data sharing platform and will be able to share secure access to the dataset once the platform has been completely built and data integrated from Consortium members. Requests to access the datasets should be addressed to the corresponding author.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of Wisconsin–Madison, Georgetown University, University of Michigan Medical School, and Brigham Young University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

All authors have contributed substantially and in a meaningful way to the manuscript. All authors are original members of the CAFE Consortium that conceptualized the CAFE suite of tools. Data has been collected by all authors except the data scientists, ME and JD who built the OpenLattice dashboard where the data were integrated. The suite was translated into Swedish, German, Italian, and Czech by AS, CK, FB, and MC respectively before implementing the data collection in each country. RB, JR, SC, and DN wrote the grant and were awarded funding to build the database.

## FUNDING

Funding for this project was supported by a grant to RB, JR, DN, HK, and SC by the Children and Screens: Institute of Digital Media and Child Development Inc. Publication fees were provided by the University of Wisconsin, University of Michigan, and Brigham Young University.

## REFERENCES


Abidin, R. R. (1995). *Parenting Stress Index: Professional Manual*, 3rd Edn. Lutz, FL: Psychological Assessment Resources, Inc.

Acevedo-Polakovich, I. D., Lorch, E. P., Milich, R., and Ashby, R. D. (2006). Disentangling the relation between television viewing and cognitive processes in children with attention-deficit/hyperactivity disorder and comparison children. *Arch. Pediatric. Adolesc. Med.* 160, 354–360.

Anand, S., and Krosnick, J. (2005). Demographic predictors of media use among infants, toddlers, and preschoolers. *Am. Behav. Sci.* 48, 539–561. doi: 10.1177/0002764204271512

Anderson, D. R., Field, D. E., Collins, P. A., Lorch, E. P., and Nathan, J. G. (1985). Estimates of young children's time with television: a methodological comparison of parent reports with time-lapse video home observation. *Child Dev.* 56, 1345–1357.

Anderson, D. R., and Hanson, K. G. (2017). *Screen Media and Parent-Child Interactions. Media Exposure During Infancy and Early Childhood: The Effect of Content and Context on Learning and Development*. New York, NY: Springer, 173–194.

Anderson, D. R., and Kirkorian, H. L. (2015). "Media and cognitive development," in *Handbook of Child Psychology and Developmental Science*, 7th Edn, eds R. M. Lerner, L. S. Liben, and U. Mueller (Hoboken, NJ: Wiley), 949–994. doi: 10.1002/9781118963418.childpsy222

Barr, R., and Linebarger, D. L. (eds) (2017). *Media Exposure During Infancy and Early Childhood: The Effect of Content and Context on Learning and Development*. New York, NY: Springer.

Bayer, J. B., and Campbell, S. W. (2012). Texting while driving on automatic: considering the frequency-independent side of habit. *Comput. Hum. Behav.* 28, 2083–2090. doi: 10.1016/j.chb.2012.06.012

Bayer, J. B., Dal Cin, S., Campbell, S. W., and Panek, E. (2016). Consciousness and self-regulation in mobile communication. *Hum. Commun. Res.* 42, 71–97. doi: 10.1111/hcre.12067

Bleakley, A., Jordan, A. B., and Hennessy, M. (2013). The relationship between parents' and children's television viewing. *Pediatrics* 132, 364–371.

Bronfenbrenner, U., and Morris, P. A. (2006). "The bioecological model of human development," in *Handbook of Child Psychology: Theoretical Models of Human Development*, eds R. M. Lerner and W. Damon (Hoboken, NJ: John Wiley & Sons Inc), 793–828.

Burns, J. J., and Anderson, D. R. (1993). Attentional inertia and recognition memory in adult television viewing. *Commun. Res.* 20, 777–799. doi: 10.1177/009365093020006002

Calvert, S., Rideout, V., Woolard, J., Barr, R., and Strouse, G. (2005). Age, ethnicity, and socioeconomic patterns in early computer use: a national survey. *Am. Behav. Sci.* 48, 590–607. doi: 10.1177/0002764204271508

Chaudron, S. (2015). *Young Children (0-8) and Digital Technology: A Qualitative Exploratory Study Across Seven Countries*. Brussels: Publications Office of the European Union.

Cheung, C. H. M., Bedford, R., Saez De Urabain, I. R., Karmiloff-Smith, A., Tim, J., and Smith, T. J. (2017). Daily touchscreen use in infants and toddlers is associated with reduced sleep and delayed sleep onset. *Sci. Rep.* 7:46104.

Christakis, D. A., Zimmerman, F. J., DiGiuseppe, D. L., and McCarty, C. A. (2004). Early television exposure and subsequent attentional problems in children. *Pediatrics* 113, 708–713. doi: 10.1542/peds.113.4.708

Connell, S. L., Lauricella, A. R., and Wartella, E. (2015). Parental co-use of media technology with their parents in the U.S.A. *J. Child. Media* 9, 5–21. doi: 10.1080/17482798.2015.997440

Dinleyici, M., Carman, K. B., Ozturk, E., and Sahin-Dagli, F. (2016). Media Use by Children, and Parents'. Views on Children's Media Usage. *Interact. J. Med. Res.* 5:e18. doi: 10.2196/ijmr.5668

Domoff, S. E., Radesky, J. S., Harrison, K., Riley, H., Lumeng, J. C., and Miller, A. L. (2018). A naturalistic study of child and family screen media and mobile device use. *J. Child Fam. Stud.* 28, 401–410. doi: 10.1007/s10826-018-1275-1

Elhai, J. D., Tiamiyu, M. F., Weeks, J. W., Levine, J. C., Picard, K. J., and Hall, B. J. (2018). Depression and emotion regulation predict objective smartphone use measured over one week. *Pers. Individ. Differ.* 133, 21–28. doi: 10.1016/j.paid.2017.04.051

Fedele, D. A., McConville, A., Moon, J., and Thomas, J. G. (2019). Topical review: design considerations when creating pediatric mobile health interventions: applying the IDEAS framework. *J. Pediatr. Psychol.* 44, 343–348. doi: 10.1093/jpepsy/jsy084

Fenson, L., Pethick, S., Renda, C., Cox, J. L., Dale, P. S., and Reznick, J. S. (2000). Short-form versions of the MacArthur communicative development inventories. *Appl. Psycholinguist.* 21, 95–116. doi: 10.1017/s0142716400001053

Fikkers, K. M., Piotrowski, J. T., and Valkenburg, P. M. (2017). A matter of style? Exploring the effects of parental mediation styles on early adolescents' media violence exposure and aggression. *Comput. Hum. Behav.* 70, 407–415. doi: 10.1016/j.chb.2017.01.029

Fisch, S. M. (2004). *Children's Learning From Educational Television: Sesame Street and Beyond*. Mahwah, NJ: Lawrence Erlbaum Associates.

Foster, E. M., and Watkins, S. (2010). The value of reanalysis: TV viewing and attention problems. *Child Dev.* 81, 368–375. doi: 10.1111/j.1467-8624.2009.01400.x

Friedrich, L. K., and Stein, A. H. (1973). Aggressive and prosocial television programs and the natural behavior of preschool children. *Monogr. Soc. Res. Child Dev.* 38:63. doi: 10.2307/1165725

Fu, K., Ho, F. K. W., Rao, N., Jiang, F., Li, S. L., Lee, T. M. C., et al. (2017). Parental restriction reduces the harmful effects of in-bedroom electronic devices. *Arch. Dis. Childh.* 102, 1125–1131. doi: 10.1136/archdischild-2017-312639

Gilmore, R. O., and Adolph, K. E. (2017). Video can make behavioural science more reproducible. *Nat. Hum. Behav.* 1:0128. doi: 10.1038/s41562-017-0128

Goedhart, G., Kromhout, H., Wiart, J., and Vermeulen, R. (2015). Validating self-reported mobile phone use in adults using a newly developed smartphone application. *Occupat. Environ. Med.* 72, 812–818. doi: 10.1136/oemed-2015-102808

Goh, S. N., Teh, L. H., Tay, W. R., Anantharaman, S., van Dam, R. M., Tan, C. S., et al. (2016). Sociodemographic, home environment and parental influences on total and device-specific screen viewing in children aged 2 years and below: an observational study. *BMJ Open* 6, e009113. doi: 10.1136/bmjopen-2015-009113

Hiniker, A., Patel, S. N., Kohno, T., and Kientz, J. A. (2016). "Why would you do that? predicting the uses and gratifications behind smartphone-usage behaviors," in *Paper presented at: the 2016 Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing*, Heidelberg.

Jackson, D. M., Djafarian, K., Stewart, J., and Speakman, J. R. (2009). Increased television viewing is associated with elevated body fatness but not with lower total energy expenditure in children. *Am. J. Clin. Nutr.* 89, 1031–1036. doi: 10.3945/ajcn.2008.26746

Kirkorian, H. L., Choi, K., and Anderson, D. R. (2019). American parents' active involvement mediates the impact of background television on young children's toy play. *J. Child. Media* 13, 377–394. doi: 10.1080/17482798.2019.1635033

Kostyrka-Allchorne, K., Cooper, N. R., and Simpson, A. (2017). The relationship between television exposure and children's cognition and behaviour: a systematic review. *Dev. Rev.* 44, 19–58. doi: 10.1016/j.dr.2016.12.002

Lapierre, M. A., Piotrowski, J. T., and Linebarger, D. L. (2012). Background television in the homes of US children. *Pediatrics* 130, 839–846. doi: 10.1542/peds.2011-2581

Lauricella, A. R., Blackwell, C. K., and Wartella, E. (2017). "The "New" technology environment: the role of content and context on learning and development from mobile media," in *The Effect of Content and Context on Learning and Development*, eds R. Barr and D. N. Linebarger (New York, NY: Springer), 1–24.

Linder, J., and Werner, N. E. (2012). Relationally aggressive media exposure and children's normative beliefs: does parental mediation matter? *Fam. Relat.* 61, 488–500. doi: 10.1111/j.1741-3729.2012.00707.x

Linebarger, D., Barr, R., Lapierre, M., and Piotrowski, J. (2014). Parenting, media use, cumulative risk, and children's executive functioning. *J. Dev. Behav. Pediatr.* 35, 367–377. doi: 10.1097/DBP.0000000000000069

Madigan, S., Browne, D., Racine, N., Mori, C., and Tough, S. (2019). Association between screen time and children's performance on a developmental screening test. *JAMA Pediatr.* 173, 244–250. doi: 10.1001/jamapediatrics.2018.5056

McDaniel, B. T., and Radesky, J. S. (2018). Technoference: parent distraction with technology and associations with child behavior problems. *Child Dev.* 89, 100–109. doi: 10.1111/cdev.12822

Nikken, P., and Schols, M. (2015). How and Why Parents Guide the Media Use of Young Children. *J. Child Fam. Stud.* 24, 3423–3435. doi: 10.1007/s10826-015-0144-4

Oakes, L. M. (2010). Using habituation of looking time to assess mental processes in infancy. *J. Cogn. Dev.* 11, 255–268. doi: 10.1080/15248371003699977

Oulasvirta, A., Tamminen, S., Roto, V., and Kuorelahti, J. (2005). "Interaction in 4-second bursts: the fragmented nature of attentional resources in mobile HCI," in *Paper Presented at: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Montreal.

Pempek, T. A., and Lauricella, A. R. (2017). "The effects of parent-child interaction and media use on cognitive development in infants, toddlers, and preschoolers," in *Cognitive Development in Digital Contexts*, eds F. C. Blumberg, and P. J. Brooks (Amsterdam: Elsevier Inc), 53–74. doi: 10.1016/B978-0-12-809481-5.00003-1

Pempek, T. A., and McDaniel, B. T. (2016). Young Children's Tablet Use and Associations with Maternal Well-Being. *J. Child Fam. Stud.* 25, 2636–2647. doi: 10.1007/s10826-016-0413-x

Pew Research Center (2019). *Smartphone Ownership Is Growing Rapidly Around the World, but Not Always Equally*. Washington, DC: Pew Research Center.

Piotrowski, J. T. (2017). "The parental media mediation context of young children's media use," in *Media Exposure During Infancy and Early Childhood: The Effect of Content and Context on Learning and Development*, eds R. Barr and D. Linebarger (New York, NY: Springer), 205–220.

Przybylski, A. K., and Weinstein, N. (2017). Digital screen time limits and young children's psychological well-being: evidence from a population-based study. *Child Dev.* 90, e56–e65. doi: 10.1111/cdev.13007

R Core Team (2013). *R: A Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing.

Radesky, J. S., Kistin, C., Eisenberg, S., Gross, J., Block, G., Zuckerman, B., et al. (2016). Parent perspectives on their mobile technology use: the excitement and exhaustion of parenting while connected. *J. Dev. Behav. Pediatr.* 37, 694–701. doi: 10.1097/dbp.0000000000000357

Radesky, J. S., Kistin, C. J., Zuckerman, B., Nitzberg, K., Gross, J., Kaplan-Sanoff, M., et al. (2014). Patterns of mobile device use by caregivers and children during meals in fast-food restaurants. *Pediatrics* 133, 843–849.

Radesky, J. S., Miller, A. L., Rosenblum, K. L., Appugliese, D., Kaciroti, N., and Lumeng, J. C. (2015a). Maternal mobile device use during a structured parent–child interaction task. *Acad. Pediatr.* 15, 238–244. doi: 10.1016/j.acap.2014.10.001

Radesky, J. S., Schumacher, J., and Zuckerman, B. (2015b). Mobile and interactive media use by young children: the good, the bad, and the unknown. *Pediatrics* 135, 1–3. doi: 10.1542/peds.2014-2251

Radesky, J., Weeks, H., Ball, R., Schaller, A., Yeo, S., Durnez, J., et al. (2020). Mobile device sampling: an unobtrusive, objective measure of child smartphone and tablet use. *Pediatrics* 146:e2019351

Rasmussen, E. E., Shafer, A., Colwell, M. J., White, S., Punyanunt-Carter, N., Densley, R. L., et al. (2016). Relation between active mediation, exposure to Daniel Tiger's neighborhood, and US preschoolers' social and emotional development. *J. Child. Media* 10, 443–461.

Reed, J., Hirsh-Pasek, K., and Golinkoff, R. (2017). Learning on hold: cell phones sidetrack parent-child interactions. *Dev. Psychol.* 53, 1428–1436. doi: 10.1037/dev0000292

Rich, M., Bickham, D. S., and Shrier, L. A. (2015). Measuring youth media exposure: a multimodal method for investigating the influence of media on digital natives. *Am. Behav. Sci.* 59, 1736–1754. doi: 10.1177/0002764215596558

Rideout, V. (2017). *The Common Sense Census: Media Use by Kids Age Zero to Eight*. San Francisco, CA: Common Sense Media.

Sadeh, A. (2004). A brief screening questionnaire for infant sleep problems: validation and findings for an internet sample. *Pediatrics* 113, e570–e577. doi: 10.1542/peds.113.6.e570

St.Peters, M., Fitch, M., Huston, A. C., Wright, J. C., and Eakins, D. J. (1991). Television and families: what do young children watch with their parents? *Child Dev.* 62, 1409–1423. doi: 10.1111/j.1467-8624.1991.tb01614.x

Troseth, G. L., Russo, C. E., and Strouse, G. A. (2016). What's next for research on young children's interactive media? *J. Child. Media* 10, 54–62. doi: 10.1080/17482798.2015.1123166

Valkenburg, P. M., Krcmar, M., Peeters, A. L., and Marseille, N. (1999). Developing a scale to assess three styles of television mediation: "Instructive mediation", "restrictive mediation", and "social coviewing". *J. Broadcast. Electr. Media* 43, 52–66. doi: 10.1080/08838159909364474

Valkenburg, P. M., and Peter, J. (2013). The differential susceptibility to media effects model. *J. Commun.* 63, 221–243. doi: 10.1111/jcom.12024

Vandewater, E. A., and Lee, S. J. (2009). Measuring Children's media use in the digital age: issues and challenges. *Am. Behav. Sci.* 52, 1152–1176. doi: 10.1177/0002764209331539

Vygotsky, L. S. (1978). *Mind in society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.

Wartella, E., Rideout, V., Lauricella, A., and Connell, S. (2014). *Revised Parenting in the Age of Digital Technology: A National Survey*. Evanston, IL: Northwestern University.

Wright, J. C., Huston, A. C., Murphy, K. C., St. Peters, M., Piñon, M., Scantlin, R., et al. (2001). The relations of early television viewing to school readiness and vocabulary of children from low-income families: the Early Window Project. *Child Dev.* 72, 1347–1366. doi: 10.1111/1467-8624.t01-1-00352

Yip, S. (2003). Synergistic science. *Nat. Matter* 2, 3–5. doi: 10.1038/nmat778

Zack, E., and Barr, R. (2016). The role of interactional quality in learning from touch screens during infancy: context matters. *Front. Psychol.* 7:1264. doi: 10.3389/fpsyg.2016.01264

Zimmerman, F. J., Christakis, D., and Meltzoff, A. N. (2007). Associations between Media Viewing and Language Development in Children Under Age 2 Years. *The Journal of Pediatrics* 151, 364–368. doi: 10.1016/j.jpeds.2007.04.071

Zimmerman, F. J., and Christakis, D. A. (2007). Associations between content types of early media exposure and subsequent attentional problems. *Pediatrics* 120, 986–992. doi: 10.1542/peds.2006-3322

**Conflict of Interest:** JD and ME were employed by company OpenLattice Inc.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 22 March 2021
doi: 10.3389/fpsyg.2021.589664

# How Infant and Toddlers' Media Use Is Related to Sleeping Habits in Everyday Life in Italy

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***Specialty section:***
*This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology*

***Received:*** *31 July 2020*
***Accepted:*** *24 February 2021*
***Published:*** *22 March 2021*

***Citation:***
*Bellagamba F, Presaghi F, Di Marco M, D'Abundo E, Blanchfield O and Barr R (2021) How Infant and Toddlers' Media Use Is Related to Sleeping Habits in Everyday Life in Italy. Front. Psychol. 12:589664. doi: 10.3389/fpsyg.2021.589664*

**Background:** Heavy media use has been linked to sleep problems in children, which may also extend to the infancy period. While international parent-advisory agencies, such as the American Academy of Pediatrics (2016), advise no screen time before 18 months, parents often do not follow this recommendation. Research on Italian infants' early access to media is sparse, and only very few studies have investigated links with sleeping habits.

**Method:** To address this gap, we examined concurrent associations between parent-reported surveys of child technology use and sleeping patterns. The Italian version of the 60 item Comprehensive Assessment of Family Media Exposure (CAFE) Survey, developed as part of a larger international study, the Brief Screening Questionnaire for Infant Sleep Problems (BISQ) were completed online by 264 Italian parents of 8- to 36-month-olds and a subset ($n$ = 134) completed the Parenting Stress Index (PSI) between April 2017 and April 2018.

**Results:** More devices located in the child's room and the more time spent watching TV or using an iPad were associated with less hours of sleep at night. Furthermore, more time spent watching TV or using a smartphone, as well as the number of devices in the room was associated with going to sleep later at night. Instrumental media use was associated with less sleep.

**Conclusion:** Like other countries, Italian infants have high levels of exposure to media, and differences in media patterns were associated with sleep patterns. Cultural factors influence both instrumental reasons for media use and sleep practices. Further research should explore how media use may serve to regulate emotion as a function of both contextual factors and individual differences.

**Keywords: digital media, sleep, early childhood, household usage patterns, culture**

## INTRODUCTION

The rapid proliferation of digital media has drastically changed the way parents use and allow their children to use media (Rideout and Robb, 2020). On one hand, digital media may provide new opportunities for learning, playing, and interacting. On the other hand, rapid changes in the digital environment engender concern in parents about the possible impact of digital media on their children (Reid Chassiakos et al., 2016; Barr, 2019a). Households are now immersed in digital media (e.g., TV, videos, and mobile technologies such as smartphones and tablets). The American Academy of Pediatrics has recommended that parents of children under 18 months limit exposure to electronic screen-based media (Reid Chassiakos et al., 2016). This guideline is reinforced by even stricter recent recommendations by the World Health Organization (WHO), which has stated infants under a year old should not have screen time (World Health Organization [WHO], 2019). The Italian Pediatric Society (Bozzola et al., 2018) has recently suggested that media exposure during early childhood should be carefully monitored by parents. Not all parents appear to follow these recommendations, as media and touchscreen devices are clearly becoming a common part of parents' and toddlers' everyday environment (Balbinot et al., 2016).

In a typical day, children under 5 in the United States spend ∼2 h using media (Rideout, 2017; Rideout and Robb, 2020). These estimates fail to capture background media exposure (Barr, 2019a,b). Such exposure comprises a large part of the child's waking life. Research on newer mobile technologies such as smartphones, now owned by 97% of American parents, and tablets owned by 75% of American households (Rideout and Robb, 2020), has lagged behind their rate of adoption. Despite almost universal ownership, data on mobile device use and parent–child outcomes is sparse; this paucity of data may be due, in part, to gaps in methodological expertise: mobile device use is difficult to measure reliably through traditional self-report methods used for TV (Bickham et al., 2015; Radesky et al., 2020). Increasing immersion and exposure is evident in other countries as well; digital media use in Sweden has significantly increased over the last 10 years (Swedish Media Council [SMC], 2019). From research on television, we know that high quality and developmentally appropriate TV media content is associated with better language and social outcomes. Poor quality, inappropriate, and unsupervised media use has been linked to poorer sleep, physical activity, and behavioral and cognitive outcomes (see Barr and Linebarger, 2017, for review). Despite the availability of such population-based survey data, concerns remain about the accuracy of global estimates derived from limited questions (Vandewater and Lee, 2009).

Most of the reported literature on infant media exposure comes from samples in the United States; only a few studies report on infants from different cultures and nationalities. A small but growing body of research on Italian infants' and toddlers' early access to media is emerging (Mascheroni and Ólafsson, 2014; Balbinot et al., 2016; Chindamo et al., 2019). Mascheroni and Ólafsson (2014) conducted a pilot qualitative study with in-depth interviews with 10 Italian families with a child in the 0–8 age group, aimed at exploring their experience with new technologies. The study focused on their (online) technological engagement as well as the potential risks and benefits associated with new technologies. The children who took part in this pilot study were mainly low or medium users of digital devices, as their screen time was below or around 2 h per day. The interviews conducted in Italy were consistent with prior research on preschool and primary school children, indicating that beginning at an early age children are immersed in media-rich experiences in their homes.

Balbinot et al. (2016) used a survey to collect data on attitudes and practices of Italian parents regarding the use of digital technologies by their children under 5 years. The survey was conducted through a questionnaire administered to parents via two different channels: family pediatricians ($n$ = 604 parents) and online via social networks and websites ($n$ = 745 parents). Consistent with findings from the United States (Rideout, 2017) and Hong Kong (Fu et al., 2017), Balbinot and colleagues' results showed that: (a) 30% of parents use digital technologies to keep their kids calm before their child's first birthday and over 50% before their child's second birthday; and (b) both the proportion of children using digital technologies and the duration of utilization increase rapidly over the first 3 years. These patterns were observed despite widespread concerns about the risks connected with early use of digital technologies reported from parents in the same survey (Balbinot et al., 2016). Cautious restricted use was more likely to be observed in parents belonging to the online data collection sample and was associated with higher educational level. The findings of the survey were the first to address use of digital technologies in young children in Italy. These data did not capture the content and context of early media exposure, and developmental outcomes were not assessed.

Previous cross-cultural research has shown that the widespread Italian cultural model encourages "emotional closeness" between parent and child (Axia and Weisner, 2002). Italian parents tend to give more importance to interdependence than German and American parents do (Hsu and Lavelli, 2005; Taverna et al., 2011), and they highly regulate children's routines and foster low autonomy. Moreover, Italian parents socialize very young children to respond to peers' emotions, especially crying (New, 1988; Molina et al., 2014).

Cultural practices influence multiple child behaviors, such as sleep, and these factors are interdependent. Theorists have highlighted the need for a transactional model for infants' sleep that integrates biology, individual family practices, and culture (Jenni and O'Connor, 2005; El-Sheikh and Sadeh, 2015). For example, El-Sheikh and Sadeh present a model of sleep based both on Bronfenbrenner's model of ecological context and on Sameroff's transactional model. They suggest a child's world is framed through a nest of contexts: the child, the intermediate, the social, and the cultural. Child temperament would fall within the child context, family sleep routines within the intermediate context, the role of media within the social context, and international differences comprise the cultural context. We utilize El-Sheikh and Sadeh's conceptual framework to consider how technology's social context and the immediate parenting practices may relate to parent reports of child sleep patterns in Italian families.

Cultural differences in parenting behaviors aimed at regulating children's sleep have been considered only recently (Mindell et al., 2010; Brambilla et al., 2017). Considerable cultural variability in approaches, expectations, training, and patterning of children's sleep have been documented in the literature (El-Sheikh and Sadeh, 2015; Jenni and O'Connor, 2005). Even in highly industrialized countries, such as the United States and Japan, parental beliefs and cultural preferences placing high value on individual independence (individualism) versus familial interdependence (collectivism) are reflected in different approaches, choices, and training of children's sleep. In Japan, for example, children and parents frequently co-sleep, while in the United States children are more likely to have a rigid bedtime "ritual" with the child sleeping in their own room under firm supervision (Wolf et al., 1996; Steger and Brunt, 2003). Bed-sharing and room-sharing are indeed involved in parental regulation of infants' sleep and are considered in a different light in the Italian versus American culture (Cortesi et al., 2004; Mileva-Seitz et al., 2017; Beijers et al., 2019). In a recent longitudinal study (Beijers et al., 2019) and in a review paper (Task Force on Sudden Infant Death Syndrome, 2011), no support was found for the notion that early parent–infant room sharing (without bed sharing) during the first 6 months of life has negative consequences on later child behavior. Beijers and colleagues proposed that maternal proximity associated with parent–infant room sharing may contribute to infant emotional and behavioral regulatory capacities. Access, regulation, and management of a child's experience with media is also likely to be shaped by parental values.

Transactional models have also highlighted the importance of a social context, such as technology, impacting child sleep (El-Sheikh and Sadeh, 2015). The availability and exposure to digital media in many households has implications for sleep routines (LeBourgeois et al., 2005). Correlational studies have reported that exposure to screen-based media in infancy, toddlerhood, and early childhood is negatively associated with duration and quality of sleep (Hale and Guan, 2015; Cheung et al., 2017; Ribner et al., 2019; Benita et al., 2020), and that sleep duration is positively associated with emotion regulation and cognitive skills in preschoolers (Bernier et al., 2013). Chindamo et al. (2019) found that everyday use of a tablet or smartphone increased the odds of a shorter total sleep time and a longer sleep onset latency, irrespective of other factors, such as temperament or traditional screen exposure. Benita et al. (2020) conducted a brief longitudinal study of 150 parents in the United Kingdom of 22- and 26-month-old infants. They found that parental use of media to calm 22-month-old infants at T1 predicted longer latency to fall asleep at 26 months (T2). They noted more media exposure at T1 was associated with less nighttime sleep at T2. This study controlled for a number of demographic variables and other factors known to be associated with sleep outcomes. But, to date, very few studies have yet investigated links between media and sleep in Italian infants.

Just as parents have different sleep practices, they have different reasons for using media–that is they differ in their instrumental media use as well. For example, parents typically regard video watching as an activity children can do alone, and they often use it to entertain the child while they are busy or to calm the child down when upset (Radesky et al., 2014b; Troseth et al., 2016). Researchers have demonstrated that adults may use media in order to calm young children, much like "comfort food," especially when parents perceive their children to have a more difficult temperament (McDaniel and Radesky, 2018). McDaniel and Radesky (2020) further investigated whether child externalizing behavior would predict later media use, mediated by parenting stress, and found that greater child externalizing behavior predicted greater parenting stress, which predicted increases in child media use.

Research on family media use has also shown that maternal depression is associated with both children's increased television exposure and less parental interaction during television viewing (Bank et al., 2012). Depressed mothers may use media and television as a coping mechanism, both in terms of their emotions and as a parenting tool. Even more recently, mounting evidence indicates that during the COVID crisis, screen time increased dramatically as a direct result of sudden decrease of caretaker availability, so media practices may be driven more by necessity and instrumental use than by preference (Hartshorne et al., 2021).

The current research provides a rich and detailed description of how Italian families with an infant or a toddler use media and arrange sleeping routines for their young children. The present study is part of a larger international collaborative project, the Comprehensive Assessment of Family Media Exposure (CAFE; see Barr et al., 2020). The collective decision to collect a more comprehensive measure of the family media ecology was based on the fact that prior research had taken a very narrow view of media usage and a number of conclusions had been drawn regarding the relation between media usage and child outcomes based on single estimates of media exposure (Barr, 2019b; Barr et al., 2020). In the present study, we investigated not only the amount of time that children were exposed to media, but also how and where media was used by both children and their parents. We examined these media variables in the context of household demographics and parent-reported child sleep patterns.

On the basis of the available literature, our study had two main research questions: first, to evaluate the dissemination and use of digital technologies in Italian families with an infant or a toddler and second, to examine the concurrent association between children's media use and parent-reported sleep practices and sleeping habits. We predicted that higher levels of overall media viewing would be associated with more parent-reported disruptions to sleep in children and that these associations would be higher for families with higher perceived stress. Research indicates that stress may interfere with media use (McDaniel and Radesky, 2020).

# MATERIALS AND METHODS

## Procedure and Participants

An online survey was distributed to Italian families who had at least one child between the ages of 8 and 36 months. The survey was created collectively by CAFE Consortium members, pooling knowledge from complementary disciplines of psychology, pediatrics, communications, and human development with the goal of developing more accurate early digital media assessments (Barr et al., 2020). The research team developed protocols for translations, de-identifying data, and data sharing across sites. The English version of the survey was translated into Italian by an Italian native and English fluent-speaking researcher. The researcher discussed the translation with the research group, and an independent English native speaker performed a back-translation. The researchers discussed the back-translation, and consensus was reached through discussion.

Families were recruited at community events, through childcare centers, and pediatricians' offices. Responses from 264 eligible families were collected. Participants were predominantly well-educated (45.7% completed high school and 46.7% completed University) mothers (5% fathers) with a mean age of 35 years (range 20–50 years). Of the sample 52% of the children were boys ($M_{age}$ = 23.1 months, SD = 8.3), and 48% girls ($M_{age}$ = 23.9 months, SD = 8.47). Families were recruited from central Italy and lived in non-urban (Rieti, Terni, and Ischia) and metropolitan areas (Rome). The survey was administered between January 2017 and April 2018. Parents participated on a voluntary basis and signed an informed consent form outlining the aim of the study before responding to the survey. The study complied with the ethical guidelines of the Italian Association of Psychology (AIP) and was approved by the Ethical Committee of the Department of Dynamic and Clinical Psychology of the Sapienza University of Rome. An additional total of 42 participants started the survey but were not included for the following reasons: responded in less than 10 min ($n$ = 29), completed less than 90% of the survey ($n$ = 9), and had children outside the 8–36 month age range ($n$ = 4).

## Materials

### Media Assessment

The survey consists of 58 items covering 10 topics relevant to the child's immediate media context, including household composition and demographics, parental mediation of media use, parent attitudes toward media use, and access to and regularity of use of different devices frequently used in the modern household. Demographic information included parental education, age of the survey participant, and composition of the household. All questions about the child's media usage were asked regarding the day prior to taking the survey in order to minimize memory biases. Participants were instructed to complete the survey with their 8- to 36-month-old in mind.

### Sleep Inventory

The second part of the survey consisted of the Brief Infant Sleep Questionnaire (BISQ), a 15-item parent-report survey, which has previously been shown to be a valid, psychometrically sound measure of infant sleep (Sadeh, 2004; Spruyt et al., 2008). Parents reported the amount of time infants slept during an average night (7 pm–7 am) and how long they napped during an average day (7 am–7 pm). Parents also reported the average number of times their infant woke during the night and the degree to which they considered their infant's sleep to be a problem. The sleep problem question was a three-point scale whose options were "a serious problem," ($n$ = 6) "a small problem," ($n$ = 38) and "not a problem" ($n$ = 206).

### Parental Stress

A measure of Parenting Stress Index (PSI) was added but only after the data collection had begun. It was administered to a subset of 134 parents. The Italian version of the PSI (Abidin, 1995; Guarino et al., 2008) is a 101-item parent self-report questionnaire that assesses parenting stress for three areas: parental distress (PD, $M$ = 25.16, SD = 8.30), parent–child dysfunctional interaction (P–CDI,$M$ = 18.97, SD = 4.95), and difficult child (DC, $M$ = 21.71, SD = 7.28).

# RESULTS

## Data Analysis Plan

All statistical analyses were conducted in IBM SPSS Statistics for Windows, version 26 (IBM Corp, 2019). We were interested in the association between media availability, media use, and parental media practices and their associations with parent-reports of children's sleep habits, parental sleep practices, and parenting stress. We therefore reported a series of descriptive statistics on the availability of devices in the home and time spent on different types of media, parental media practices and child sleep patterns and parental sleep practices and parenting stress. In our final series of analyses, we conducted broad exploratory first order correlations between parent reports of media use and sleep patterns. To better understand habits and contexts related to the usage of media, we then conducted regressions to examine what was associated with parental media practice, time spent with TV/DVD, time to fall asleep, and amount of time slept at night.

We visually inspected variables to assess whether they were normally distributed. For categorical variables, when we observed very uneven group sizes (e.g., $<$10 per cell), we collapsed categories to create new variables to avoid reporting spurious findings based on very small cells. Sleep variables: For the waking variable, we collapsed it into three categories, collapsing into 1, 2, or $>$2 wakings per night. For sleep as a problem, we collapsed the categories "sleep is a serious problem" and "somewhat of a problem" into one category. The variable was then reverse coded so that sleep is a problem = 1, and sleep is not a problem = 0. For continuous variables, both nighttime sleep and time to fall asleep, outliers that were more than 2SD below the mean were removed. Media variables: For the viewing TV/videos per day, we included the categories, "no TV," "$<$30 min," "30 min to 1 h," "1–2 h," and we collapsed the highest categories of "2–3 h" and "3–4 h" into a "$>$2 h" category. Because the usage of the smartphone during a bedtime routine was low, two categories were created (never or unlikely in one category and neutral to very likely as another category). Finally, we calculated a binary composite measure by combining reports of when parents used various forms of media to indicate whether they used any type of device to calm the baby (proportion of parents who used media to calm their child,

$M = 0.18$, SD = 0.38) and another binary composite measure to indicate whether parents endorsed using various forms of media to keep children busy (proportion of parents who used media to keep their child busy, $M = 0.25$, SD = 0.43).

## Number of Devices Available at Home

We provide detailed data about the availability of devices in Italian homes because this has not been reported by previous studies. We describe parent responses to two questions assessing the type and number of devices available at home and which of the devices they owned were regularly located in the child's room when the child was awake. These data are reported in **Table 1**. Almost all families owned a television (97%), personal computer (88%), and smartphone that can access the internet (90.02%). Approximately half the families owned a DVD player (51.5%), landline phone (47%), iPad or other tablet device (53.4%), educational game device (39%), or video game console (Nintendo Wii or Playstation) (42%). Few devices were regularly in the child's room, except a television (32.7%) and a smartphone (can access internet) (16.7%).

## Time Spent on Different Media by Children and During Routines

We now report estimated times children spent on the different media on the day before the survey. Parents were asked the following question: "Thinking about your child, yesterday, how much time did your child spend doing each of the following activities at home? Watch TV or DVDs, use the computer, read books, play video games on a console game player, use an iPad, iTouch, or similar device, and use a smartphone for things like texting, playing games, watching videos, or surfing the Internet (don't count time spent talking on the phone)." For each device, parents were asked to select one of the following options: not used, used for less than 30 min, used between 30 min and 1 h, used between 1 and 2 h, or used between 2 and 3 h. The TV/video viewing was the most frequently reported type of media in this age range, and it has been reported the most in prior research. To compare across different media types, we reported the % of children who viewed more than 30 min for all media categories. Watching television or DVDs were the most common activities.

**TABLE 1 |** Media available at home and regularly in child's room (total sample).

| Type of media | Available at home (%) | In child's room (%) |
|---|---|---|
| Television | 97 | 32.7 |
| DVD televised content | 6.1 | 0 |
| DVD player | 51.5 | 5.7 |
| Personal computer | 88 | 7.2 |
| Landline phone | 47 | 3.4 |
| Regular mobile phone | 19.7 | 1.5 |
| Smartphone | 90.2 | 16.7 |
| iPad, tablet of similar | 53.4 | 8.3 |
| MP3 player (iPod) | 24 | 1.5 |
| Educational game device | 39 | 3 |
| Video game console | 42 | 5.3 |

**TABLE 2 |** Percentages of children using different media for different amount of times in the day before the survey (total sample).

| Amount of time | Never | Less than 30 min | More than 30 min |
|---|---|---|---|
| Watch TV or DVDs | 28.4 | 25.0 | 46.6 |
| Use the computer | 90.9 | 3.4 | 5.7 |
| Read books | 45.1 | 30.3 | 24.6 |
| Play video games | 92.8 | 1.1 | 6.1 |
| Use an iPad, tablet or similar | 70.1 | 17.4 | 12.5 |

*We analyze the TV variable in five categories, the three listed and two additional categories (>1 h, >2 h).*

**Table 2** shows that almost half the children (46.6%) spent more than 30 min watching television or DVDs, and a quarter (24.6%) spent more than 30 min reading books. Fewer children spent more than 30 min using a tablet (12.5%), playing video games (6.1%), or using a PC (5.7%). Of the children watching television or DVDs for more than 30 min, 26.9% watched between 30 min to 1 h, 12.1% between 1 and 2 h, 6.4% more than 2 h per day.

Parents used their devices infrequently during child routines, defined as events that occur every day with a definite scope and function, such as meals or bedtime (see **Table 3**). When asked how likely parents were to use their phone or other devices, about 3/4 of parents reported they never used devices during dressing (79.5%) or bedtime routines (70%) and never or were not likely to use devices during mealtimes (75.9%), playtime (75.7%), and during traveling (79.9%).

## Child Sleep Patterns and Parental Sleep Practices

Parents completed the BISQ (Sadeh, 2004) and answered the following questions regarding their children's sleeping habits. "How much time does your child spend in sleep during the night (between 7 in the evening and 7 in the morning)?", "Average number of wakings per night," "How much time does your child spend in sleep during the day (between 7 in the morning and 7 in the evening)?", "How long does it take to put your baby to sleep in the evening?", "When does your baby usually fall asleep for the night?", "How long does it take to put your baby to sleep in the evening?", and "Do you consider your child's sleep as a problem?". Parents reported that it took an average of 1.42 (SD = 1.88) hours to put the baby to sleep in the evening. Children were reported to sleep on average 8.90 h (SD = 1.44, min = 1, max = 12) at night and 2.69 h (SD = 1.93, min = 1, max = 11) during the day. Most parents (82.4%) did not consider their child's sleep a problem. Almost 60% of children slept in their parents' room and many fell asleep in bed near the parent (52.3%). The sleep position and how children fell asleep varied across children (see **Table 4**).

## Relation Between Media Use and Sleep

Zero-order correlations (Spearman's Rho, **Table 5**) showed that having devices located in the child's room while awake was associated with taking longer to fall asleep ($r = 0.22$, $p = 0.006$ and going to sleep later at night ($r = 0.31$, $p < 0.001$). Interestingly,

**TABLE 3 |** Parental practices with media during child routines.

| Parental device usage | Never (%) | Not likely (%) | Neutral (%) | Likely (%) | Very likely (%) |
|---|---|---|---|---|---|
| During meals | 38.3 | 37.1 | 15.1 | 8.6 | 0.4 |
| Getting child dressed | 79.5 | 15.3 | 3.2 | 2 | 0.0 |
| During playtime | 35.8 | 40.9 | 19.3 | 3.9 | 0.0 |
| During bedtime routine | 70.0 | 16.2 | 6.7 | 5.1 | 2.0 |
| When driving or on public transit | 53.8 | 26.1 | 9.6 | 10.0 | 0.4 |

**TABLE 4 |** Parental practices with sleeping.

| Sleep habits | | Percentage |
|---|---|---|
| Location | Separate room from parents' | 37.1 |
| | Crib in parents' room | 40.9 |
| | In parents' bed | 18.6 |
| Position | Belly | 32.2 |
| | Side | 45.5 |
| | Back | 25.4 |
| Method | While feeding | 10.6 |
| | While being rocked | 10.2 |
| | While being held | 15.9 |
| | In bed alone | 17.0% |

**TABLE 5 |** Bivariate correlations (Spearman Rho) between number of different media present at home and time spent sleeping.

| | Number of devices | Devices located in child's room awake |
|---|---|---|
| Hours of sleep at night | −0.04 | −0.12 |
| Average wakings | 0.06 | −0.07 |
| Hours of sleep during the day | 0.13 | 0.10 |
| Time to fall asleep at night | 0.11 | 0.22** |
| Time going to bed | 0.04 | 0.31** |
| Child sleep is a problem | 0.138* | 0.04 |

*$p < 0.05$, **$p < 0.01$.

**TABLE 6 |** Bivariate correlations (Spearman rho) between time spent on different media and time spent sleeping.

| | TV | Smartphone | Book | Tablet |
|---|---|---|---|---|
| Hours of sleep at night | −0.22** | −0.11 | 0.10 | −0.19** |
| Average wakings | −0.03 | 0.09 | 0.006 | −0.04 |
| Sleep hours during the day | 0.02 | −0.04 | −0.14* | 0.06 |
| Time falling asleep at night | 0.19** | 0.03 | −0.13* | 0.05 |
| Time going to bed | 0.36** | 0.19* | −0.13* | 0.06 |
| Child sleep is a problem | 0.05 | 0.16* | 0.11 | 0.02 |

**$p \leq 0.01$; *$p \leq 0.05$.

parents perceived sleep to be more of a problem when there were more devices available in the home ($r = 0.14$, $p = 0.03$).

Turning to amount of sleep related to media use, Zero-order correlations (Spearman's Rho, **Table 6**) showed that time spent watching TV ($r = -0.23$, $p < 0.001$) and using a tablet ($r = -0.2119$, $p = 0.004$) was negatively associated with hours of sleep at night. Time spent watching TV/DVDs ($r = 0.36$, $p < 0.001$) and on a smartphone ($r = 0.19$, $p = 0.003$) was associated with going to sleep later at night. Time spent with books was associated with going to sleep earlier at night ($r = -0.13$, $p = 0.045$), taking less time to fall asleep ($r = -0.13$, $p = 0.045$) and sleeping less during the day ($r = -0.14$, $p = 0.003$). Night waking was not associated with any outcomes and will not be considered further.

## Relations Between Parenting Media Practices, Child TV Use, and Sleep Patterns

Our overarching goal was to take a more comprehensive approach to assessing associations between contextual factors, family media ecology, and sleep patterns. Prior research had ignored a number of potential factors. We therefore conducted an exploratory correlational analysis to examine whether demographic factors, TV usage patterns, parental media practices (using media to calm or keep the child busy), parental stress, and parent-reported sleep patterns (time to fall asleep, sleep duration) were associated with each other. All first order associations are presented in **Table 7**. A more in depth analysis aimed at identifying factors associated with the amount of TV/video viewing, use of strategies (to calm or keep busy), amount of time to fall asleep, and amount slept was reported in a series of regressions. The predictor variables were chosen based on whether these variables had previously been observed to be associated in the literature and whether they were theoretically important to the development of sleep or media usage. Given the fact that comprehensive measures of family media ecology had not previously been measured, we also took a data-driven approach by only including variables that showed a correlation to the dependent variables. To avoid problems of collinearity, we did not include all associated variables; if two variables were highly associated with one another, then just one variable was chosen for the regression that was more closely associated in the first order analysis. For example, age was regressed on the amount of TV/video usage because only this dependent variable was correlated with age. We tested all models for collinearity and did not find any evidence of collinearity (for all predictors the VIFs < 2).

### Correlational Analysis

Due to the mix of continuous and rank variables, we ran first order Spearman's Rhos and Pearson $r$ correlations across these variables (see **Table 7**). It is important to note that sample size varies due to the fact that only a subset of participants completed the PSI, and some participants missed some questions. The $n$ per correlation is therefore reported. **Table 7** shows that there

**TABLE 7 |** Top diagonal Pearson's correlation and bottom diagonal Spearman's Rho to allow for the combination of rank and continuous variables.

| | Age (months) | Ed (rank) | Fall asleep (cont.) | Time sleep (cont.) | TV/DVDs (rank) | Busy (rank) | Calm (rank) | Media routine (rank) | PSI distress (Cont.) | PSI difficult |
|---|---|---|---|---|---|---|---|---|---|---|
| Age (months) | | −0.13* | 0.05 | −0.075 | 0.26** | 0.18** | 0.11 | 0.09 | 0.12 | 0.22* |
| *N* | 271 | 271 | 256 | 248 | 267 | 271 | 271 | 257 | 134 | 134 |
| Education | −0.09 | – | −0.18** | 0.11 | −0.15* | −0.21** | −0.19** | −0.14* | −0.09 | −0.17* |
| *N* | 271 | | 260 | 248 | 267 | 276 | 276 | 257 | 134 | 134 |
| Time to fall asleep | 0.04 | −0.17** | – | −0.16* | 0.19** | 0.11 | 0.15* | 0.08 | 0.15 | 0.18* |
| *N* | 256 | 260 | | 247 | 254 | 272 | 272 | 251 | 133 | 133 |
| Amount of sleep (min) | −0.08 | 0.10 | −0.14 | – | −0.22** | 0.05 | −0.01 | 0.09 | −0.04 | −0.13 |
| *N* | 248 | 248 | 247 | | 247 | 248 | 248 | 244 | 133 | 133 |
| Exposure to TV/DVDs | 0.21** | −0.10 | 0.14* | −0.17** | – | 0.20** | 0.13* | −0.01 | 0.22** | 0.25** |
| *N* | 267 | 267 | 254 | 247 | | 267 | 267 | 256 | 134 | 134 |
| Busy | 0.17** | −0.19** | 0.12* | 0.03 | 0.22** | – | 0.40** | 0.15* | 0.27** | 0.29** |
| *N* | 271 | 276 | 272 | 248 | 267 | | 306 | 257 | 134 | 134 |
| Calm | 0.10 | −0.16** | 0.13* | 0.01 | 0.18** | 0.40** | – | 0.09 | 0.21* | 0.23** |
| *N* | 271 | 276 | 272 | 248 | 267 | 306 | | 257 | 134 | 134 |
| Media routine | 0.09 | −0.13* | 0.13* | 0.08 | −0.02 | 0.15* | 0.10 | – | 0.31** | 0.29** |
| *N* | 257 | 257 | 251 | 244 | 256 | 257 | 257 | | 131 | 131 |
| PSI distress | 0.13 | −0.08 | 0.14 | −0.04 | 0.19* | 0.28** | 0.18* | 0.28** | – | 0.49** |
| *N* | 134 | 134 | 133 | 133 | 134 | 134 | 134 | 131 | | 134 |
| PSI difficult | 0.21* | −0.12 | 0.17* | −0.13 | 0.27** | 0.29** | 0.22* | 0.28** | 0.47** | – |
| *N* | 134 | 134 | 133 | 133 | 134 | 134 | 134 | 131 | 134 | |

**p* < 0.05; ***p* < 0.01.

were a number of significant (although modest) associations between how media was used in households (amount child viewed, parental usage, use to calm or keep busy) and sleep variables (time to fall asleep and minutes slept).

*What is associated with the use of media to calm the child or keep the child busy?* As noted above, a binary variable was created for use of either strategy. We therefore conducted logistic regressions to predict whether parents were likely to use either strategy. For the prediction of using a device to keep the child busy, we included age of the child (months), parental education, the PSI DC, and the PSI general parenting distress factor.

The overall model is significant at the 0.01 level, according to the model chi square ($\chi^2 = 26.70$, df = 4). The results of the logistic regression for keeping a child busy revealed that age of the child was significant, and there was a trend for the PSI general distress factor associated with parental use of media to keep a child busy (**Table 8**). For age, the odds ratio of 1.08 ($p = 0.002$) indicated that for each month of age, parents were 1.08 times more likely to use media to keep their children busy (**Table 8**).

**TABLE 8 |** Logistic regression associated with parental reports of using device to keep a child busy.

| | *B* | SE | *p* value | Odds ratio |
|---|---|---|---|---|
| Age (months) | 0.076 | 0.024 | 0.002 | 1.08 |
| Education | 0.019 | 0.297 | 0.949 | 1.02 |
| General distress | 0.048 | 0.026 | 0.069 | 1.049 |
| Difficult child | 0.052 | 0.032 | 0.102 | 1.053 |

*B: unstandardized estimates; SE: standard error.*

The accuracy of the prediction of this logistic regression was good, as 72.4% of participants were correctly classified according to the considered predictors in the regression. Although the results of the logistic regression for using devices to calm a child down showed a similar pattern of results, the classification analysis indicated that the model was not a good fit and did not provide a good prediction of the parent report, and therefore it is not reported.

*What is associated with television usage?* We conducted a linear regression that included age (months), education, parental use of devices to calm the child down, parental use of devices to keep the child busy, and DC factor from the PSI on the television/video use variable. This regression model explained a significant portion ($R^2 = 0.48$) of estimated television/DVD use variability, $F(5, 128) = 7.67$, $p < 0.0001$ (see **Table 9**). Parents who reported using media to calm their child or keep them busy were more likely to report that their children viewed more TV/videos the previous day. There was a trend for parents of older children to use television longer.

*What is associated with the amount of night time sleep?* We conducted a linear regression that included use of media to keep the child busy, time to fall asleep, and television/DVD usage on time spent sleeping at night (in min). The variance explained by the regression model was significant albeit smaller than that of the previous model ($R^2 = 0.05$), $F(3, 242) = 4.36$, $p < 0.005$ (see **Table 10**). Children who took longer to fall asleep and who viewed more TV/videos were reported to sleep for less time at night. We also tested another model that included the sum of devices available when the child was awake. However, this variable was not significant.

**TABLE 9 |** Regression of associations with the amount of TV/DVDs viewed per day.

| | Unstandardized coefficients | | Standardized | | |
|---|---|---|---|---|---|
| | ***B*** | **SE** | **β** | ***t*** | ***p* value** |
| (Constant) | | | | 3.61 | 0.000 |
| Age (months) | 0.032 | 0.017 | 0.160 | 1.88 | 0.06 |
| Education | −0.090 | 0.199 | −0.036 | −0.45 | 0.65 |
| PSI difficult child | 0.028 | 0.019 | 0.120 | 1.44 | 0.15 |
| Calm the child down | 0.661 | 0.284 | 0.187 | 2.33 | 0.02 |
| Keep child busy | 0.826 | 0.284 | 0.247 | 2.91 | 0.004 |

**TABLE 10 |** Regression of associations with the number of minutes slept per night.

| | Unstandardized coefficients | | Standardized | | |
|---|---|---|---|---|---|
| | ***B*** | **SE** | **β** | ***t*** | ***p* value** |
| (Constant) | 610.25 | 18.87 | | 32.34 | 0.00 |
| Use media to keep child busy | 15.82 | 11.39 | 0.09 | 1.39 | 0.17 |
| Estimated TV/video viewing | −9.05 | 3.28 | −0.18 | −2.76 | 0.01 |
| Time to fall asleep | −0.28 | 0.14 | −0.13 | −2.03 | 0.04 |

# DISCUSSION

Considering media use practices in Italian children between 8 and 36 months, on a typical day, parents reported that half of the children spent more than 30 min watching television or DVDs, while 24% spent more than 30 min listening to caregivers read books. This pattern of results is consistent with similar census reports from the United States conducted at the same time (Rideout, 2017). A number of factors were examined to assess which parents were more likely to expose their children to more media, which strategies they used, and how these patterns were related to parents' reports of their children's sleep.

Our descriptive analyses showed the Italian households were media saturated like those in other parts of Europe and the United States and that the amount of media usage was similar to other recent reports in Western countries (Rideout and Robb, 2020). We found that the highest category of media use was for viewing prerecorded video content on TV/DVDs. This is consistent with reports from the United States where 85% of the media that children under 5 consume is prerecorded video content (Rideout, 2017). Higher use of TV/DVDs was associated with instrumental parenting practices of keeping the child busy or calming the child down. The focus of the present study was on how media usage was associated with perceived sleep patterns which we discuss next.

## Media and Sleep

When we consider the results obtained with the measures of the BISQ, media use was associated with sleeping patterns in our sample. First of all, when more devices were available to the child in their rooms while they were awake, parents reported that children went to sleep later, had less nighttime sleep, and slept more during the daytime. With time spent with books, the opposite pattern occurred with less daytime sleep and going to sleep earlier at night. Also, parents perceived sleep to be more of a problem when there were more devices available in the home. Previous research has demonstrated that children who sleep more during the day – at this developmental age – tend to sleep less during the night (Anders et al., 2012; Nakagawa et al., 2016) and are more slowly regulating their sleeping routines along with the circadian timing of day–night cycles. These findings suggest that greater access to devices may be associated with lower regulation of sleep patterns. Having portable media devices in the child's room – much easier today than in the past – makes devices very strong attractors of the child's attention. It is possible that having more media available displaces other non-screen based activities (such as solitary playing with blocks, singing, looking at books, symbolic play, playing in a structured game with a social partner, or even sleeping). Our age range included younger children with more regular daytime naps as well as older children transitioning out of regular daytime naps. It is possible that during this transition period older children may be more vulnerable to the availability of devices in their home and disrupted sleep patterns. But using the current dataset, it is not possible to distinguish between an indirect explanation of age-related vulnerability to sleep disruption or a direct explanation that the number of devices resulted in more media usage, which directly disrupted sleep patterns. This pattern of results, however warrants further investigation.

Parental use of media to keep the child busy and viewing more television per day was also associated with less sleep at night. Our results are consistent with those of Benita et al. (2020) who reported that more exposure to media during the day was associated with less nighttime sleep. They are also consistent with Brockmann et al. (2016) who found that the presence of a TV set in the child's bedroom was associated with significant reductions in the quality of young children's sleep and that evening exposure to TV was associated with significantly worse sleep quality. Based on the current pattern of results, parents should consider having a designated place at home dedicated to media use, separated from the space where children usually play and sleep.

Finally, considering the time children spent on different kinds of media, the current study documented a negative association between hours children sleep at night and time spent on a typical day watching TV or using an iPad. Moreover, time spent watching TV or on a smartphone on a typical day was positively associated with going to bed later. Sleep fragmentation, measured by the number of night awakenings reported by parents, was not associated with media use in our data. However, it is important to note that parents often underestimate nighttime wakings, and we did not collect actigraphy data, which is the "gold standard" for monitoring sleep and a future direction for this work (Mantua et al., 2016; Sadeh, 2004). Our pattern of results is quite consistent with another study of touchscreen usage and changes in sleep patterns (Cheung et al., 2017). These researchers also did not report that touchscreen use was associated with changes in nighttime wakings. However, Cheung et al. (2017) did report that higher touchscreen use was associated with sleep problems in infants and toddlers between 6 and 36 months of age. Although there were indications from first order correlations, our results did not, however, reveal associations between media availability, usage, or parental strategies with disruptions to night waking or latency to fall asleep. It is not clear from our pattern of results whether the timing of exposure to media was associated with nighttime sleep or not. Further empirical research should examine whether media exposure closer to bedtime is a better predictor of sleep disruption.

Going to bed and falling asleep requires that the toddlers soothe themselves during bedtime and reduce their arousal. Interestingly, Benita et al. (2020) proposed that parental use of media as a child regulatory strategy may particularly affect the regulatory component of sleep, as measured by latency to fall asleep, and investigated empirical evidence in this direction using a longitudinal design. They indeed found that maternal use of media to regulate child distress predicted difficulties in child self-soothing abilities like time for falling asleep (sleep latency) and that total screen time negatively predicted sleep duration (Benita et al., 2020). However, although our first order correlations suggested a similar pattern of results when we included other sleep practices, the use of media as a regulatory strategy was no longer significant.

Four potential mechanisms have been hypothesized to explain the association between media use and sleep (Cheung et al., 2017). First, screen time may directly displace the time the children have available for sleep, leading to later bedtime and shorter nighttime sleep duration. Second, the content of media may be scary or arousing, resulting in longer times to fall asleep and reductions in the quality of sleep due to more nighttime wakings. Third, the bright blue light of screens may suppress the release of melatonin affecting the circadian timing (LeBourgeois et al., 2017). Widespread implementation of automatic blue light filters were added to Android and Apple phones by 2015, before the present data were collected (Apple Insider, 2016). It is possible that older devices that had not been updated did not include these filters. Fourth, temperamental traits, such as impulsiveness and sensation seeking, may correlate with irregular sleep patterns and lead to higher exposure to screen media. In our regression analyses we also found that parent report on the PSI DC factor was associated with more parental use of media and more frequent use of media to keep the child busy as well as with a longer latency to fall asleep. These findings are consistent with other reports showing complex bidirectional interactions between media use, child temperament, and sleep (El-Sheikh and Sadeh, 2015; McDaniel and Radesky, 2018; Ribner et al., 2020). Future longitudinal studies should clarify the direction of the effects and the mechanisms between media, temperament, and sleep underlying these associations using direct measures of sleep tracking such as actigraphy (El-Sheikh and Sadeh, 2015).

Finally, it may be useful to consider the negative association that emerged in our data between the number of hours the child sleeps during the day and time spent in a typical day listening to caregivers read books. Children sleeping a lot during the day, rather than at night, may be missing opportunities for shared reading, an activity that may be especially important to socialize children to culture, to personal narratives, and to shared meanings (Duursma et al., 2008). As noted before, further studies should dedicate more attention to the context in which children's shared book reading occurs with parents, as this routine may occur in the afternoon, as part of a shared play activity, before nap times, or as a routine for preparing to go to bed. Having more information from families about the context of media use, including joint media engagement with digital devices and shared book reading, may provide researchers with new insight on how screen time is associated with sleeping practices. These findings will have implications for recommendations for parents and childcare providers regarding integration of digital media in children's lives. Examining how factors such as sleep, temperament, and parental media usage are associated both with one another and with household media use patterns will aid in the development of evidence-based recommendations that support shared activity, promote cognitive development, and do not disturb sleep (see El-Sheikh and Sadeh, 2015).

## Cultural Aspects of Children's Sleep Behavior

Traditionally, sleep has been seen as a biological regulatory mechanism (Aeschbach et al., 2003). But more recently, researchers have begun to consider that many aspects of sleep are influenced by cultural norms, and these norms may have an impact on children's sleep behaviors. According to transactional theorists, culture influences how we sleep, with whom we sleep, and where we sleep, as well as sleeping and waking times (Jenni and O'Connor, 2005; El-Sheikh and Sadeh, 2015). It is very important therefore to consider how parental strategies interact with the individual child's sleep biology.

Within the Italian culture, parents tend to have infants sleep in their rooms with them, irrespective of the availability of separate rooms, in contrast with American parents who tend to put children to bed in separate rooms (Wolf et al., 1996). Also, Italian children tend to have less rigid bedtime schedules, less consistent bedtime rituals, and later bedtimes than American ones. This is because in Italy, children often participate in the family's evening life, including a late dinner, and often fall asleep before they are put to bed (New and Richman, 1996; Ottaviano et al., 1996). Moreover, infant feeding practices should also be taken into account, since nursing on demand may interact with sleeping habits. Nursing on demand may be less stressful for mothers who co-sleep with their infants, because this practice does not require their full arousal during the night (Morelli et al., 1992). These parental practices reflect the prevalence of a cultural model encouraging emotional closeness in Italy (Hsu and Lavelli, 2005; Molina et al., 2014).

In our data, different cultural aspects deserve attention. We turn now to consider Italian vs. American parental responses, using American participant's data from the same survey (CAFE) to highlight different cultural practices and parental beliefs about sleep, following the transactional model offered by El-Sheikh and Sadeh (2015). First of all, in relation to sleep arrangement, only 37.1% of the Italian children in our sample were sleeping in a separate room from their parents (vs. 58% of American ones in the same age range), 40.9% of them slept in a crib in parents' room (vs. 19% American ones), and 18.6% in their parents' bed (vs. 9.8% of the American ones). Considering how children are used to falling asleep, the starkest differences are that only 17% fell asleep in bed alone (vs. 68% of Americans), and 52% in bed near a parent (vs. 23% Americans). Where the child slept was associated with latency to fall asleep and may also contribute to the relatively long latency to fall asleep in the current study. However, most parents reported that their child slept well; 82.4% of the parents in Italy stated that they did not consider their child's sleep a problem, while 14.4% considered it a small problem, and only 2.3% considered it a serious problem. Finally, 18% of Italian parents tend to use media to calm their child versus 44% of American parents. In relation to mealtime, another important everyday routine, Italian and American parents diverge as well, as only 25% of Italian parents tended to use media during mealtimes compared to 38% of American ones. Preliminary research has demonstrated associations between parent mobile device use and fewer parent–child verbal and non-verbal interactions (Radesky et al., 2015) and possibly more parent–child conflict (Radesky et al., 2014a). These disruptions to ongoing interactions due to parental media usage have been termed "technoference" (McDaniel and Radesky, 2018). The present findings suggest that Italian infants may be less likely to experience technoference during their everyday routines. Because responsive parent–child interactions are crucial to healthy social-emotional development, particularly for children growing up in adversity (Johnson et al., 2013), more research is needed to examine how mobile device use throughout a family's day relates to child outcomes. When asked if they used media to keep their child busy, 25% of Italian vs. 58% of American parents affirmed that they do so. The use of media to calm the child and to keep the child busy was associated with media usage and sleep patterns in our sample, but the cultural difference in the use of these strategies and how they are related to sleep patterns will be important to compare directly in future studies.

These results are in line with previous work documenting significant differences in parenting behaviors related to sleep across cultural groups (Mindell et al., 2010; Brambilla et al., 2017). The picture is complex and denotes that Italian parents on the one hand tend to be more involved in their children's bedtime routines. They share beds and rooms with their children more in comparison to American parents. On the other hand, they tend to use less media during routines, such as bedtime and mealtime, and less media to calm down and to keep their children busy compared to American parents. So it appears that the Italian style of child rearing tends to have more interdependent sleeping practices and tends to protect children from media intrusion during these routines.

Further attention should be given to how these parental behaviors, in concert with other factors, may influence developmental outcomes. Correlation does not imply causation, rather parenting behaviors and infant sleep are bi-directional in nature (see also Sadeh et al., 2010; El-Sheikh and Sadeh, 2015). Specifically, both parenting behaviors and culture determine how infant sleep patterns develop, and infants with more difficult sleep patterns may require more parental involvement within a given culture.

## Limitations of the Study and Final Remarks

In this study, using parental self-reports, we investigated how media use was associated with parent-reported child sleep patterns. We included a detailed range of specific measures related to media exposure, encompassing time spent by the child on different devices and arrangement of the media at home, as well as access to and regularity of use of different devices frequently used in the modern household. We carefully avoided questions asking parents to estimate mean media use in the last month or week, as these kind of questions require the respondent to make a complex judgment in few seconds, and we only asked them to estimate amount of time spent on media yesterday, to enhance accuracy in memory (Vandewater and Lee, 2009).

In spite of the substantial increase in usage of new technologies by very young children, research regarding the 0–3 age group has been sparse. The present study replicates and extends prior findings often concentrated on English-speaking United States and United Kingdom families to Italian families. The present findings demonstrate that Italian infants grow up in a rich technological environment, and that they are frequently exposed to media from early in development. These patterns of media exposure are associated with sleeping habits. Correlations found between media devices and sleep outcomes are weak to moderate but they add to a growing body of literature demonstrating small but significant associations between media use and sleep patterns during early childhood. We hope that these results will be useful for evidenced-based recommendations for Italian parents on the benefits and challenges associated with young children's use of new media, and given early exposure, should be provided to parents within the first months of life (Balbinot et al., 2016).

Some limitations should be noted. First, our research is based on cross-sectional data, therefore, a directional relationship between media use and sleep patterns could not be drawn. Moreover, our findings are based entirely on self-reports. We cannot exclude the possibility that parents responded on the basis of social norms, stereotypes, social desirability in a given culture. We plan to use our CAFE assessment tool (see Barr et al., 2020) which includes both surveys and direct measures to assess media use and sleep patterns. Future longitudinal studies using both direct measures and self-reports will be needed to clarify the direction of the relationships that were observed.

One aspect not addressed in our study, but that deserves more attention, is how parents use technology themselves and how parents "teach' infants rules about using technology. Technology has an impact on children but parental style mediates this effect (Zack and Barr, 2016; Kirkorian et al., 2019). Along these lines, Radesky et al. (2014a) documented that American parents vary a lot in the degree of absorption with their device during the routine of lunch in fast food restaurants. For some parents it can be very difficult to interact with the child, as they tend to be much more involved and engaged with the device rather than with their child. The present study provides some initial suggestions that Italian children may be more protected from technoference than American children are, but that this was not the case for all children. Additional longitudinal cross-cultural examination of these patterns particularly with regard to media usage during everyday routines is warranted.

The present study addressed the question of how early media exposure can be associated with an important developmental milestone: achieving the self-regulatory ability of sleep. Given the rapid evolution of technology, it will be useful to take lessons learned from shared book reading to apply to technology. Specifically, associations between media and sleep may differ based on the context in which media is used. More media use was associated with strategies of keeping the child occupied or calming the child and were not always associated with desirable outcomes. An alternative strategy is joint media engagement, by infants and parents, with affordances that are similar to those offered by the format of shared book reading. When sharing a book with an adult, children not only acquire knowledge about the story but also learn about their own personal narrative, learn to connect the images in the book with the outside world, learn to make predictions about characters and their feelings, and to label and remember their own past emotions in joint engagement with the parent. Creating devices and smart apps that promote and engage parents more in this type of interaction may be of special importance, especially for children growing up in poorly resources homes, who have parents with little education, and that tend to read less than parents with higher levels of formal education (Hirsh-Pasek et al., 2015). Since we know that modern low-income families tend to have and use smartphones (Kabali et al., 2015), new technology could be developed to promote joint media engagement (Hirsh-Pasek et al., 2015; Barr, 2019b), which may also have the added benefit of decreased sleep disruption. These new affordances in technology that promote joint media engagement may also be relevant in periods of emergencies, such as the one we have been experiencing in the past months due to the COVID-19 pandemic, when many children and their families worldwide have been forced to be at home for long periods.

## DATA AVAILABILITY STATEMENT

The datasets presented in this article will not be made publicly available. We have built a data sharing platform and will be able to share secure access to the dataset once the platform has been built and data integrated from Consortium members. Requests to access the datasets should be addressed to the corresponding author. Requests to access the datasets should be directed to FB, francesca.bellagamba@uniroma1.it.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethical Committee of the Department of Dynamic and Clinical Psychology, and Health Studies, Faculty of Medicine and Psychology, Sapienza University of Rome. The participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

## FUNDING

This project was supported by a grant to RB by the Children and Screens: Institute of Digital Media and Child Development Inc. Children and Screens: Institute of Digital Media and Child Development is a 501C(3) non-profit organization founded by Dr. Pamela Hurst-Della Pietra. Publication fees will be provided by the Sapienza University of Rome.

## ACKNOWLEDGMENTS

Preliminary findings were presented at the XXXI Italian National Congress in Developmental Psychology, September 17–19, 2018, Torino, Italy. Special thanks to families who participated in this research and to the undergraduate students Maria Francesca Buzzi, Giorgia Marini, Chiara Marzullo, and Aurora Tarricone for helping with subject recruitment.

## REFERENCES

Abidin, R. R. (1995). *Parenting Stress Index*. Lutz, FL: Psychological Assessment Resources.

Aeschbach, D., Sher, L., Postolache, T. T., Matthews, J. R., Jackson, M. A., and Wehr, T. A. (2003). A longer biological night in long sleepers than in short sleepers. *J. Clin. Endocrinol. Metab.* 88, 26–30. doi: 10.1210/jc.2002-020827

Anders, T., Iosif, A. M., Schwichtenberg, A. J., Tang, K., and Goodlin-Jones, B. (2012). Sleep and daytime functioning: a short-term longitudinal study of three preschool-age comparison groups. *Am. J. Intellect. Dev. Disabil.* 117, 275–290. doi: 10.1352/1944-7558-117.4.275

Apple Insider (2016). *How to Use Apple's Night Shift Mode in iOS 9.3*. Available online at: https://appleinsider.com/articles/16/03/24/how-to-use-apples-new-night-shift-mode-in-ios-93 (accessed March 24, 2016).

Axia, V. D., and Weisner, T. S. (2002). Infant stress reactivity and home cultural ecology of Italian infants and families. *Infant Behav. Dev.* 25, 255–268. doi: 10.1016/s0163-6383(02)00099-1

Balbinot, V., Toffol, G., and Tamburlini, G. (2016). Tecnologie digitali e bambini: un'indagine sul loro utilizzo nei primi anni di vita. *Med. Bambino* 35, 631–636.

Bank, A. M., Barr, R., Calvert, S. L., Parrott, W. G., McDonough, S. C., and Rosenblum, K. (2012). Maternal depression and family media use: a questionnaire and diary analysis. *J Child Fam. stud.* 21, 208–216. doi: 10.1007/s10826-011-9464-1

Barr, R. (2019a). "Parenting in the digital age," in *Handbook of Parenting: The Practice of Parenting*, 3rd. Edn, Vol. 5, ed. M. Bornstein (New York, NY: Routledge), 380–408. doi: 10.4324/9780429401695-13

Barr, R. (2019b). Growing up in the digital age: early learning and family media ecology. *Curr. Dir. Psychol. Sci.* 28, 341–346. doi: 10.1177/0963721419838245

Barr, R., and Linebarger, D. N (eds) (2017). *Media exposure During Infancy and Early Childhood: The Effect of Content and Context on Learning and Development*. New York, NY: Springer.

Barr, R., Kirkorian, H., Radesky, J., Coyne, S., Nichols, D., Blanchfield, O., et al. (2020). Beyond Screen Time: a synergistic approach to a more comprehensive assessment of family media exposure during early childhood. *Front. Psychol.* 11:1283. doi: 10.3389/fpsyg.2020.01283

Beijers, R., Cassidy, J., Lustermans, H., and de Weerth, C. (2019). Parent–infant room sharing during the first months of life: longitudinal links with behavior during middle childhood. *Child Dev.* 90, 1350–1367. doi: 10.1111/cdev.13146

Benita, N., Gordon-Hacker, A., and Gueron-Sela, N. (2020). Sleep through toddlerhood, the distinct roles of overall media use and use of media to regulate child distress. *J. Dev. Behav. Pediatr.* doi: 10.1097/DBP.0000000000000836 E-PubAhead of Print,

Bernier, A., Beauchamp, M. H., Bouvette−Turcot, A. A., Carlson, S. M., and Carrier, J. (2013). Sleep and cognition in preschool years: specific links to executive functioning. *Child Dev.* 84, 1542–1553. doi: 10.1111/cdev.12063

Bickham, D. S., Hswen, Y., and Rich, M. (2015). Media use and depression: exposure, household rules, and symptoms among young adolescents in the USA. *Int. J. Public Health* 60, 147–155. doi: 10.1007/s00038-014-0647-6

Bozzola, E., Spina, G., Ruggiero, M., Memo, L., Agostiniani, R., Bozzola, M., et al. (2018). Media devices in pre-school children: the recommendations of the Italian pediatric society. *Ital. J. Pediatr.* 44, 69.

Brambilla, P., Giussani, M., Pasinato, A., Venturelli, L., Privitera, F., del Giudice, E. M., et al. (2017). Sleep habits and pattern in 1-14 years old children and relationship with video devices use and evening and night child activities. *Ital. J. Pediatr.* 43:7.

Brockmann, P. E., Diaz, B., Damiani, F., Villarroel, L., Núñez, F., and Bruni, O. (2016). Impact of television on the quality of sleep in preschool children. *Sleep Med.* 20, 140–144. doi: 10.1016/j.sleep.2015.06.005

Cheung, C. H., Bedford, R., De Urabain, I. R. S., Karmiloff-Smith, A., and Smith, T. J. (2017). Daily touchscreen use in infants and toddlers is associated with reduced sleep and delayed sleep onset. *Sci. Rep.* 7:46104.

Chindamo, S., Buja, A., DeBattisti, E., Terraneo, A., Marini, E., Gomez, P. L., et al. (2019). Sleep and new media usage in toddlers. *Eur. J. Pediatr.* 178, 483–490. doi: 10.1007/s00431-019-03318-7

Cortesi, F., Giannotti, F., Sebastiani, T., and Vagnoni, C. (2004). Cosleeping and sleep behavior in Italian school-aged children. *J. Dev. Behav. Pediatr.* 25, 28–33. doi: 10.1097/00004703-200402000-00005

Duursma, E., Pan, B. A., and Raikes, H. (2008). Predictors and outcomes of low-income fathers' reading with their toddlers. *Early Child. Res. Q.* 23, 351–365. doi: 10.1016/j.ecresq.2008.06.001

El-Sheikh, M., and Sadeh, A. (2015). Sleep and development: introduction to the monograph. 80, 1–14. doi: 10.1111/mono.12141

Fu, K. W., Ho, F. K. W., Rao, N., Jiang, F., Li, S. L., Lee, T. M. C., et al. (2017). Parental restriction reduces the harmful effects of in-bedroom electronic devices. *Arch. Dis. Child.* 102, 1125–1131. doi: 10.1136/archdischild-2017-312639

Guarino, A., Di Blasio, P., D'Alessio, M., Camisasca, E., and Serantoni, M. (2008). *Parenting Stress Index Short Form: Adattamento Italiano*. Firenze: Giunti, Organizzazioni Speciali.

Hale, L., and Guan, S. (2015). Screen time and sleep among school-aged children and adolescents: a systematic literature review. *Sleep Med. Rev.* 21, 50–58. doi: 10.1016/j.smrv.2014.07.007

Hartshorne, J., Huang, Y. T., Paredes, P. M. L., Oppenheimer, K., Robbins, P. T., and Molino, M. D. V. (2021). Screen time as an index of family distress. *Curr. Res. Behav. Sci.* (in press). doi: 10.1016/j.crbeha.2021.100023

Hirsh-Pasek, K., Zosh, J. M., Golinkoff, R. M., Gray, J. H., Robb, M. B., and Kaufman, J. (2015). Putting education in "educational" apps: lessons from the science of learning. *Psychol. Sci. Public Interest* 16, 3–34. doi: 10.1177/1529100615569721

Hsu, H. C., and Lavelli, M. (2005). Perceived and observed parenting behavior in American and Italian first-time mothers across the first 3 months. *Infant Behav. Dev.* 28, 503–518. doi: 10.1016/j.infbeh.2005.09.001

IBM Corp (2019). *IBM SPSS Statistics for Windows, Version 26.0*. Armonk, NY: IBM Corp.

Jenni, O. G., and O'Connor, B. B. (2005). Children's sleep: an interplay between culture and biology. *Pediatrics* 115(Suppl. 1), 204–216. doi: 10.1542/peds.2004-0815b

Johnson, S. B., Riley, A. W., Granger, D. A., and Riis, J. (2013). The science of early life toxic stress for pediatric practice and advocacy. *Pediatrics* 131, 319–327. doi: 10.1542/peds.2012-0469

Kabali, H. K., Irigoyen, M. M., Nunez-Davis, R., Budacki, J. G., Mohanty, S. H., Leister, K. P., et al. (2015). Exposure and use of mobile media devices by young children. *Pediatrics* 136, 1044–1050. doi: 10.1542/peds.2015-2151

Kirkorian, H., Choi, K., and Anderson, D. R. (2019). American parents' active engagement mediates the impact of background television on toddlers' play. *J. Child. Media* 13, 377–394. doi: 10.1080/17482798.2019.1635033

LeBourgeois, M. K., Giannotti, F., Cortesi, F., Wolfson, A. R., and Harsh, J. (2005). The relationship between reported sleep quality and sleep hygiene in Italian and American adolescents. *Pediatrics* 115(Suppl. 1), 257–265. doi: 10.1542/peds.2004-0815h

LeBourgeois, M. K., Hale, L., Chang, A., Akacem, L. D., Montgomery-Downs, H. E., and Buxton, O. F. (2017). Digital media and sleep in childhood and adolescence. *Pediatrics* 140 (Suppl. 2), S92–S96. doi: 10.1542/peds.2016-1758J

Mantua, J., Gravel, N., and Spencer, R. (2016). Reliability of sleep measures from four personal health monitoring devices compared to research-based actigraphy and polysomnography. *Sensors* 16:646. doi: 10.3390/s16050646

Mascheroni, G., and Ólafsson, K. (2014). *Net Children Go Mobile: Risks and Opportunities*. Milano: Educatt.

McDaniel, B. T., and Radesky, J. S. (2018). Technoference: parent distraction with technology and associations with child behavior problems. *Child Dev.* 89, 100–109. doi: 10.1111/cdev.12822

McDaniel, B. T., and Radesky, J. S. (2020). Longitudinal associations between early childhood externalizing behavior, parenting stress, and child media use. *Cyberpsychol. Behav. Soc. Netw.* 23, 384–391. doi: 10.1089/cyber.2019.0478

Mileva-Seitz, V. R., Bakermans-Kranenburg, M. J., Battaini, C., and Luijk, M. P. (2017). Parent-child bed-sharing: the good, the bad, and the burden of evidence. *Sleep Med. Rev.* 32, 4–27. doi: 10.1016/j.smrv.2016.03.003

Mindell, J. A., Sadeh, A., Kohyama, J., and How, T. H. (2010). Parental behaviors and sleep outcomes in infants and toddlers: a cross-cultural comparison. *Sleep Med.* 11, 393–399. doi: 10.1016/j.sleep.2009.11.011

Molina, P., Bulgarelli, D., Henning, A., and Aschersleben, G. (2014). Emotion understanding: a cross-cultural comparison between Italian and German preschoolers. *Eur. J. Dev. Psychol.* 11, 592–607. doi: 10.1080/17405629.2014.890585

Morelli, G. A., Rogoff, B., Oppenheim, D., and Goldsmith, D. (1992). Cultural variation in infants' sleeping arrangements: questions of independence. *Dev. Psychol.* 28:604. doi: 10.1037/0012-1649.28.4.604

Nakagawa, M., Ohta, H., Nagaoki, Y., Shimabukuro, R., Asaka, Y., Takahashi, N., et al. (2016). Daytime nap controls toddlers' nighttime sleep. *Sci. Rep.* 6:27246.

New, R. S. (1988). Parental goals and Italian infant care. *New Dir. Child Dev.* 40, 51–63. doi: 10.1002/cd.23219884007

New, R. S., and Richman, A. L. (1996). "Maternal beliefs and infant care practices in Italy and the United States," in *Parents' Cultural Belief Systems: Their Origins, Expressions, and Consequences*, eds S. S. Harkness and C. M. Super (New York, NY: Guilford), 385–404.

Ottaviano, S., Giannotti, F., Cortesi, F., Bruni, O., and Ottaviano, C. (1996). Sleep characteristics in healthy children from birth to 6 years of age in the urban area of Rome. *Sleep* 19, 1–3.

Radesky, J. S., Kistin, C. J., Zuckerman, B., Nitzberg, K., Gross, J., Kaplan-Sanoff, M., et al. (2014a). Patterns of mobile device use by caregivers and children during meals in fast food restaurants. *Pediatrics* 133, e843–e849.

Radesky, J. S., Schumacher, J., and Zuckerman, B. (2015). Mobile and interactive media use by young children: the good, the bad, and the unknown. *Pediatrics* 135, 1–3. doi: 10.1542/peds.2014-2251

Radesky, J. S., Silverstein, M., Zuckerman, B., and Christakis, D. A. (2014b). Infant self-regulation and early childhood media exposure. *Pediatrics* 133, e1172–e1178.

Radesky, J., Weeks, H., Ball, R., Schaller, A., Yeo, S., Durnez, J., et al. (2020). Mobile device sampling: an unobtrusive, objective measure of child smartphone and tablet use. *Pediatrics.* 146:e2019351.

Reid Chassiakos, Y., Radesky, J., Christakis, D., Moreno, M. A., and Corinn Cross and council on Communications and Media (2016). Children and adolescents and digital media. *Pediatrics* 138:e20162593. doi: 10.1542/peds.2016-2593

Ribner, A. D., Barr, R. F., and Nichols, D. L. (2020). Background media use is negatively related to language and literacy skills: indirect effects of self-regulation. *Pediatr. Res.* doi: 10.1038/s41390-020-1004-5 [Epub Ahead of Print],

Ribner, A. D., McHarg, G. G., and The NewFAMS Study Team (2019). Why won't she sleep? Screen exposure and sleep patterns in young infants. *Infant Behav. Dev.* 57, 1–7.

Rideout, V., and Robb, M. (2020). *The Common Sense Census: Media use by Kids Age Zero to Eight*. San Francisco, CA: Common Sense Media.

Rideout, V. (2017). *The Common Sense Census: Media use by Kids Age Zero to Eight*. San Francisco, CA: Common Sense Media.

Sadeh, A. (2004). A brief screening questionnaire for infant sleep problems: validation and findings for an Internet sample. *Pediatrics* 113, e570–e577.

Sadeh, A., Tikotzky, L., and Scher, A. (2010). Parenting and infant sleep. *Sleep Med. Rev.* 14, 89–96. doi: 10.1016/j.smrv.2009.05.003

Spruyt, K., Aitken, R. J., So, K., Charlton, M., Adamson, T. M., and Horne, R. S. (2008). Relationship between sleep/wake patterns, temperament and overall development in term infants over the first year of life. *Early Hum. Dev.* 84, 289–296. doi: 10.1016/j.earlhumdev.2007.07.002

Steger, B., and Brunt, L. (eds) (2003). *Night-Time and Sleep in Asia and the West: Exploring the Dark Side of Life*. London: Routledge Curzon.

Swedish Media Council [SMC] (2019). *Little Kids and Media*. Available online at: http://statensmedierad.se/publikationer/publicationsinenglish/littlekidsmedia2015.611.html (accessed June 1, 2020).

Task Force on Sudden Infant Death Syndrome (2011). SIDS and other sleep-related infant deaths: expansion of recommendations for a safe infant sleeping environment. *Pediatrics* 128, e1341-67.

Taverna, L., Bornstein, M. H., Putnick, D. L., and Axia, G. (2011). Adaptive behaviors in young children: a unique cultural comparison in Italy. *J. Cross Cult. Psychol.* 42, 445–465. doi: 10.1177/0022022110362748

Troseth, G. L., Russo, C. E., and Strouse, G. A. (2016). What's next for research on young children's interactive media? *J. Child. Media* 10, 54–62. doi: 10.1080/17482798.2015.1123166

Vandewater, E. A., and Lee, S. J. (2009). Measuring children's media use in the digital age: issues and challenges. *Am. Behav. Sci.* 52, 1152–1176. doi: 10.1177/0002764209331539

Wolf, A. W., Lozoff, B., Latz, S., and Paludetto, R. (1996). *Parental Theories in the Management of Young Children's Sleep in Japan, Italy, and the United States. Parents' Cultural Belief Systems*. New York, NY: Guilford Press, 364–384.

World Health Organization [WHO] (2019). *WHO Global Report on Traditional and Complementary Medicine 2019*. Geneva: World Health Organization.

Zack, E., and Barr, R. (2016). The role of interactional quality in learning from touch screens during infancy: context matters. *Fron. Psychol.* 7:1264. doi: 10.3389/fpsyg.2016.01264

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 18 March 2021
doi: 10.3389/fpsyg.2021.569920

# Growing Up in a Digital World – Digital Media and the Association With the Child's Language Development at Two Years of Age

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OPEN ACCESS

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***Specialty section:***
*This article was submitted to*
*Developmental Psychology,*
*a section of the journal*
*Frontiers in Psychology*

***Received:*** *05 June 2020*
***Accepted:*** *01 February 2021*
***Published:*** *18 March 2021*

***Citation:***
*Sundqvist A, Koch F-S, Birberg Thornberg U, Barr R and Heimann M (2021) Growing Up in a Digital World – Digital Media and the Association With the Child's Language Development at Two Years of Age. Front. Psychol. 12:569920. doi: 10.3389/fpsyg.2021.569920*

Digital media (DM), such as cellphones and tablets, are a common part of our daily lives and their usage has changed the communication structure within families. Thus, there is a risk that the use of DM might result in fewer opportunities for interactions between children and their parents leading to fewer language learning moments for young children. The current study examined the associations between children's language development and early DM exposure.

**Participants:** Ninety-two parents of 25 months olds (50 boys/42 girls) recorded their home sound environment during a typical day [Language ENvironment Analysis (LENA)] and participated in an online questionnaire consisting of questions pertaining to daily DM use and media mediation strategies, as well as a Swedish online version of the MacArthur Communicative Development Inventory, which includes a vocabulary scale as well as a grammar and pragmatics scale.

**Results:** Through correlations and stepwise regressions three aspects of language were analyzed. The child's vocabulary was positively associated with interactional turn-taking. The child's vocabulary and grammar were negatively associated with the likelihood of parent's device use during everyday child routines and the amount of TV watched by the child. The child's pragmatic development was also positively associated with the parent's device use in child routines but also with the parent's joint media engagement (JME), as well as the child's gender (where girls perform better).

**Conclusion:** Our study confirms that specific aspects of the 2-year old's DM environment are associated with the child's language development. More TV content, whether it is viewed on a big screen or tablet, is negatively associated with language development. The likelihood of parents' use of DM during everyday child routines is also negatively associated with the child's language development. Positive linguistic parental strategies such as interactional turn-taking with the child, JME, and book reading, on the other hand, are positively associated with the child's language development.

**Keywords: digital media, joint media engagement, technoference, Language ENvironment Analysis, language development, parent-child turn-taking**

# INTRODUCTION

Living in a digital world is changing the way we interact with each other, for children and adults alike. This may consequently change the way young children, growing up today, acquire language, as language development is dependent on the linguistic input achieved through the interactions that occur during child-adult conversations (e.g., Tomasello, 2003; Romeo et al., 2018). The limited empirical research has, thus far, investigated associations between television exposure and conversational turns in language input and shown a negative association (Christakis et al., 2009). Despite rapid changes in the availability of digital media (DM) in the home, including Smartphones, television, gaming consoles, and tablets, as well as a number of digital services like streaming television and social media, little research has examined whether DM in the home is associated with child-adult conversations. The child-adult conversations may, in turn, be associated with child language, and foremost vocabulary. The present study focuses on the importance of child-adult interactions to language development and how this development may be associated with the use of DM and digital devices in the home environment.

## Development of Language

Early social interactions between the adult and child shape and act as the foundation of the child's linguistic learning (Golinkoff et al., 2019). Previous studies have shown that parent-child interactional turn-taking is of importance for the child's language development, more so than the number of words the child hears (Romeo et al., 2018). Making time to engage with the child, conversing back and forth, describing and explaining the child's activities, actions and thoughts will expand and develop the child's linguistic capacity and understanding (Meins and Fernyhough, 1999; Tamis-LeMonda et al., 2018; Golinkoff et al., 2019).

When parents converse with their young child, they will often use child-directed language (Westerlund and Lagerberg, 2008). Studies of the parent's child-directed speech suggest several important aspects. The key ingredients are that the language responses the child encounters must be immediate, reliable, and accurate in content and relevance (Roseberry et al., 2014), which assumes that the parent is attentive and not preoccupied. This attentive communication style maintains an environment that is stimulating for language development (Karrass et al., 2003) and can occur during frequent routines such as book reading, car trips, feeding, and potty-training (Bruner, 1983; Zimmerman et al., 2009). Book reading for small children generally occurs in a dialog with the child; maintaining child-directed speech, stopping to explain matters the adult decides to explain, or to expand on matters the child questions. Positive effects from picture book reading or e-book reading are often attained through the interactions between the child and the adult (Kucirkova, 2019). It is the interactive aspect of reading that is of utmost importance for linguistic development (Mol et al., 2008). Unlike a TV show or a YouTube clip, an adult who reads to a child is enabling the child to listen at his or her own pace and perhaps rehearse and repeat words and actions depicted in the book and for adults to broaden the understanding of the topic by focusing on the child's current understanding. When parents pause a recorded TV episode similar effects are observed (Strouse et al., 2013).

A common way to describe language is through the three concepts of form (e.g., syntax), content (e.g., vocabulary), and use (pragmatics; Bloom and Lahey, 1978). Often described through a Venn diagram where each concept has its unique characteristics, but they also share characteristics. Thus, each is a synergetic system, each concept developing independently, but acting as an integrative whole (ASHA, 1993). Consequently, when analyzing the development of language, one should take into account that different aspects in the child's development or different aspects in the environment may differentially affect the form, content, or use of language (Bloom and Lahey, 1978).

## Digital Media and Family Life

Digital media fulfill diverse functions in parents' and families' lives and DM are used in as many as 98% of families with children in Sweden [Swedish Media Council (SMC), 2019]. This may lead to an overuse of DM, and users describe an attraction to DM including a desire to repeatedly check their social media or mail for possible updates, a desire they find hard to resist even in situations when the parents are spending time with their child (Oulasvirta et al., 2012). Adult DM use may hinder interactions between the child and the adult, thus affecting the language development of the child. If the child also independently uses DM, the child's DM use is also a factor that changes the child's language learning environment.

Disruption in interactions due to DM by parents or by children has been termed *technoference* (Reed et al., 2017, McDaniel and Radesky, 2018a,b, Sundqvist et al., 2020). This may occur in any situation where the adult and the child are interacting, such as during play-situations, book reading, or meal-time (Radesky et al., 2014; McDaniel and Radesky, 2018a,b). Parents estimated that an average of four instances of technoference occurred per day, where the parent's DM use accounted for the majority of instances of technoference (Sundqvist et al., 2020). The exact number may be much higher as this can be hard to remember retrospectively (see Barr et al., 2020). Christakis et al. (2009) showed that the parents' interactions with their child decreased as the digital sounds, predominantly television sounds in the vicinity of the child, increased. Additionally, a recent meta-analysis has shown that a greater quantity of screen use during infancy may be related to a delay in language development (Madigan et al., 2020).

The amount of DM and the occurring incidences of technoference is of importance, but research has shown that it is equally important to analyze if and how the parents use media together with the child (Nathanson, 2015). Research suggests, specifically, that parental mediation of children's media use, such as discussing the content with the child, may reduce negative associations with DM usage (Nathanson, 2015; Madigan et al., 2020). This type of interaction is termed *joint media engagement* (JME) and shapes how children will respond to and use media. Higher JME has been associated with positive outcomes in family connectedness (Padilla-Walker et al., 2012) increased infant attention and responsiveness (Barr et al., 2008) and increased infant learning from touchscreens (Zack and Barr, 2016). Valkenburg et al. (1999) describe three different parental mediation styles restrictive mediation, instructive mediation, and social co-viewing. Instructive mediation describes parental behaviors that are comprised of JME including discussions with the child during and about the media activities. Social co-viewing represents behaviors in which the parent co-view media together but without the joint engagement in the DM task. Finally, restrictive mediation entails the parent enforcing device/content rules and/or time allowances connected to DM use.

Various family routines and activities which promote interaction between the child and the adult such as increased conversations in ordinary situations with the child, book reading (paper or e-books), and JME when using DM may be conducive for the child's language development (Nathanson, 2015). It has been suggested that technoference or excessive child solitary use of DM decreases or disrupts typical interactions between adults and children, essential for language development, and consequently interferes with language development (Zimmerman et al., 2009).

Digital media exposure often reduces child-adult interaction because DM does not facilitate socially contingent conversational turns with a language partner whose responses are immediate, reliable, and accurate in content and relevance (Anderson and Hanson, 2017). Although some parents provide descriptions and even pause the video to discuss content with some success, such language-rich interactions tend to occur less often than during face-to-face interactions (Strouse et al., 2013). Without the support of an actively and instructively mediating adult, DM alone cannot repeat or explain the content according to the child's specific needs. It is, thus, possible that solitary DM engagement, by the parent or by the child, will be negatively associated with the child's language development. The use of DM may consequently limit the interactions between the child and the adult. It is, nevertheless, possible that even though the child or the adult uses DM, they could still maintain a high level of adult-child interaction, which would be associated with positive language outcomes. Examples of activities that support an increased interaction and thus would be positively associated with child language development are for instance JME and book reading (paper/e-books). Most studies of young children, so far, have examined how DM is associated with one specific aspect of language (for instance vocabulary) or a more general language measure (Madigan et al., 2020). We hypothesized that different aspects of language may be differentially associated with types of DM usage and this study will examine three aspects of language (content, form, and use of language) in 2-year olds who are at the early stages of expressively using grammar, vocabulary, and pragmatics. It is important to note that DM in the context of this study will include all digital devices that enable the display of the audio-visual output: TV, smartphones, tablets, and computers. Using today's technology, casting your favorite music to a TV screen or watching TV on a smartphone is just as common as watching broadcast TV on a TV. Different devices do not necessarily display different content.

Our study asks three questions: (1) What are the characteristics of the child's and parent's DM use and what are the characteristics of children's language development and home sound environment? We hypothesized that 2-year-olds would use DM on a daily basis and that parents would use their own device during child routines. We also hypothesized, given the nature of our sample, that their language development would be in the typical range for Swedish children. (2) Are 2-year-old's DM use and parents' DM use associated with the child's language development? Based on the research on child DM use, we hypothesized that an increase in the family DM use would be negatively associated with child language development, specifically vocabulary. Based on the research on technoference, we hypothesized that a higher likelihood of parental DM use during ordinary child routines would be negatively associated with the child's language development. Based on research on background TV use, we hypothesized that background TV would be negatively associated with the child's language development. We did not have specific hypotheses for whether each of these variables would be associated with form, content, and use, except for predicting that higher child DM use would be associated with poorer vocabulary. (3) Are factors in the home sound environment such as increased interaction (adult-child turn-taking), increased book reading (e-books or paper books), and JME (interactional mediation) positively associated with the child's language development? We hypothesized that increased interaction, book reading, and JME, respectively, would be positively associated with the child's language development.

## MATERIALS AND METHODS

### Participants

Parents were invited by mail to participate with their child in a study at the Baby and Child Lab, Linköping University. All children ($N$ = 1,324) born within a specified time period within the Linköping municipal area were invited by letter. Addresses were obtained from Statens personadressregister, a database that includes everybody that is registered as resident in Sweden. Those who expressed an interest were contacted by phone and informed about the current study. This study which commenced when the children were 9 months of age ($N$ = 127) is part of a larger study which also entails laboratory testing of the child. In the second wave of this study, at 2 years of age, 92 families participated. The families that took part in this study all spoke Swedish with their child. In three homes another language was also spoken. Based on a well-baby clinic visit, all children were reported to be typically developing. This article presents data collected from 2018 to 2019 when children were 2 years old. The families that took part in the current study all spoke Swedish with their child. In three homes another language was also spoken. Based on a well-baby clinic visit, all children were reported to be typically developing. This article presents data collected from 2018 to 2019 when children were 2 years old.

Parents: The questionnaires were filled out by the 92 parents (80% mothers/20% fathers) at home, some parents did not answer certain questions, leading to missing data on some questions. The sample is noted in relation to specific questions. They were well educated (12% high school, 6% completed vocational training, 73% had completed university, and 9% held a Ph.D.).

Children: The 92 children (50 boys/42 girls) were on average 25.1 months old (*SD* 0.31 months). At the time of the study, 51% of the children did not have any siblings and 42% had one sibling.

In Sweden, there is a state-subsidized childcare program in which 100% of the children in this sample attended. The Swedish parental-leave system allows the parents to stay at home with their child for over a year from birth with 80% of their wages. When the child starts childcare the parents also have paid sick days if the child is sick, as well as on average 25 days of paid vacation/year. All the children in this study attended childcare, and 75% attended more than 20 h a week, which is common in this age group in Sweden (Swedish National Agency for Education, 2013). Even though most children spend several hours a week in childcare, the time they spend in the home is a significantly greater proportion of the time.

Digital media was available in all households and used by the parents as well as actively used by the children, at least once within the last 2 weeks. Ninety-five percent of the households had a TV (used by 87% of the children), all of the households had smartphones (used by 100% of the children), 95% of the households had a computer (used by 93% of the children), 81% of the households had a tablet (used by 81% of the children), and 30% of the households had a DVD-player (used by 28% of the children). The frequency of digital device use in this sample is in line with other reports of digital device usage in Sweden (SMC, 2019).

## Procedure

After the phone call with the parents when information regarding the study was communicated, an email with a link to the questionnaire was mailed out to the parent as well as a letter containing instructions and the home recording device Language ENvironment Analysis, LENA (LENA Foundation, 2020).

Parents were instructed to choose a typical day, when the child was not attending childcare, and they would be spending time at home with their child for the recording of their child's home sound environment (21% chose a weekday and 79% of the parents chose a weekend/holiday for the recording). The reasons for choosing a day when the child was not attending childcare were twofold, first, we would receive a recording of a typical day when the child spends time with their family and second, it was not feasible to receive consent from all the different preschools and all the different parents to record during a preschool day. The curriculum of all the childcare facilities is governed by the national school law and curricula were, therefore, likely to be similar to each other. The home sound environment at 2 years of age is also likely to be similar to the first 17 months of the child's life when most of the children had not yet started childcare. When the child woke up in the morning, the parent was instructed to place the LENA recording device in the designated pocket on a specifically provided vest and to push the record button and leave it recording the whole day. The recorder turned off automatically after 16 h. When asked which parent takes the most responsibility for the child during a day off from preschool, 40% reported that the mother takes most of the responsibility, 26% reported that the father takes most responsibly, and 29% reported that both parents take an equal amount of responsibly for the child.

The questionnaires were administered through Qualtrics™ software (Qualtrics, Provo, UT, United States) which is a research software company offering online data collection. The media questions in the questionnaire were developed by the Comprehensive Assessment of Family Exposure (CAFE) Consortium. The original media questions were in English and were translated to Swedish and back-translated by a native English speaker. The questionnaires were also pilot tested to make sure the questions were phrased and understood properly by parents with children in a similar age group. The CAFE consortium is an interdisciplinary international network of researchers that has developed a reliable and valid tool for assessing DM during childhood (Barr et al., 2020). The focus for the present study is the children's language development assessed through the Swedish version of MacArthur Communicative Development Inventory, the Swedish Early Communicative Development Inventory – Words and Sentences (SECDI-2), and assessment of the parents and children's media use and strategies through the CAFE questionnaire. Although the questionnaire was self-administered online, a lab visit occurred shortly after the administration of the online questionnaires and parents ask questions as needed regarding the questionnaire during the lab visit.

## Ethics

Written informed consent was obtained from the caregivers. The regional ethical review board, Linköping, Sweden, approved this study (2016/490-31 and 2018/609-32).

## Online Questionnaire

To address our research question, the following media questions from the CAFE battery (version 2) were analyzed:

### Estimated Daily Use of Media

A daily estimated measurement of how much time the parent and the child spent using media. We asked how much time during a regular weekday the parent would spend doing one of six different activities, watching TV/DVD, using computers, reading books, using a tablet, using a smartphone, and playing video games on a play console. Parents choose from the following options: not at all, <30 min, 30–60 min, 1–2 h, or >2 h. The parents were asked to answer the same questions but with regards to their child as well.

Additionally, we asked: Has your child ever used mobile digital devices (smartphone, tablet, etc.) to do any of the following activities? View TV shows or movies, play games, use apps that are not games (e.g., FaceTime), listen to books, listen to music on digital devices. The choices were (1) we do not have the device, (2) never or less than once a week, (3) once a week, (4) 2–4 times a week, (5) daily, and (6) several times a day.

### Digital Media Use During Child Routines

The likelihood that parent's used digital devices during common everyday routines when their child was present were also estimated using a Likert type scale (I never do this, not very likely, neutral, likely, very likely, represented by values 1–5, respectively). The questions asked were: There are often times when parents have to use their smartphone or tablet when spending time with their child. How likely are you to use your phone or other devices (e.g., to make calls, text, check email, watch a video): (1) During meals, (2) getting your child ready for childcare, (3) during playtime, (4) during the bedtime routine, (5) while driving them to or from activities or when riding on public transportation. For the analysis, the mean value of the five routine activities, representing the most common DM behavior pattern of the parent was chosen, with higher values indicating higher DM usage during their children's activities. The parents were also asked about if they had the TV on in the background while no one was watching (with the option never, almost never, sometimes, often, or always).

### Media Mediation Strategies (an Adapted Version of the Valkenburg Scale)

This scale is aimed at analyzing how parents mediate their children's media access and use (Valkenburg et al., 1999). The scale was translated from English to Swedish and adapted for today's media environment. Originally, the scale focused on TV watching, but the scope of the questions was broadened in the current study to include other types of media, such as smartphones and tablets. The three different styles of parental mediation in media viewing that the scale covers are (a) Restrictive mediation where the parent prohibits viewing according to a set of rules, (b) Instructive mediation which henceforth will be called JME, where parents explain and discuss aspects of the media, and (c) Social co-viewing where parents and children simply watch together. Each of the styles is assessed and scored through five separate questions and the parents grade the likelihood of the mediation style on a Likert scale from never to always (1–5) from which a mean value for each strategy is calculated.

## Language Development SECDI-2

A Swedish online version of the MacArthur Communicative Development Inventory, the SECDI-2, was used to assess productive vocabulary, grammatical use, and pragmatic use. Good validity and reliability of the Swedish SECDI-2 have been established for the 16- to 28-month age group and the test-retest reliability of SECDI-2 is close to or above 0.90 (Berglund and Eriksson, 2000). SEDCI-2 contains: (A) Vocabulary production checklist (710 frequent Swedish words), (B) Feedback morphemes (words that signal that one has understood the interlocutor like yeah, mmh, or no), (C) Pragmatic scale which includes questions about how the child uses language. For instance, one question is "Does your child point to someone's object and say the name of that person? For instance, the child could point to daddy's bike and say: 'daddy'" (max 10 points), (D) Grammar scale estimates how the child uses, for instance, plural, past tense, possessive inflections (max 12 points), *E. Maximum* length utterance of the child. We have chosen three subscales for analysis tapping Content (Vocabulary), Form (Grammar), and Use (Pragmatics) The subscales B and E were not included in the present analysis.

## Home Sound Environment

The naturalistic home language environment was recorded during a whole day using LENA. The recorder is a small device that fits into a pocket of a specially designed vest the child uses and records up to 16 h of the child's sound surroundings (LENA Foundation, 2020). The audio recordings are downloaded and analyzed through LENA Software Advanced Data Extractor (ADEX). The ADEX automatically categorizes the data according to preset algorithms into a variety of different variables; e.g., child speaker, female speaker, male speaker, duration of speech, and distant speech (LENA Foundation, 2020). The Lena's segmentation and labeling process are designed to identify the dominant sound source in the child's environment. This is accomplished in intervals of 800 milliseconds. In a segment, for instance, where the child is playing with his parent with the TV in the background for 5 min. LENA will add all the intervals where the TV is dominant, where the key child's voice is dominant, and where the adult voice is dominant. Algorithms also automatically calculate conversational turns, where there were <5 s of silence or other sounds (i.e., in this example the TV) between the child's and the adult's utterances (LENA Foundation, 2020).

The variables included in the current analysis are: (1) Adult word count which is the number of adult words spoken (female and male voices) to and near the child; (2) Target child's vocalizations/words; (3) Interactional turn-taking is the total number of conversational interactions between the child and an adult where one speaker initiates and the other responds within 5 s. All recordings that were longer than 10 h were selected for analysis (LENA Foundation, 2020). Due to technical difficulties, one recording was only 4 h and was not included in the final sample. The reliability of LENA was originally established for American English but has also been evaluated in other languages, such as Swedish (Schwarz et al., 2017), showing that comparison within the same language will yield comparable results.

## Statistical Analyses

Statistical Package for Social Sciences 27.0 (SPSS) was used for all statistical analyses. Two-tailed analyses are used throughout. First, relations between analysis were examined with Pearson correlation. In order to understand child language development in more detail, regression models examine the relative contribution of the factors examined here. One regression model per language variable (dependent variable respectively: vocabulary, grammar, and pragmatics). A regression was chosen to fit the variables under consideration, with a stepwise selection of variables. From the pool or variables, the one that added most to the explained variance of the model was chosen first. Then the process iterated until all variables that contributed significantly to the explained variance were included in the model, while checking at each step if variables that do not contribute significantly to the model can be removed. All three regression models started with the same pool of variables.

# RESULTS

The result section is organized according to our three main research questions. To address our first research question, we first report descriptive data of parent and child media use, JME, and the children's language development scores for vocabulary, grammar, and pragmatics. Then to address our second and third research questions we describe a series of first-order correlations we conduced regarding the child's and parent's media use and the relation to the child's language development, as well as the relation of language (i.e., vocabulary, grammar, and pragmatics) to interactional turn-taking, book reading, and JME. Finally, in order to understand vocabulary, grammar, and pragmatic development better, regression models examine the relative contribution of parent and child media use, interactional turn-taking, and JME to language development. One stepwise regression model per language variable is fitted.

## Research Question 1: Descriptive Statistics for Family Media Use, Home Environment, and Language

### Estimated Daily Use of Media

Children aged 2 years used DM daily (see **Table 1**), 86% watch TV, 64% use a smartphone, 52% used a tablet, and 16% used a computer and nearly 100% of the parents read to their child on a daily basis (27% <30 min, 52% 30–60 min, 14% 1–2 h). The question regarding books did not differentiate between e-books and print books. The question regarding books did not differentiate between e-books and print books. No child played video games at this age. Child's media use patterns were highly correlated with parent's media use patterns for most types of media (all *p's* > 0.01). The only media pattern that did not correlate between parent and child use was smartphone use. Children's media use did not differ between boys and girls (all *p's* > 0.05) nor was it associated with the amount of childcare the children attended (all *p's* > 0.05). Consistent with other studies of children in this age range viewing TV content was the most frequent form of DM exposure (Rideout, 2017; Rideout and Robb, 2020). This was irrespective of the device used for viewing the TV content. Twenty-five percent watched TV on a digital device daily or several times a day, 19% of the children watched TV on a mobile device several times a week, and 56% one time a week or less (see **Table 2**). Daily use of e-books (8%) or playing games on mobile devices (5%) were not common.

### Parental Use of Digital Media During Child Routines

Parents reported that they commonly used DM during child routines, such as mealtimes or bedtimes, but there are large individual differences (see **Table 3**). For subsequent analyses, values summarized into a mean of how likely the parent was to use DM during most child routines; would never use devices (7%), not very likely to use devices (51%), neither likely or unlikely to use devices (36%) and were likely to use devices (7%) during child routines. None of the parents selected the option "very likely" for all of the activities. Parents, furthermore, reported that they seldom had background TV on; 60% reported never or almost never, 24% reported sometimes, 13% reported often, and 3% reported always.

### Media Mediation Strategies

For clarity, all three mediation strategies of the scale are presented but based on the review of the literature we hypothesized that only the JME strategy would be associated with language outcomes and therefore only this strategy is used in the correlational and regression analysis. Parents (*n* = 91)

**TABLE 1** | Children's daily media use by type of device in percentage per time category (*n* = 88–92).

| Media | No use | 0–30 min | 30–60 min | >60 min |
|---|---|---|---|---|
| TV | 14 | 22 | 36 | 28 |
| PC | 84 | 10 | 6 | 0 |
| Tablet | 48 | 26 | 19 | 8 |
| Smartphone | 36 | 45 | 17 | 2 |
| Books[PandE] | 1 | 28 | 56 | 16 |

[PandE]*This question refers to both print and e-books.*

**TABLE 2** | Usage of digital devices for different digital media (DM) activities in percept per time category (*n* = 90).

| Percentage of children who use digital device to watch | Do not use | Once a week | Several times a week | Daily – several times a day |
|---|---|---|---|---|
| TV | 45 | 11 | 19 | 25 |
| Movies | 56 | 9 | 19 | 7 |
| Play games | 62 | 17 | 16 | 6 |
| Video chat | 49 | 24 | 23 | 3 |
| Digital books | 87 | 5 | 0 | 8 |
| Music | 44 | 19 | 23 | 15 |

**TABLE 3** | Percentage of parents stating how likely it is that they would use a digital device during common everyday routines when their child is present (*n* = 90).

| Activity | Never do this | Not very likely | Neutral | Likely | Very likely |
|---|---|---|---|---|---|
| During mealtime | 26 | 54 | 11 | 7 | 2 |
| Getting ready | 32 | 51 | 7 | 11 | 0 |
| During playtime | 3 | 21 | 29 | 44 | 2 |
| During bedtime | 48 | 20 | 8 | 4 | 10 |
| During transport | 17 | 34 | 14 | 29 | 6 |

used different media mediation strategies when viewing TV content with their child. Restrictive mediation was the most common strategy among parents of 2-year-old's ($M = 3.22$, $SD = 0.89$). That is, the parents decided when, how much and the content of the DM the child could use. The other two strategies were equally common, social co-viewing, viewing together without discussing the content ($M = 2.78$, $SD = 0.71$) and JME ($M = 2.79$, $SD = 0.92$).

### Language Development (SECDI-2)

Language development of the 2-year-olds included in the present study (see **Table 4**) is consistent with Swedish norms of language development (Berglund and Eriksson, 2000). No difference was observed in any of the language measures depending on how many hours of childcare the children attended (all *p's* > 0.05). Furthermore, no gender differences were observed on the grammar scale or for the vocabulary scale (*p's* > 0.05). The girls had a significant higher mean than the boys on the pragmatic scale [girls: $M = 8.84$, $SD = 1.9$, boys: $M = 7.4$, $SD = 1.6$; $t(86) = -2.57$, $p < 0.05$]. All the language measures of SECDI-2 correlated with each other. The vocabulary scale correlated with the grammar scale ($r = 0.77$, $p < 0.01$) and with the pragmatic scale ($r = 0.58$, $p < 0.01$). The grammar scale correlated with the pragmatic scale ($r = 0.59$, $p < 0.01$).

### Home Sound Environment (LENA)

Language ENvironment Analysis records the sound environment of the child and then uses tested algorithms to break the audio record into different categories. These categories include a number of words spoken to the child by the adult and the number of child vocalizations. Then based on the child and adult words and the time between the utterances, turn-taking between the two is calculated. Variation in how many words spoken by adults and the number of interactional turns was large, from about 4,000 to 34,000 words a day with a mean of 17,267 words and a mean of 829 episodes of turn-taking during a day (see **Table 5**). These variables are mutually dependent and adult word count was positively correlated with child word count ($r = 0.28$, $p < 0.01$) and interactional turn-taking ($r = 0.68$, $p < 0.01$). Interactional turn-taking correlated with child word count ($r = 0.81$, $p < 0.01$). In the subsequent analysis interactional turn-taking will be utilized as it contains both adult word count and child word count and the measures are highly intercorrelated, but for clarity descriptive statistics for both those measures were reported here.

**TABLE 4** | Descriptive data for three subscales of the Swedish Early Communicative Development Inventory – Words and Sentences (SECDI-2).

| Variables | *M* | *SD* | Min-Max | Percentile score |
|---|---|---|---|---|
| Vocabulary scale (*n* = 90) | 305.2 | 155.9 | 8–586 | 54 |
| Pragmatic scale (*n* = 88) | 7.9 | 1.8 | 2–10 | 50 |
| Grammar scale (*n* = 89) | 5.6 | 3.2 | 0–12 | 55 |

**TABLE 5** | Descriptive data for three measures of the home sound environment obtained from the Language ENvironment Analysis (LENA, *n* = 84).

| Variables | *M* | *SD* | Min-Max |
|---|---|---|---|
| Adult word count | 17,267 | 6,898 | 4,228–34,418 |
| Child word count | 3,178 | 1,422 | 390–7,582 |
| Turn-taking | 829 | 387 | 100–1,721 |

## Research Questions 2 and 3: Can Language Development Be Predicted by Family Media Usage Patterns and Factors in the Home Environment Such as Adult-Child Turn-Taking, Book Reading (e-Books or Paper Books), and JME?

### Correlational Analysis

In line with our second question, there was a significant negative correlation between how much the child watched TV content (defined as any TV content viewed on any device from any source) and the vocabulary scale (see **Table 6**). There was no correlation between the child's use of smartphones and tablets, and the child's language development (*p's* > 0.05). Computers were used by 14 of the children, but there was a significant positive correlation between the child's use of computers and vocabulary.

Furthermore, a correlation analysis between the parent's DM use (smartphones, computers, tablets TV, and videogames) and the child's language development revealed no significant associations (all *p's* > 0.05). This line of questions pertained to the parent's use of DM when the child was present but also when the child was not present. There was, however, a significant negative correlation between higher likelihood of parental use of DM during child routines and the child's vocabulary, grammar, and pragmatic scale (see **Table 6**). Background TV was not common in our sample and did not correlate with language measures (*p's* > 0.05).

**TABLE 6** | Correlations between three measures of language development, and child media use, parental DM use, parental mediation and home sound environment (LENA).

| | Vocabulary | Grammar | Pragmatic |
|---|---|---|---|
| **Child media use (*n* = 89–90)** | | | |
| TV content | −0.27** | −0.08 | 0.05 |
| Tablet | 0.01 | 0.06 | −0.04 |
| Smartphone | −0.09 | 0.01 | 0.12 |
| Computer | 0.21* | 0.08 | 0.01 |
| Books[PandE] | 0.21* | 0.20 | 0.28* |
| **Parental media activities (*n* = 89)** | | | |
| Likelihood of DM use | −0.27* | −0.22* | −0.30* |
| Background TV | −0.16 | −0.01 | −0.04 |
| JME | 0.15 | 0.18 | 0.29** |
| **Home sound environment (*n* = 78)** | | | |
| Turn-taking | 0.41** | 0.18 | 0.20 |

*$p < 0.05$.
**$p < 0.01$.
[PandE]*This question refers to both print and e-books.*

Our third research question addressed whether parent-child activities at home were related to language. JME was positively correlated with the child's developing pragmatics ability (see **Table 6**). There was also a positive correlation between the children being read to and both the pragmatic and vocabulary scale. In our original research question, we equated print books and e-book. E-books were, however, not commonly used in this sample therefore it is likely that this correlation is largely due to reading print books. Furthermore, adult-child interactional turn-taking, as measured with LENA, was positively correlated with the child's vocabulary.

## Regression Models

We built three separate stepwise regression models to predict the language variables: Vocabulary scale, pragmatic scale, and grammar scale, respectively. For further analysis see multiple linear regressions in the appendix. Predictor variables were the same in all three regressions and were chosen based on the first order correlational analysis and whether they were theoretically likely to predict language outcomes. From the CAFE questionnaire, we consequently included the time the child spent with books, TV content, and computers and for these, dummy variables were created with a median value as the reference category, based on the incidence of use of the specific media. TV content was recalculated into three variables of daily use: no TV, low TV (<60 min), and high TV (>60 min). Computer use was recalculated into no use, medium use (<30 min), and high use (30–60 min), Book reading was also recategorized into three variables: no/low use (<30 min), medium use (30–60 min), and high use (>60 min). Medium TV, medium computer, and medium book use were used as the reference category, respectively. We also included the likelihood of parent's device use during daily child routines, as well as the parent's use of JME during child's DM use. From the sound environment at home, measured with LENA, we included interactional turn-taking as a predictor variable. We also included gender as a predictor variable. As parental education did not have a normal distribution (over 80% of the parents had a university degree), this variable was not entered into the analysis. Additionally, as only 20% of the responders were fathers, therefore, the gender of the parent responding to the questionnaire was not entered into the model.

### *Regression 1. Vocabulary Scale*

We entered the predictor variables into a linear stepwise regression on the vocabulary scale from the SECDI-2 as the outcome variable. The final model, based on three variables (see **Table 7**) was clearly significant $F(3,69) = 9.87$, $p < 0.001$, and explained a relatively large portion of the variance (adjusted $R^2$ explaining 27% of the variance). The model included three variables; interactional turn-taking which explained 16% of the variance, TV content, which explained 9% of the variance and the likelihood of parent's device use during daily child routines which explained 5% of the variance.

### *Regression 2. Grammar Scale*

Once again, we entered the same predictors into a linear stepwise regression with a grammar scale from the SECDI-2 as the outcome variable (see **Table 8**). The overall model which included two variables was significant [$F(2,70) = 6.68$, $p < 0.01$] with an adjusted $R^2$ of 14%. TV content explaining 10% of the variance and the likelihood of parent's device use during daily child routines explained 6%.

### *Regression 3. Pragmatic Scale*

Finally, the same predictors were added into a linear stepwise regression with the pragmatics scale from the SECDI-2 as the outcome variable (see **Table 9**). The final best fit model was significant [$F(3,69) = 6.92$, $p < 0.001$] with an adjusted $R^2$ explaining 20% of the variance in the pragmatic scale and included three variables. The likelihood of parent's device use during daily child routines explained 10% of the variance, gender of the child explained 8% of the variance and JME explained an additional 5% of the variance.

## DISCUSSION

The present study confirms that specific aspects of the child's media environment were associated with the child's language development. The time spent in interaction with an adult was positively associated with the development of language. The parent's tendency to use DM during childhood routines, as well as the time children spent watching TV content was negatively associated with the child's language development.

**TABLE 7** | Summary of stepwise regression analysis for variables predicting SEDCI-2 – Vocabulary ($n = 76$).

| | Step 1 | | | Step 2 | | | Step 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | B | SE B | $\beta$ | B | SE B | $\beta$ | B | SE B | $\beta$ |
| Turn-taking (LENA) | 0.15 | 0.04 | 0.40** | 0.12 | 0.04 | 0.32** | 0.10 | 0.04 | 0.28* |
| TV content<br>No TV | | | | 130.26 | 45.77 | 0.31** | 138.35 | 44.67 | 0.33** |
| Device use | | | | | | | −40.33 | 18.08 | −0.23* |
| *R2* | 0.16 | | | 0.25 | | | 0.30 | | |
| *F* for Δ*R2* | 13.83** | | | 8.1** | | | 4.98* | | |
| *ΔR2* | 0.16 | | | 0.09 | | | 0.05 | | |

*p < 0.05.
**p < 0.01.

**TABLE 8 |** Summary of stepwise regression analysis for variables predicting SEDCI-2 – Grammar ($n$ = 76).

| | Step 1 | | | Step 2 | | |
|---|---|---|---|---|---|---|
| | B | SE B | $\beta$ | B | SE B | $\beta$ |
| TV content No TV | 2.87 | 1.01 | 0.32** | 2.94 | 0.98 | 0.33** |
| Device use | | | | –0.90 | 0.41 | –0.24* |
| $R2$ | 0.10 | | | 0.16 | | |
| $F$ for $\Delta R2$ | 8.08** | | | 4.8* | | |
| $\Delta R2$ | 0.10 | | | 0.06 | | |

*$p < 0.05$.
**$p < 0.01$.

**TABLE 9 |** Summary of hierarchical regression analysis for variables predicting SEDCI-2 – Pragmatics ($n$ = 76).

| | Step 1 | | | Step 2 | | | Step 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | B | SE B | $\beta$ | B | SE B | $\beta$ | B | SE B | $\beta$ |
| Device use | –0.62 | 0.22 | –0.31** | –0.6 | 0.22 | –0.30** | –0.48 | 0.22 | –0.24* |
| Gender | | | | 1.0 | 0.37 | 0.29** | 1.1 | 0.37 | 0.31** |
| JME | | | | | | | 0.43 | 0.20 | 0.23* |
| $R2$ | 0.10 | | | 0.18 | | | 0.23 | | |
| $F$ for $\Delta R2$ | 7.8** | | | 7.2** | | | 4.4* | | |
| $\Delta R2$ | 0.10 | | | 0.08 | | | 0.05 | | |

*$p < 0.05$.
**$p < 0.01$.

## What Is the Media Environment and Language Environment of 2-Year-Old Swedish Children?

Consistent with other recent reports (e.g., Rideout, 2017), toddlers in Sweden watch TV shows on a number of devices, on a TV or tablet/cellphone, and view content from multiple sources. Consistent with other recent reports of data collected in the United States (e.g., Rideout, 2017; Rideout and Robb, 2020) and Canada (e.g., Madigan et al., 2020), media use in Swedish 2-year-old was frequent. Children in the present study actively consumed different forms of media daily, utilizing a number of different devices: TV, smartphones, tablets, as well as books. Playing games or video chat, however, was not that common. The frequency of parent-child interactions varied between families and our findings suggest that parents are the originators of the child's home language environment and media ecology (Nathanson, 2015; Nansen and Jayemanne, 2016; Barr, 2019). Some parents were very talkative, whereas others did not interact that much, and the number of adult words directed toward the child varied from as little as 4,000 words to as many as 34,000 words a day. Children participated in interactional turn-taking, on average, 829 times a day with an adult. Once again, there were large individual differences with rates of turn-taking varying from as low as 100 to almost 2,000 interactional turns a day. The amount of language input that the children experienced, thus, varied immensely. Nevertheless, the language development of children in this study was within the typical norms.

The media habits of the parents are mimicked in the emerging media habits of the child. The time parents spend watching TV or reading books was correlated with the time the children spent watching TV or being read to, respectively. Children were read to daily, but e-books were not common. The parents reported that they frequently used DM in routine situations with the child. They also reported that they try to mediate their child's media use. The most common mediation strategy that parents reported at this age was to restrict DM use. But co-viewing or JME were common strategies as well.

## Are 2-Year-Old's DM Use and Parents' DM Use Associated With the Child's Language Development?

Our second research question and accompanying hypotheses were partially confirmed. The child's DM use was associated with the child's language development. The parent's overall DM use was not correlated with the child's language development, but the likelihood that parents use DM in child routines was associated with the child's language development.

An increase in the child's use of DM was negatively associated with language development, specifically the vocabulary and grammar scales. The regression showed that significant variance of the children's grammar development (10%) and vocabulary development (9%) can be uniquely predicted by the time the child spent watching TV content. Although the children in this study watch a fairly moderate amount of TV content, 58% of the 2-year-olds watch TV content 1 h or less a day – such exposure was associated with variation in language development. Earlier studies have shown that increased TV watching was associated with a decrease in language proficiency for children up to 2 years of age (Zimmerman et al., 2007; Madigan et al., 2020). The current study shows that watching TV may interfere with language learning after 2 years of age as well. It is important to note that the results do not point to an atypical delay in language development in 2-year olds. As a group, the children perform within the norms of typical development (Berglund and Eriksson, 2000), but one explanation for the variation in language development within this sample is their consumption of TV content on a TV, tablet, or smartphone.

It is also worth noting that we cannot make a strict distinction as to whether the children watch TV on a big screen, a tablet, or a smartphone screen. It was very common in our sample to watch TV on handheld screens and young children, view TV content on several different devices. At this age, games and educational apps are not as common as watching TV content. Unfortunately, the lack of information on the specific content of media exposure is a limitation of the current study. Additional studies should more closely examine the TV content that toddlers are exposed to in order to provide a finer-grained analysis of the types of content that are negatively associated with child language development. There was also a correlation between computer use and vocabulary, although not significant in the stepwise regression. It is difficult to know the reason for this association due to the small number of children who use computers and since the regression did not show any significance it is not a robust finding. Knowing the content of the computer use could have explained this association. One could speculate, for instance, that if the children had used the computer to video chat this could explain the positive correlation to language. About half the sample uses video chat at least once a week. The current COVID-19 pandemic has once again changed patterns of interaction and reports suggest that video chat rates are much more frequent than before the pandemic (Gaudreau et al., 2020). Future studies should examine how these increased levels of video chat are associated with language outcomes and whether video chat is differentially associated with changes in pragmatics or vocabulary or if there are gender differences.

We did not find an association between the parent's overall use of digital devices and the child's language development. Rather, it was specifically the likelihood of parental use of DM use during child routines which was negatively associated with all three measured aspects of child language development, vocabulary, grammar, and pragmatics, in line with our hypothesis. The stepwise regression analysis demonstrated that the likelihood of parental DM use during child routines predicted variation in vocabulary (5%), grammar (6%), and in pragmatic ability (10%). Parental use of DM during child routines may lead to technoference in interactions with the child, as previous research has shown (McDaniel and Radesky, 2018a). In situations, such as mealtime, getting ready, or bedtime about 80% of all parents reported that they did not use DM, whereas 20% reported using DM during these routines. In other situations, such as during transport and during playtime the numbers who reported using their DM device was considerably higher. During playtime, for instance, 75% of parents reported using their own smartphone at least some of the time. This is consistent with findings showing associations with technoference and other child outcomes, such as self-regulatory behaviors and external behavior problems (McDaniel and Radesky, 2018a; Sundqvist et al., 2020). Parental report of DM use during child routines was not a measure of technoference, *per se*, as we did not ask them if they had experienced technoference in these situations. However, as it may be difficult to always remember and accurately analyze all the cases of technoference experienced in a day, simply asking about and pinpointing certain situations of DM use might be a feasible proxy of rate of technoference. Future studies could more closely examine parental media use using passive sensing technology to more accurately measure bursts of parental DM usage (Barr et al., 2020; Milkovich and Madigan, 2020; Radesky et al., 2020). The parent's background TV is another DM use that has been seen to be a negative factor for the child's attention and learning (Pempek et al., 2014). The parents in this study did, however, not use background TV to a great extent. This is an interesting line of further study as it may indicate that not only digital sounds can be distracting but parent's "silent use" of DM and withdrawal of their attention may also interfere with language development.

Parents are the creators of the child's media and language learning environment (Nathanson, 2015; Nansen and Jayemanne, 2016; Barr, 2019). The actions of the parents, rather than other factors, seem to matter the most. All the children in this study attended state subsisted childcare daily, with most children attending more than 20 h a week. Unlike other studies (Shivers and Barr, 2007), childcare exposure was, thus, held fairly constant across participants in this study and was not found to be a relevant factor. Time spent in childcare outside the home was not associated with either the children's DM use or language development. There might, of course, be other differences in the different caregivers that will affect the child's development even though the number of hours the children attended care outside of the home did not. Although the parent's own overall media use did not correlate with the child's language development, it is evident that the child's language learning, at this age, is closely associated with parents' actions and the home environment. Future studies should examine the media environment of the childcare language and media environment to examine how home and childcare factors overlap.

## Are Parent-Child Activities in the Home Environment Associated With the Child's Language Development?

Our third study question and associated hypotheses were partially confirmed. Parents' use of JME was positively associated with language development, specifically pragmatic abilities. Talking and interacting with your child when viewing DM seems to be important and uniquely explained 5% of the variation in the understanding of pragmatics. Consistent with Beyens et al. (2019), this signified the importance of not just co-viewing media with your child but also interacting around the media content as well. Talking about the intent of the actors and explaining their actions and feelings are aspects of JME and could be considered specific linguistic input that most certainly would be related to pragmatic understanding. These findings suggest that JME may be an effective strategy for maintaining language input during media exposure. Additional longitudinal research more closely examining the content and context of media exposure is warranted to examine longer-term implications of JME.

We measured the child's sound environment at home with the digital recorder LENA analyzing conversational turns between the child and the adult. Conversational turn-taking between child-adult is important for language development (Romeo et al., 2018), and for the children in the present study, it explains 16% of the variance in vocabulary, thus, confirming the important role of child-adult interactions. As previous studies have shown, one of the most important aspects of the interactions between the child and the adult is that the interactions are immediate, reliable, and accurate in content and relevance (Roseberry et al., 2014). This attentive communication style maintains an environment that is stimulating for language development (Karrass and Braungart-Rieker, 2003) and an increase in the interactions between the child and the parent is associated with an increase in the child's language development. That is, engaging in more parent-child interactions was associated with faster vocabulary growth.

Consistent with prior research, the current study shows that media use, as well as the interactive linguistic patterns, seems to "run" in families (Nansen and Jayemanne, 2016). The child's use of DM and books were correlated with the parents' own use of the same media. Parents who themselves read more are also prone to read more to their children (Nathanson, 2015). Almost all children in this study were read to on a daily basis, and as previous studies have shown, this is associated with their parent's own literacy habits (Karrass et al., 2003; Chaparro-Moreno et al., 2017). E-books were not commonly read by families in this study. Adults and children alike mostly read paper books.

The fact that this well-educated group of parents reads to their children on a daily basis might explain the fact that time spent in book reading did not account for unique variation in language in the regression analysis although the book reading was correlated with pragmatics abilities. Thus, partly confirming our hypothesis that reading is associated with language development and possibly explaining the lack of significance in the regression. This finding suggests that unique variance may also be due to likely differences in the interactional quality during book reading and other activities. Future studies of the language environment can take advantage of transcripts from the LENA recordings to provide a more in-depth analysis of interactional quality during different everyday events involving both DM and book reading.

Analyzing the different aspects of language measured here Vocabulary (Content), Grammar (Form), and Pragmatics (Use) it is evident that they have several commonalities as well as factors that differ between them. The developmental trajectory of pragmatics is earlier than vocabulary and grammar, but the three aspects are intercorrelated, yet different aspects of the environment are associated with different language outcomes.

The child's TV content watching seems to be negatively associated with the development of vocabulary and grammar. The parent's device use during child routines seems to be negatively associated with the development of vocabulary, grammar, and pragmatics. The adult-child interactions were positively associated with the development of vocabulary. The development of pragmatics seemed to be dependent on several different factors including the gender of the child, parents' device use during child routines, and JME. It is important to note that our results say nothing about causality. It may be that parents talk less to the child just because the child's language skills are less developed, or that a parent will use their cell phones more when they are with their child since the child does not speak as much. There might also be other stressors in the family, for instance, child behavior or parent's work situation that contribute to the media usage and the child's language development (e.g., McDaniel and Radesky, 2018a; Sundqvist et al., 2020).

None of the measures of media use differed significantly between boys and girls. Boys and girls were reported to use as much DM, their parents used as much DM and there are no differences in terms of how parents mediated use between boys and girls. Girls did, however, show more advanced pragmatic ability compared to boys. Previous studies (Westerlund and Lagerberg, 2008) have also shown that girls in this age range may develop aspects of language faster than boys, but this difference does not seem to be mediated by media use.

A limitation of the present study is the construction of some of the media questions, which made a distinction between watching TV and other devices such as smartphones and tablets but not between the content being watched. Between the time when the questions were constructed and the time when they were asked it became increasingly common to watch TV on a tablet or stream from a tablet to the TV. This question will no longer easily distinguish between handheld DM and stationery viewing devices nor between the content used on different devices, for instance, if the computer is used for video chat or TV content. Future studies should instead focus on disambiguating the content and context of media usage rather than focusing on the device that is being used. Furthermore, the questions regarding time spent using different content and different devices were difficult to use and should have been on a continuous scale for more optimal analysis. One possibility would be to use a passive sensing app on the devices the child uses along with a parental report diary (Barr et al., 2020). Finally, it is also important to note that this sample consisted of parents of relatively high SES and the results may not be generalizable to a group of parents with lower SES.

Our study confirms that specific aspects of the child's DM environment are associated with child language development. Children at age 2 years actively consume different forms of media daily *via* TV, smartphones, tablets, as well as books. More TV content, whether it is viewed on a big screen or tablet is negatively associated with language development. The likelihood of parent's device use during child routines was also negatively associated with the child's language development. Positive linguistic parental strategies such as interactional turn-taking with the child, book reading, and JME when watching DM, on the other hand, were positively associated with the child's language development.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Research Ethics Review Committee at Linköping University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

The study was conceived by AS, F-SK, RB, and MH. AS, F-SK, and UT coordinated the acquisition of data and collected data. AS analyzed the data and drafted the manuscript. All authors contributed to the article and approved the submitted version.

## FUNDING

This research was supported by a grant from the Swedish Research Council for Health, Working Life and Welfare (2016-00048) to MH.

## ACKNOWLEDGMENTS

A special thanks to all the children and caregivers participating in this study and to Sandra Nyberg for helping with part of the data collection.

## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.569920/full#supplementary-material

## REFERENCES

Anderson, D. R., and Hanson, K. G. (2017). "Screen media and parent–child interactions" in *Media exposure during infancy and early childhood: The effects of content and context on learning and development*. eds. R. Barr and D. N. Linebarger (New York: Springer), 173–194.

ASHA (1993). Ad HOC Committee on Service Delivery in the Schools. *Definitions of Communication Disorders and Variations*.

Barr, R. (2019). Growing up in the digital age: early learning and family media ecology. *Curr. Dir. Psychol. Sci.* 28, 341–346. doi: 10.1177/0963721419838245

Barr, R., Kirkorian, H., Radesky, J., Coyne, S., Nichols, D., Blanchfield, O., et al. (2020). Beyond screen time: a synergistic approach to a more comprehensive assessment of family media exposure during early childhood. *Front. Psychol.* 11:1283. doi: 10.3389/fpsyg.2020.01283

Barr, R., Zack, E., Garcia, A., and Muentener, P. (2008). Infants' attention and responsiveness to television increases with prior exposure and parental interaction. *Infancy*. 13, 30–56 doi: 10.1080/15250000701779378

Berglund, E., and Eriksson, M. (2000). Communicative development in Swedish children 16-28 months old: the Swedish early communicative development inventory - words and sentences. *Scand. J. Psychol.* 41, 133–144. doi: 10.1111/1467-9450.00181

Beyens, I., Valkenburg, P. M., and Piotrowski, J. T. (2019). Developmental trajectories of parental mediation across early and middle childhood. *Hum. Commun. Res.* 45, 226–250 doi: 10.1093/hcr/hqy016

Bloom, L., and Lahey, M. (1978). *Language development and language disorders*. New York: Wiley.

Bruner, J. (1983). *Child's talk*. Oxford: Oxford University Press.

Chaparro-Moreno, L. J., Reali, F., and Maldonado-Carreño, C. (2017). Wordless picture books boost preschoolers' language production during shared reading. *Early Child. Res. Q.* 40, 52–62. doi: 10.1016/j.ecresq.2017.03.001

Christakis, D. A., Gilkerson, J., Richards, J. A., Zimmerman, F. J., Garrison, M. M., Xu, D., et al. (2009). Audible television and decreased adult words, infant vocalizations, and conversational turns: a population-based study. *JAMA Pediatr.* 163, 554–558. doi: 10.1001/archpediatrics.2009.61

Gaudreau, C., King, Y. A., Dore, R. A., Puttre, H., Nichols, D., Hirsh-Pasek, K., et al. (2020). Preschoolers benefit equally from video chat, pseudo-contingent video, and live book reading: implications for storytime during the coronavirus pandemic and beyond. *Front. Psychol.* 11:2158. doi: 10.3389/fpsyg.2020.02158

Golinkoff, R. M., Hoff, E., Rowe, M. L., Tamis-LeMonda, C. S., and Hirsh-Pasek, K. (2019). Language matters: denying the existence of the 30-million-word gap has serious consequences. *Child Dev.* 90, 985–992. doi: 10.1111/cdev.13128

Karrass, J., and Braungart-Rieker, J. M. (2003). Parenting and temperament as interacting agents in early language development. *Parenting*. 3, 235–259 doi: 10.1207/S15327922PAR0303_03

Karrass, J., VanDeventer, M. C., and Braungart-Rieker, J. M. (2003). Predicting shared parent-child book reading in infancy. *J. Fam. Psychol.* 17, 134–146. doi: 10.1037/0893-3200.17.1.134

Kucirkova, N. (2019). Children's reading with digital books: past moving quickly to the future. *Child Dev. Perspect.* 13, 208–214. doi: 10.1111/cdep.12339

LENA Foundation (2020). *A Guide to Understanding the Design and Purpose of the LENA® System*. Available at: https://www.lena.org/wp-content/uploads/2020/07/LTR-12_How_LENA_Works.pdf (Accessed February 11, 2021).

Madigan, S., McArthur, B. A., Anhorn, C., Eirich, R., and Christakis, D. A. (2020). Associations between screen use and child language skills: a systematic review and meta-analysis. *JAMA Pediatr.* 174, 665–675. doi: 10.1001/jamapediatrics.2020.0327

McDaniel, B. T., and Radesky, J. S. (2018a). Technoference: longitudinal associations between parent technology use, parenting stress, and child behavior problems. *Pediatr. Res.* 84, 210–218. doi: 10.1038/s41390-018-0052-6

McDaniel, B. T., and Radesky, J. S. (2018b). Technoference: parent distraction with technology and associations with child behavior problems. *Child Dev.* 89, 100–109. doi: 10.1111/cdev.12822

Meins, E., and Fernyhough, C. (1999). Linguistic acquisitional style and mentalising development: the role of maternal mind-mindedness. *Cogn. Dev.* 14, 363–380 doi: 10.1016/S0885-2014(99)00010-6

Milkovich, L. M., and Madigan, S. (2020). Using mobile device sampling to objectively measure screen use in clinical care. *Pediatrics* 146:e20201242. doi: 10.1542/peds.2020-1242

Mol, S. E., Bus, A. G., de Jong, M. T., and Smeets, D. J. H. (2008). Added value of dialogic parent-child book readings: a meta-analysis. *Early Educ. Dev.* 19, 7–26. doi: 10.1080/10409280701838603

Nansen, B., and Jayemanne, D. (2016). Infants, interfaces, and intermediation: digital parenting and the production of "iPad baby" videos on YouTube. *J. Broadcast. Electron. Media* 60, 587–603. doi: 10.1080/08838151.2016.1234475

Nathanson, A. I. (2015). Media and the family: reflections and future directions. *J. Child. Media* 9, 133–139. doi: 10.1080/17482798.2015.997145

Oulasvirta, A., Rattenbury, T., Ma, L., and Raita, E. (2012). Habits make smartphone use more pervasive. *Pers. Ubiquit. Comput.* 16, 105–114. doi: 10.1007/s00779-011-0412-2

Padilla-Walker, L. M., Coyne, S. M., and Fraser, A. M. (2012). Getting a high-speed family connection: associations between family media use and family connection. *Fam. Relat.* 61, 426–440. doi: 10.1111/j.1741-3729.2012.00710.x

Pempek, T. A., Kirkorian, H. L., and Anderson, D. R. (2014). The effects of background television on the quantity and quality of child-directed speech by parents. *J. Child. Media* 8, 211–222. doi: 10.1080/17482798.2014.920715

Radesky, J. S., Kistin, C. J., Zuckerman, B., Nitzberg, K., Gross, J., Kaplan-Sanoff, M., et al. (2014). Patterns of mobile device use by caregivers and children during meals in fast food restaurants. *Pediatrics* 133, e843–e849. doi: 10.1542/peds.2013-3703

Radesky, J. S., Weeks, H. M., Ball, R., Schaller, A., Yeo, S., Durnez, J., et al. (2020). Young children's use of smartphones and tablets. *Pediatrics* 146: e20193518. doi: 10.1542/peds.2019-3518

Reed, J., Hirsh-Pasek, K., and Golinkoff, R. M. (2017). Learning on hold: cell phones sidetrack parent-child interactions. *Dev. Psychol.* 53, 1428–1436. doi: 10.1037/dev0000292

Rideout, V. (2017). *The common sense census: Media use by kids age zero to eight*. San Francisco, CA: Common Sense Media, 263–283.

Rideout, V., and Robb, M. (2020). *The common sense census: Media use by kids age zero to eight*. San Francisco, CA: Common Sense Media.

Romeo, R. R., Leonard, J. A., Robinson, S. T., West, M. R., Mackey, A. P., Rowe, M. L., et al. (2018). Beyond the 30-million-word gap: children's conversational exposure is associated with language-related brain function. *Psychol. Sci.* 29, 700–710. doi: 10.1177/0956797617742725

Roseberry, S., Hirsh-Pasek, K., and Golinkoff, R. M. (2014). Skype me! Socially contingent interactions help toddlers learn language. *Child Dev.* 85, 956–970. doi: 10.1111/cdev.12166

Schwarz, I. -C., Botros, N., Lord, A., Marcusson, A., Tidelius, H., and Marklund, E. (2017). "The LENATM system applied to Swedish: Reliability of the adult word count estimate" in *Interspeech 2017*; August 20–24, 2017; Stockholm, Sweden: The International Speech Communication Association (ISCA), 2088–2092.

Shivers, E. M., and Barr, R. (2007). Exploring cultural differences in children's exposure to television in home-based child care settings. *Zero to Three* 27, 39–45.

Strouse, G. A., O'Doherty, K., and Troseth, G. L. (2013). Effective coviewing: preschoolers' learning from video after a dialogic questioning intervention. *Dev. Psychol.* 49, 2368–2382. doi: 10.1037/a0032463

Sundqvist, A., Heimann, M., and Koch, F. -S. (2020). Relationship between family technoference and behavior problems in children aged 4–5 years. *Cyberpsychol. Behav. Soc. Netw.* 23, 371–376. doi: 10.1089/cyber.2019.0512

Swedish Media Council (SMC) (2019). *Little kids and media*. Available at: http://statensmedierad.se/publikationer/publicationsinenglish/littlekidsmedia2015.611.html (Accessed February 11, 2021).

Swedish National Agency for Education (2013). *Föräldrars val och inställning till förskola och fritidshem. Parental chocies and attitueds towards preschool and afterschool care*. Available at: https://www.skolverket.se/publikationer?id=3067 (Accessed February 11, 2021).

Tamis-LeMonda, C. S., Custode, S., Kuchirko, Y., Escobar, K., and Lo, T. (2018). Routine language: speech directed to infants during home activities. *Child Dev.* 90, 2135–2152. doi: 10.1111/cdev.13089

Tomasello, M. (2003). *Constructing a language: A usage-based theory of language acquisition*. Cambridge, MA and London: Harvard University Press.

Valkenburg, P. M., Krcmar, M., Peeters, A. L., and Marseille, N. M. (1999). Developing a scale to assess three styles of television mediation: "instructive mediation," "restrictive mediation," and "social coviewing." *J. Broadcast. Electron. Media*. 43, 52–66. doi: 10.1080/08838159909364474

Westerlund, M., and Lagerberg, D. (2008). Expressive vocabulary in 18-month-old children in relation to demographic factors, mother and child characteristics, communication style and shared reading. *Child Care Health Dev.* 34, 257–266. doi: 10.1111/j.1365-2214.2007.00801.x

Zack, E., and Barr, R. (2016). The role of interactional quality in learning from touch screens during infancy: context matters. *Front. Psychol.* 7:1264. doi: 10.3389/fpsyg.2016.01264

Zimmerman, F. J., Christakis, D. A., and Meltzoff, A. N. (2007). Associations between media viewing and language development in children under age 2 years. *J. Pediatr.* 151, 364–368. doi: 10.1016/j.jpeds.2007.04.071

Zimmerman, F. J., Gilkerson, J., Richards, J. A., Christakis, D. A., Xu, D., Gray, S., et al. (2009). Teaching by listening: the importance of adult-child conversations to language development. *Pediatrics* 124, 342–349. doi: 10.1542/peds.2008-2267

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer ADR and handling editor declared their shared affiliation. The reviewer ADR declared a past collaboration with the authors to the handling editor.

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ORIGINAL RESEARCH
published: 29 March 2021
doi: 10.3389/fpsyg.2021.616656

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# Quality of Mother-Child Interaction Before, During, and After Smartphone Use

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Studies have demonstrated that parents often exhibit a still face while silently reading their cell phones when responding to texts. Such disruptions to parent-child interactions have been observed during parental media use such as texting and these disruptions have been termed technoference. In the present study, we explored changes to mother-child interactions that occur before, during and after interruptions due to texting using an adapted naturalistic still face paradigm. Specifically, we examined the effect of an interruption due to either maternal smartphone use or use of an analog medium on maternal interaction quality with their 20- to 22-month-old children. Mother-child interactions during free play were interrupted for 2 min by asking the mothers to fill out a questionnaire either (a) by typing on the smartphone (smartphone group) or (b) on paper with a pen (paper-pencil group). Interactional quality was compared between free-play and interruption phases and to a no-interruption control group. Mixed ANOVA across phase and condition indicated that maternal responsiveness and pedagogical behavior decreased during the interruption phase for both the interruption groups (smartphone and paper-and-pencil) but not for the no-interruption group. Children also increased their positive bids for attention during the paper-and-pencil and the smartphone conditions relative to the no-interruption control. These findings are consistent with a large body of research on the still-face paradigm and with a recent study demonstrating that smartphone interruptions decreased parenting quality. The present study, however, connects these lines of research showing the many everyday disruptions to parent-child interactions are likely to decrease parenting quality and that toddlers are likely to detect and attempt to repair such interruptions.

**Keywords: technoference, parent-child interaction, still face, interactional quality, interruption, smartphone, media use**

OPEN ACCESS

***Edited by:***
*Christiane Lange-Küttner, University of Bremen, Germany*

***Reviewed by:***
*Lara Nikola Wolfers, Leibniz-Institut für Wissensmedien (IWM), Germany*
*Sarah Myruski, Pennsylvania State University (PSU), United States*
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***Specialty section:***
*This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology*

***Received:*** *12 October 2020*
***Accepted:*** *02 March 2021*
***Published:*** *29 March 2021*

***Citation:***
*Konrad C, Hillmann M, Rispler J, Niehaus L, Neuhoff L and Barr R (2021) Quality of Mother-Child Interaction Before, During, and After Smartphone Use. Front. Psychol. 12:616656. doi: 10.3389/fpsyg.2021.616656*

## INTRODUCTION

The quality of early mother-child interactions during play contributes to both child development and the mother-child relationship (e.g., Tamis-LeMonda et al., 2001; Landry et al., 2006; Ginsburg, 2007). Playing together offers mothers and their toddlers a unique opportunity for language-rich interactions and emotional engagement (Ginsburg, 2007; Yogman et al., 2018). Furthermore, there is evidence that the quality of such early mother-child interactions—especially maternal responsiveness as a prompt, contingent, and appropriate reaction to child behavior (Bornstein et al., 2008)—is a powerful predictor of social-emotional, cognitive, and linguistic child development and the parent-child bond (Ainsworth and Bell, 1974; Tamis-LeMonda et al., 2001; Landry et al., 2006).

It is evident that during the digital age where mobile technology is ubiquitous that such interactions are shaped by digital media (Radesky J. S. et al., 2015; Barr and Linebarger, 2017; Rideout, 2017; McDaniel, 2019; Vanden Abeele et al., 2020; Wolfers et al., 2020). New mobile devices, including smartphones, differ from traditional digital media (e.g., TVs) in that parents and their children can take them with them wherever they go and use them in a variety of ways at any time (Wartella, 2019). Thus, mobile media enable parents to spend time with their children and at the same time be available for friends or professional partners (Radesky et al., 2016a; Mangan et al., 2018). As a result, parents use smartphones a significant proportion of the time in everyday family situations, in the presence of their small children, for example during play, meal, and bedtime routines (McDaniel and Coyne, 2016; Yuan et al., 2019; Barr et al., 2020; Vanden Abeele et al., 2020; Wolfers et al., 2020). With the ubiquity of smartphones in everyday family life, there is a risk that mother-infant interactions will be interrupted and qualitatively impaired. Smartphone use during interactions results in repeated disconnections between social partners which has recently been labeled "technoference" (McDaniel and Radesky, 2018). Infants might be especially sensitive to those disruptions because they resemble a classical still face (Myruski et al., 2018). As a result, mothers of toddlers report experiencing smartphone interruptions during interactions with their toddlers—which they report are either self-initiated or due to device notifications (McDaniel and Coyne, 2016; Newsham et al., 2020).

Frequent smartphone checking and pickups interrupts early mother-child interactions and impairs the quality, because mothers may be less responsive. Such repeated interruptions to play could have negative consequences for the mother-child relationship. It is therefore particularly important to examine the effect of maternal smartphone use on the quality of mother-child interactions. Initial, predominantly qualitative observational studies provide evidence that parental smartphone use affects parent-child interactions. Observational studies conducted in a fast food restaurant (Radesky et al., 2014) and on playgrounds (Hiniker et al., 2015; Abels et al., 2018; Lemish et al., 2019; Vanden Abeele et al., 2020; Wolfers et al., 2020) found that parents who were immersed in smartphone use communicated less frequently with their children and were less responsive to children's needs and attention-seeking behavior. Sometimes the parents appeared to be annoyed (Lemish et al., 2019) or even hostile after repeated child attempts to call parental attention (Radesky et al., 2014). Rather than just the frequency of use, the duration of use was also a factor. Wolfers et al. (2020) reported that mothers who were observed on play-grounds using their smartphones for longer were also rated lower on maternal sensitivity. A laboratory study simulating a mealtime situation found that mothers who used their mobile device spontaneously during a structured situation were less likely to initiate verbal and non-verbal interactions with their children (Radesky J. et al., 2015). Interestingly, it was observed that other parental activities on playgrounds (reading a magazine, talking to another person) also absorbed parents and impaired parental responsiveness, but not as much as parental smartphone use (Abels et al., 2018; Lemish et al., 2019; Vanden Abeele et al., 2020). Taken together, these findings suggest that immersive smartphone use by parents disrupt every-day routine parent-child interactions.

There have been few experimental studies, however, that have investigated how smartphone use might disrupt interactions. In an experimental study, Reed et al. (2017) tested whether cell phone calls interrupted language learning by 2-year-olds. Using a within-subjects design, 38 mothers taught their 2-year-olds two novel words. Mothers received a call that interrupted them while teaching one of the words, but for the other word the call occurred prior to teaching. Children were significantly more likely to learn the uninterrupted word than the interrupted word. This finding remained despite the fact that the mother taught the word the same number of times on average in both conditions. However, this was a phone call interruption and it is not clear whether a text that simply involves silent reading and responding would be as disruptive.

When checking mobile phones, parents' faces frequently have no expression, and these periods of time may be perceived by young children as a "still face," to which children respond aversively (Adamson and Frick, 2003). The "still face" presented to the infant during smartphone use may disrupt communication from the infant to the parent as well. Using a standard still-face paradigm, Goldstein et al. (2009) reported that parents respond to infant vocalizations 30 to 50% of the time. When parents present a "still face" response, 5-month-olds increase their vocalizations, presumably to regain the adult's attention. When the interaction resumes, the infant decreases vocalizations and re-engages in turn-taking with the parent. The greater the increase in vocalizations in response to a "still face' the better language outcomes are at 1 year of age.

In an experimental study, while parents were teaching their infants how to make a rattle, parents were interrupted by a text asking them to complete a questionnaire instead. In this study, parents were randomly assigned to one of four experimental conditions: interruption-first condition, one-interruption condition (occurred in the middle), three-interruptions condition and a no-interruption condition (Konrad et al., 2021). Parents demonstrated how to make the rattle 4 times. Text interruptions occurred before or between demonstrations. After the demonstration was complete, infants were given the opportunity to make the rattle themselves. Their performance was compared to a baseline control condition who had not seen how to make the rattle. Most parents (77%) exhibited a still face during the text interruption. Despite this brief period of technoference, infants in all experimental groups performed significantly above the baseline control condition, showing evidence of learning from the parental demonstration.

Finally, researchers used a modified version of the still face procedure to examine changes in interactional quality during smartphone use. Myruski et al. (2018) instructed 50 mothers of 7- to 23-month-olds to assume a still face when looking at a smartphone during a 2 min interruption to a free play period.

In the first phase of the study, mothers played freely with their infants for 5 min. Then in the still face phase, they were asked to interact only with their phone for 2 min. Finally, there was a one minute second free play phase, called the reunion phase. The authors reported that there were changes in infant exploration which was highest during phase 1 free play and decreased during the still face and reunion phases of the study. During the adapted mobile device still face phase, infants exhibited the typical protest and distress response exhibited in other versions of the still-face paradigm (Myruski et al., 2018). Myruski et al. (2018), asked parents 4 self-report questions to assess habitual mobile device use. More frequent habitual maternal mobile device use was correlated with less engagement with the mother during reunion. However, there were a number of limitations to the study. The reunion phase was shorter than the initial free play phase, making it difficult to compare between the initial free play and the reunion phases. Although mothers were instructed to interact with their phones and not with their infants they did not receive a text and were not reading or responding to a text. There were no other control conditions. An open question is whether other non-media related absorbing activities that limit maternal responsiveness trigger negative child emotions comparable to that of maternal mobile device use.

In summary, these studies provide initial indications that parental smartphone use has a particularly negative impact on parental interaction quality and attention to their children compared to other activities that engage them. Researchers have not previously investigated whether smartphone use can lead to changes in maternal behavior. Furthermore, they have not tested the assumption that smartphone use is more disruptive for an interaction than other non-digital media. Here, we explored changes to mother-child interactions that occur before, during and after interruptions due to texting. We wanted to examine how parents would typically respond to their infants while answering texts on a smartphone. We did not specifically try to replicate a still face paradigm. We did not explicitly instruct them to assume a still face but rather used a detailed coding scheme to code parent behavior before, during, and after the interruption. Following previous studies we also coded child behavior. We compared the effect of maternal smartphone use to an analog medium on maternal interaction quality with their 20- to 22-month-old children. Following the Myruski et al. (2018) procedure, there was a free play period followed by a 2-min interruption. During the interruption, mothers were asked to fill out a questionnaire either a) by typing on the smartphone (smartphone group) or b) on paper with a pen (paper-pencil group). The interruption groups were compared to a no-interruption group.

We hypothesized an interaction effect between phase and condition. For the interruption conditions we hypothesized that there would be a u-shaped function in interactions with high rates of positive mother-child interactions and child behavior during the first free play period, a decrease in positive interactions during the interruption phase and an increase in positive interaction in phase 3. We hypothesized that the interaction quality and the child's behavior would remain constant in the no-interruption group across phases. Focusing on the interruption phase, we hypothesized that the quality of interaction in the no-interruption group would be higher than in the paper-pencil group and higher in the paper-pencil group than in the smartphone group. Likewise, we hypothesized that child negative affect, social bids and forbidden behavior would increase during the interruption phase, but more so in the smartphone than in the paper-pencil condition and least in the no-interruption group.

# METHODS

## Participants

We conducted an a priori power analysis for a mixed ANOVA for an effect size of 0.25 (Myruski et al., 2018), power of 0.95, alpha 0.05, 3 groups and 3 measurements and received a required sample size of 54. Fifty-four full-term, healthy 20-22-month-old infants ($M_{age} = 20.8$ months, $SD = 0.5$ months) were randomly assigned to one of two interruption conditions (smartphone: $n = 18$, 10 female; paper-pencil: $n = 20$, 9 female) or a no-interruption control condition ($n = 16$, 8 female). Three additional families participated, but had to be excluded from analysis due to technical difficulties ($n = 1$) or the interruption being too long ($n = 2$).

Mothers were on average 33.8 years ($SD = 3.6$ years, range = 24–42 years), well-educated (62% had a university degree as the highest educational qualification), and German nationals (88.7% were of German nationality, 3.8% had a nationality different from German, and 7.5% had a German and another nationality, 53 mothers reporting). Mothers also reported family's yearly income before taxes (44 reporting). 2.3% had <10.000€, 18.2% had 20.000€ to 39.000€, 25% had 40.000–59.000€, 27.2% had 60.000–80.000€, 15.9% had more than 80.000€, 11.4% preferred not to answer the question. 100% of the mothers owned a smartphone (51 mothers reporting). The families were recruited via the local birth register of the city of Bochum. The children received a small book and a certificate and the mothers received 5€. The study was approved on January 27, 2019 by the local ethics committee of the Faculty of Psychology at the Ruhr University Bochum. Data was collected between February and August, 2019.

## Design

Mothers were instructed to play with a standard set of toys. Analogous to the standard phases of a still face procedure, there were three phases of the study for the smart-phone and paper-and-pencil interruption conditions. There was an initial 3 min free play period, followed by a 2 min interruption phase and a second 3 min free play period. The no-interruption group had an 8 min uninterrupted free play period.

## Material

### CAFE Media Assessment Questionnaire

Parents completed a 74-item Qualtrics survey covering 10 topics, including household composition and demographics, parental mediation of media use, parent attitudes toward media use, and access to and regularity of use of different devices frequently used in the modern household (Barr et al., 2020) (average time to complete in our sample ∼30 min). The questions

**FIGURE 1 |** Set of toys used during free play.

were derived from a number of existing surveys (e.g., Lapierre et al., 2012; Rideout, 2017) and were updated to reflect current technologies and research on the content and context of early media exposure. Established measures of parent media use, behaviors, and attitudes, such as Valkenburg et al. (1999) parent mediation scale are also part of the survey. Since we were especially interested in maternal smartphone use in this study, we selected the following items for the analyses: duration of phone use on typical weekdays (scale from 1 to 8: "1" = never, "2" = <30 min, "3" = 30-60 min, "4" = 1-2 h, "5" = 2-3 h, "6" = 3-4 h, "7" = 4-5 h, "8" = more than 5 h), frequency of checking the phone per day, and likeliness of phone use while being with the child.

### Set of Toys Free Play

Mother-child dyads received a standardized set of toys for the free play consisting of building blocks, a ball, two soft toys, a wooden book and three gardening toys (see **Figure 1**).

### Smartphone

A Samsung Galaxy J5 DUOS® connected to the internet was used by parents to answer the questions during interruption periods. We only put the SMS-icon on the front page so that operation was as easy as possible. The tone for incoming messages was set to "Charming Bell."

### Paper-Pencil

In the paper-pencil condition, mothers received the questionnaire on paper on a clipboard that mothers filled out using a pencil when the experimenter sounded a bell.

## Procedure

Mothers completed the CAFE media questionnaire online before coming into the lab for the experiment. Upon arrival, there was a brief warm-up so the child could get used to the surroundings. The experimenter explained the experiment using a cover-story and the procedure to the mother and obtained informed consent. All mothers were unaware of the reasons for the interruption and hypotheses of the study. The room was divided into a testing room and a control room by a curtain where the experimenter controlled the cameras. There were three cameras filming the room from different angles.

After a warm-up phase with the experimenter, mothers received a book that they read with their child for 5 min. Afterwards, there was a 5 min break where the experimenter entered the room again and interacted with mother and child. Then, mother and child participated in a demonstration phase where the mother demonstrated novel actions to her child. These results are not reported here. After another 5 min break the experiment started and mothers were instructed to play with their child, as they would normally do at home for 3 min. Mother and child sat on a play mat on the floor and received a box of toys (**Figure 1**). In the smartphone condition, mothers also received a smartphone and in the paper-pencil condition a chart with the questionnaire and a pencil. "While you are playing, I will use an SMS [smartphone group]/a bell [paper-pencil group] to advise you to carefully answer the questions about your situation. Then please just keep playing." The experimenter then went behind the curtain and the dyads played together for 3 min until the experimenter interrupted the play. For the smartphone condition the experimenter sent a text and for the paper-and-pencil condition the experimenter rang a bell.

Mothers in the smartphone condition received a text and responded to questions on the phone during the 2 min interruption period. The questionnaire was active for 2 min and would close after this time in order to control the amount of time that mothers were given to fill out the questions. Mothers in the paper-pencil conditions responded to the same questions on paper when the experimenter rang a bell. The experimenter indicated to resume playing by ringing the bell again. Afterwards, mothers and children had another 3 min free play. Toys were present during the interruptions and children could move freely around the room like in Myruski et al. (2018) but unlike (Konrad et al., 2021). In the control condition, there was no interruption and mothers and children had a free play episode for 8 min to control for natural changes in maternal behavior over time. At the end of the session, mothers were debriefed about the nature of the study.

## Video Coding

### Maternal Behavior

Maternal behavior was coded offline from videos for each phase by three of the authors (phase 1 free play, phase 2 interruption, phase 3 free play 2). The coding scheme for the maternal interaction quality during free play was based on existing coding schemes and consisted of 16 variables (see **Table 1**; Dixon et al., 1984; Fiese, 1990; Wagner et al., 2017). In accordance with the Play-PAB coding scheme (Wagner et al., 2017), the variables were coded on a rating scale from 0 to 4, with the verbal anchoring of the scales mostly varying from 0 (never) to 4 (frequently or constantly). The variables "initiate interaction" and "direct attention" were coded as absolute frequencies and for the statistical analysis, they were calculated as frequencies per minute since the three phases were of different lengths. We aimed to partially replicate existing scales so we used the original scales and then conducted a factor analysis on our data to test whether factors emerged using the combined scales. Intraclass correlations (ICCs) were used as a measure of inter-rater reliability and are displayed in **Table 1**. The following benchmarks were applied: > 0.9: Excellent, > 0.8: Good, > 0.7: Acceptable, > 0.6: Questionable, > 0.5: Poor, and < 0.5: Unacceptable (George and Mallery, 2003). Data were coded by a primary coder and a second independent rater who as a trained masters student blind to the hypotheses. Our initial apriori reliability check (the inter-rater reliability, 16.7% of the videos, $n = 9$ of 54) revealed that the apriori reliability was excellent to acceptable except for dynamic affect, ICC = 0.06, and criticism, ICC = 0.42). A review of the literature (Hallgreen, 2012) indicated that reliability can be lower than expected due to low base rates and that then doing an additional reliability check might increase reliability of those codes. We decided to code 5 additional videos for reliability (final reliability based on 25.9% of the data ($n = 14$ of 54) and reliability remained high for the codes overall but increased to acceptable levels for dynamic affect, ICC = 0.73, criticism, ICC = 0.76). We therefore included dynamic affect and criticism in a second factor analysis. Although the pattern of results did not change after adding the additional codes, we included them in order to include as many aspects of parenting as possible. Inclusion of these two codes also allows our data to be more consistent with prior literature examining parent-child interactions in similar studies.

Scores on the variables during phase 1 were used for the factor analysis. Only variables were included in the factor analysis where at least 20% of mothers had some scores/values in any of the phases. Overall, maternal negative behavior was very low (often only visible in one or two mothers) and therefore five variables were excluded from the factor analysis (verbal threat, anger, flat affect, impatience, excessive control).

We then used several well-recognized protocols to conduct a factor analysis with the remaining 11 items. First, examination of the pattern of first order correlations showed that all items correlated at least 0.3 with at least one other item. Second, the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.603, above the commonly recommended value of 0.6, and Bartlett's test of sphericity was significant [$\chi 2_{(55)} = 177.9$, $p < 0.001$]. Finally, the communalities were above 0.3 except for two variables (criticism, rebukes), further confirming that each item shared some common variance with other items. Given these

**TABLE 1 |** Coding scheme for maternal behavior.

| Code | Description | ICC |
|---|---|---|
| Instruct | 0 = The mother never gives instructions to the child<br>1 = 1 to 2 instructions<br>2 = 3 to 4 instructions<br>3 = 5 instructions<br>4 = The mother gives frequent or constant instructions | 0.89 |
| Direct attention | Mother directs the child's attention. For example, drawing attention to an object by pointing at it, labeling the object, instructing the child to get an object, or moving the child's hand toward an object | 0.81 |
| Initiate interaction | The mother initiates the interaction or makes a social offer to the child. | 0.73 |
| Responsiveness | 0 = The mother never or rarely behaves responsively<br>1 = The mother is occasionally responsive but for less than half the time<br>2 = The mother is responsive about half the time<br>3 = The mother is often responsive, but not always<br>4 = The mother behaves responsively frequently or consistently | 0.89 |
| Dynamic emotional response | 0 = The mother never or rarely shows an excited or energetic mood<br>1 = The mother occasionally shows an excited or energetic mood, but less than half the time<br>2 = The mother shows an excited or energetic mood for about half the time<br>3 = The mother often shows an excited or energetic mood, but not always<br>4 = The mother frequently or constantly shows an excited or energetic mood | 0.73 |
| Reciprocity | 0 = Mother and child are never or rarely involved in joint activities<br>1 = Mother and child are occasionally involved in joint activities<br>2 = Mother and child are involved in joint activities for approximately half of the time<br>3 = Mother and child are often involved in joint activities<br>4 = Mother and child are frequently or consistently involved in joint activities | 0.89 |
| Praise | 0 = The mother never praises the child<br>1 = 1 to 2 occasions with implied praise; the praise can be weak or inauthentic<br>2 = 3 to 4 occasions of indirect praise and/or 1 to 2 occasions with clear praise<br>3 = 5 occasions with indirect praise and/or 3 to 4 occasions with clear praise<br>4 = The mother praises the child frequently or constantly | 0.90 |
| Criticism | 0 = The mother never criticizes the child<br>1 = 1 occasion with slight rejection or criticism<br>2 = 2 occasions with slight rejection or criticism and/or 1 occasion with clear rejection or criticism<br>3 = 3 occasions with slight rejection or criticism and/or 2 occasions with clear rejection or criticism<br>4 = The mother shows frequent or constant rejection or criticism | 0.75 |
| Verbalize | 0 = The mother never makes neutral comments about the child's activity and mood<br>1 = The mother makes 1 to 2 neutral comments about the child's activity and moo<br>2 = The mother makes 3 to 4 neutral comments about the child's activity and mood<br>3 = The mother makes neutral comments about 5 statements the child's activity and mood<br>4 = The mother often or consistently makes neutral comments about the child's activity and mood | 0.89 |
| Rebukes | 0 = the mother /expresses to the child no corrective/admonishing behavior<br>1 = 1 occasion with slight corrective/admonishing behavior<br>2 = 2 occasions with slight and/or 1 occasion with distinct corrective/admonishing behavior<br>3 = 3 occasions with slight and/or 2 occasions with clear<br>corrective/admonishing behavior<br>4 = The mother expresses frequent or constant corrective /admonishing behavior | 0.92 |
| Interference | 0 = The mother never interferes with the ongoing activity of the child<br>1 = 1 occasion with slight interference<br>2 = 2 occasions with slight interference and/or 1 occasion with<br>clear interference<br>3 = 3 occasions with slight interference and/or 2 occasions with clear interference<br>4 = The mother interferes frequently or consistently in the ongoing activities of the child | 0.96 |
| Verbal threat | 0 = The mother never utters verbal threats<br>1 = 1 occasion with mild verbal threat<br>2 = 2 occasions with mild and/or 1 occasion with clearer verbal threat<br>3 = 3 occasions with mild and/or 2 occasions with clear verbal threat<br>4 = The mother utters frequent or constant verbal threats | 1.0 |
| Anger | 0 = The mother never shows anger or hostility toward the child<br>1 = 1 occasion of slight anger or hostility<br>2 = 2 occasions with slight anger or hostility and/or 1 occasion with moderate anger or hostility<br>3 = occasions with slight and/or 2 occasions with moderate anger or hostility; the mother generally shows slight anger or hostility toward the child<br>4 = The mother shows frequent or constant anger or hostility the child | 0.97 |

*(Continued)*

**TABLE 1 |** Continued

| Code | Description | ICC |
|---|---|---|
| Flat affect | 0 = The mother never shows shallow affect/emotional withdrawal<br>1 = The mother occasionally shows shallow affect/emotional withdrawal, but for less than half the time<br>2 = The mother shows shallow affect/emotional withdrawal, for about half the time<br>3 = The mother often shows shallow affect/emotional withdrawal, but not always<br>4 = The mother shows frequent or persistent shallow affect/emotional withdrawal | 0.46 |
| Impatience | 0 = The mother never shows impatience with the child<br>1 = 1 occasion with a slight impatience<br>2 = 2 occasions with slight impatience and/or 1 occasion with clear impatience<br>3 = 3 occasions with slight impatience and/or 2 occasions with clear impatience<br>4 = The mother shows frequent or constant impatience | 0.89 |
| Excessive control | 0 = The mother never shows excessive control over task/activity<br>1 = 1 occasion with slightly excessive control over the task/activity<br>2 = 2 occasions with slightly excessive control and/or 1 occasion with excessive control over the task/activity<br>3 = 3 occasions of slightly excessive control and/or 2 occasions with excessive control over the task/activity<br>4 = The mother shows frequently or consistently excessive control over the task/activity | 0.93 |

overall indicators, factor analysis was deemed to be suitable with all 11 items.

A principal axes factor analysis was used. Initial eigenvalues indicated that the first two factors explained 26 and 12% of the variance, respectively. The third and fourth factors had eigen values under one, and each explained 7% of the variance. Solutions for two, three, and four factors were each examined using oblimin rotations of the factor loading matrix. The two factor solution, which explained 39% of the variance, was preferred because of: (a) its previous theoretical support; (b) the "leveling off" of eigenvalues on the screen plot after two factors; and (c) the insufficient number of primary loadings and difficulty of interpreting the third and fourth factor. The two factors shown in **Table 2** were pedagogical behavior (variables: instruct, mother directs attention, interfere with the child's actions, verbalize the child's activities) and responsiveness (variables: responsiveness, reciprocity, dynamic affect). A total of four items (praise, criticism, rebukes, initiate interaction) were eliminated because they did not contribute to a simple factor structure and failed to meet a minimum criteria of having a primary factor loading of 0.30 or above on factor 1 or 2. We then calculated a mean score for each of the factors. Note that interfere with the child's actions was reverse coded before calculating the composite score.

We hypothesized that operating a smartphone use might be more absorbing than filling out a paper sheet, and therefore coded the absorption of maternal attention during the interruption. For this purpose, phase 2 (the 2 min interruption phase for the experimental groups) was divided into four 30-s blocks. In these four blocks, absorption with the questionnaire was assessed on a 3-point rating scale (1 = occasional attention to the questionnaire/changing attention between child and questionnaire; 2 = occasional attention to the questionnaire/monitoring the child; 3 = exclusive attention to the questionnaire/no interaction with the child; based on Abels et al., 2018). Level 3 represented the highest degree of maternal distraction. A second rater coded 15.8% ($n$ = 6 of 38) of the mothers. The ICCs were excellent (ICC = 0.91). For the final analysis, the variable maternal absorption during the interruption was calculated as the mean of the four coded absorption values.

**TABLE 2 |** Factor analysis on maternal behavior variables.

| Variable | Rotated factor loading | |
|---|---|---|
| | Pedagogical behavior | Responsiveness |
| Criticism | 0.04 | −0.22 |
| Rebukes | 0.27 | 0.04 |
| direct attention | **0.38** | 0.20 |
| initiate interaction | 0.24 | 0.19 |
| Responsiveness | −0.15 | **0.61** |
| Interference | **0.71** | −0.11 |
| instruct child | **0.67** | 0.04 |
| Verbalize | **−0.58** | 0.13 |
| Praise | −0.09 | 0.07 |
| Reciprocity | 0.03 | **0.82** |
| Dynamic affect | 0.29 | **0.41** |
| **Eigenvalues** | **2.87** | **1.37** |

*N = 54. The extraction method was principal axis factoring with an oblimin (Promax with Kaiser Normalization) rotation. Factor loadings 0.30 or above are in bold.*

## Child Behavior

A coding scheme by Myruski et al. (2018) was modified and expanded to assess child behavior. The coded variables of child behavior analyzed here were: positive social bids to the mother (the child tries to get the mother's attention physically or vocalically, in a positive or neutral way), negative social bids to the mother (the child tries to get the mother's attention physically or vocalically in a negative way), prohibited behavior (the child does something that the mother or the experimenter has forbidden beforehand, or something that the child knows is forbidden), negative affect (negative expression or vocalization; the child protests, withdraws herself/himself or cries), and toy engagement (child plays alone with the toys provided or with other objects that belong to the play situation, e.g., chair, box, blanket). The variables negative affect, and toy engagement were coded as duration in seconds, all other variables were coded as absolute frequencies. Times when negative affect/toy engagement were not visible on the video (e.g., face was hidden) was coded as "non-codable" in seconds and later relativized for the duration of the variable. All variables were included in the analysis since at least 20% of children had some scores/values in any of the phases.

Videos were coded by one author. A second rater who was another author coded 20.4% of the videos ($n = 11$ of 54). The following benchmarks were applied: $> 0.9$: Excellent, $> 0.8$: Good, $> 0.7$: Acceptable, $> 0.6$: Questionable, $> 0.5$: Poor, and $< 0.5$: Unacceptable (George and Mallery, 2003). The ICCs were acceptable (negative affect, 0.69) to good (positive social bids, 0.88; negative social bids, 0.85; prohibited behavior, 0.95; toy engagement, 0.90). For the final analyzes, the frequency variables were calculated as frequencies per minute and the duration variables as a percentage of the time, since the three phases were of different lengths.

## Statistical Analyses

For hypothesis 1, two mixed ANOVAs, with phase as a within-subject factor (phase 1, phase 2, phase 3) and condition as a between subject-factor (smartphone, paper-pencil, no-interruption) with responsiveness and pedagogical behavior as dependent variables were calculated. For hypothesis 2, five mixed ANOVAs, with phase as a within-subject factor (phase 1, phase 2, phase 3) and condition as a between subject-factor (smartphone, paper-pencil, no-interruption) with positive social bids per minute, negative social bids per minute, prohibited behavior per minute, negative affect and toy engagement as a percentages of the time, were calculated. Follow-up ANOVAs at each phase were conducted to disentangle interactions. We used the software IBM SPSS Statistics 25 (IBM Corp., 2017) for the analyses.

# RESULTS

## Descriptive Statistics for Maternal Mobile Device Use

For a typical weekday, 13% of mothers reported to use their phone <30 min, 36% use it 30–60 min, 32% use it 1–2 h, and 15% use it 2–3 h, 2% 3–4 h, and 2% 4–5 h ($n = 47$ reporting). This indicates that on average mothers used their smartphones for between 30 min and 2 h per day, consistent with other reports of daily maternal smartphone usage (e.g., Yuan et al., 2019; Barr et al., 2020). 8.5% of mothers reported that they typically check their smartphone every 3 h, 30% every 2 h, 34% every hour, 19% every half an hour, 8.5% every 15 min ($n = 47$ reporting). Seventeen percent of mothers indicated that they never use the smartphone during play with the child, 32% indicated that it is not very likely, 26% indicated neutral, 21% indicated that it is likely, and 4% indicated that it is very likely ($n = 47$ reporting).

There was no difference between conditions in how much mothers reported using their phone during a typical weekday, $F_{(2, 45)} = 0.2$, $p = 0.80$, $\eta p2 = 0.01$. Furthermore, mothers from the three groups did not differ in how likely they would use their smartphone in front of their child, $F_{(2, 45)} = 0.7$, $p = 0.49$, $\eta p2 = 0.03$, or how often they check their smartphone per day, $F_{(2, 45)} = 1.4$, $p = 0.27$, $\eta p2 = 0.06$.

## Absorption During the Interruption

Mothers were occasionally absorbed by the questionnaire, both in the smartphone- ($M = 2.06$, $SD = 0.52$, $n = 18$) as well as the paper-pencil group ($M = 2.2$, $SD = 0.73$, $n = 20$). Absorption did not differ between mothers who used a smartphone and mothers who used the paper-pencil questionnaire, $t_{(36)} = 0.45$, $p = 0.65$. We found no significant correlations between self-reported habitual maternal mobile device use and absorption in the smartphone or in the paper-pencil condition (biggest $r = 0.26$, $p = 0.30$). The more mothers were absorbed by the questionnaire, the less they exhibited responsiveness and pedagogical behavior in both the smartphone ($r = -0.72$, $p = 0.001$; $r = -0.59$, $p = 0.01$) and in the paper-pencil conditions ($r = -0.84$, $p < 0.001$; $r = -0.80$, $p < 0.001$).

## Maternal Behavior

**Figure 2A** displays maternal responsiveness as a function of condition and phase. A mixed-ANOVA with phase (play, interruption, play) as a within-subject factor and condition (smartphone, paper-pencil, no-interruption) as a between-subject factor revealed significant main effects for phase, $F_{(2, 102)} = 111.4$, $p < 0.001$, $\eta p2 = 0.67$, and condition, $F_{(2, 51)} = 7.3$, $p = 0.002$, $\eta p2 = 0.22$. The main effects were qualified by a significant interaction between condition and phase on maternal responsiveness, $F_{(4, 102)} = 26.1.4$, $p < 0.001$, $\eta p2 = 0.51$. To disentangle the interaction, we conducted follow-up one-way between-subjects ANOVAs at each phase. These analyses showed that there was no difference between conditions in maternal responsiveness before [$F_{(2, 51)} = 0.2$, $p = 0.79$, $\eta p2 = 0.01$] and after the interruption [$F_{(2, 51)} = 0.1$, $p = 0.38$, $\eta p2 = 0.04$]. Conditions differed during the interruption period [$F_{(2, 51)} = 41.1$, $p < 0.001$, $\eta p2 = 0.62$] and Bonferroni *post-hoc t*-tests indicated that mothers were more responsive to their child in the no-interruption condition compared to the smartphone (*Mdiff* $= 1.67$, $p < 0.001$) and paper-pencil conditions (*Mdiff* $= 2.01$, $p < 0.001$) (**Figure 2A**), but responsiveness did not differ between the paper-pencil and smartphone conditions, *Mdiff* $= 0.34$, $p = 0.42$. To capture within-subject changes, we conducted repeated-measures ANOVAs for each condition. Maternal responsiveness decreased across phases in the no-interruption condition, $F_{(2, 30)} = 3.9$, $p = 0.031$, $\eta p2 = 0.21$. Pairwise comparisons indicated that mothers showed marginally less responsiveness in phase 3 compared to phase 1 (*Mdiff* $= 0.44$, $p = 0.051$). Maternal responsiveness changed significantly in the paper-pencil condition across phases, $F_{(2, 38)} = 82.1$, $p < 0.001$, $\eta p2 = 0.81$. Pairwise comparisons indicated that mothers showed more responsiveness in phase 1 compared to phase 2 (*Mdiff* $= 2.08$, $p < 0.001$), and less responsiveness in phase 2 compared to phase 3 (*Mdiff* $= -1.77$, $p < 0.001$). Likewise, maternal responsiveness changed significantly in the smartphone condition across phases, $F_{(2, 34)} = 77.9$, $p < 0.001$, $\eta p2 = 0.82$. Pairwise comparisons indicated that mothers showed

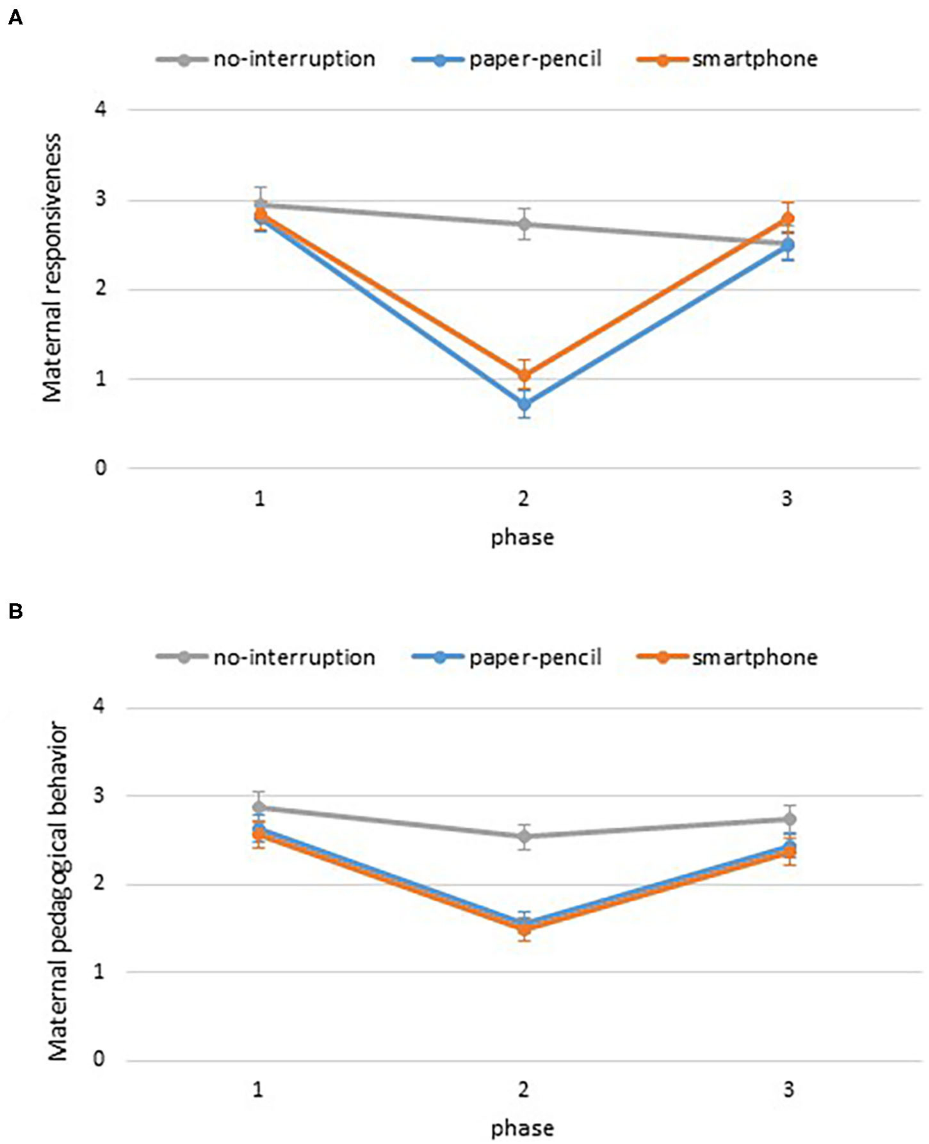


**FIGURE 2 |** Maternal responsiveness **(A)** and pedagogical behavior **(B)** as a function of phase and condition. Error bars are SE of M. *$p < 0.05$.

more responsiveness in phase 1 compared to phase 2 (*Mdiff* = 1.78, $p < 0.001$), and less responsiveness in phase 2 compared to phase 3 (*Mdiff* = −1.74, $p < 0.001$). These findings are consistent with our hypothesis that there would be a u-shaped function in responsiveness in the smartphone and paper-and-pencil conditions.

As shown in **Figure 2B**, pedagogical behavior decreases during phase two in the smartphone and paper-pencil condition, but not in the no-interruption condition. A mixed-ANOVA with phase (play, interruption, play) as a within-subject factor and condition (smartphone, paper-pencil, no-interruption) as a between-subject factor revealed significant main effects for phase, $F_{(2, 102)} = 39.5$, $p < 0.001$, ηp2 = 0.44, and condition, $F_{(2, 51)} = 8.0$, $p = 0.001$, ηp2 = 0.24. The main effects were qualified by a significant interaction between condition and phase on pedagogical behavior, $F_{(4, 102)} = 3.6$, $p = 0.008$, ηp2 = 0.12. To disentangle the interaction, we conducted follow-up one-way between-subjects ANOVAs at each phase. These analyses showed that there was no difference between conditions in maternal pedagogical behavior before [$F_{(2, 51)} = 1.0$, $p = 0.38$, ηp2 = 0.04] and after the interruption [$F_{(2, 51)} = 1.7$, $p = 0.20$, ηp2 = 0.06]. Conditions differed during the interruption period [$F_{(2, 51)} = 19.3$, $p < 0.001$, ηp2 = 0.43] and Bonferroni *post-hoc t*-tests indicated that mothers were more pedagogical to their child in the no-interruption condition compared to the smartphone (*Mdiff* = 1.05, $p < 0.001$) and paper-pencil conditions (*Mdiff* =

0.97, $p < 0.001$) (**Figure 2B**), but pedagogical behavior did not differ between the paper-pencil and smartphone conditions, $p = 0.10$. To capture within-subject changes, we conducted repeated-measures ANOVAs for each condition. Pedagogical behavior did not change across phases in the no-interruption condition, $F_{(2, 30)} = 1.3$, $p = 0.29$, ηp2 = 0.08. Pedagogical behavior changed significantly in the paper-pencil condition across phases, $F_{(2, 38)} = 23.5$, $p < 0.001$, ηp2 = 0.55. Pairwise comparisons indicated that mothers showed more pedagogical behavior in phase 1 compared to phase 2 (*Mdiff* = 1.08, $p < 0.001$), and less pedagogical behavior in phase 2 compared to phase 3 (*Mdiff* = −0.87, $p < 0.001$). Likewise, pedagogical behavior changed significantly in the smartphone condition across phases, $F_{(2, 34)} = 42.4$, $p < 0.001$, ηp2 = 0.71. Pairwise comparisons indicated that mothers showed more pedagogical behavior in phase 1 compared to phase 2 (*Mdiff* = 1.08, $p < 0.001$), and less pedagogical behavior in phase 2 compared to phase 3 (*Mdiff* = −0.89, $p < 0.001$). These findings once again indicated the predicted u-shaped function.

## Child Behavior

**Figure 3** displays child behaviors as a function of condition and phase. A mixed-ANOVA with phase (play, interruption, play) as a within-subject factor and condition (smartphone, paper-pencil, no-interruption) as a between-subject factor revealed a significant interaction between phase and condition for positive social bids, $F_{(3.12, 79.67)} = 4.1$, $p = 0.004$, ηp2 = 0.14. There were significant main effects of phase, $F_{(1.56, 79.67)} = 20.8$, $p < 0.001$, ηp2 = 0.29, and condition, $F_{(2, 51)} = 6.2$, $p = 0.004$, ηp2 = 0.20. To disentangle the interaction, we conducted follow-up one-way between-subjects ANOVAs at each phase. These analyses showed that there was no difference between conditions in positive social bids before, $F_{(2, 51)} = 1.3$, $p = 0.28$, ηp2 = 0.05, and after the interruption, $F_{(2, 51)} = 1.7$, $p = 0.19$, ηp2 = 0.06. Conditions differed during the interruption period $F_{(2, 51)} = 6.9$, $p = 0.002$, ηp2 = 0.21, and Bonferroni *post-hoc t*-tests indicated that children in the smartphone and paper-pencil conditions displayed more positive social bids toward their mother compared to the no-interruption condition (*Mdiff* = −0.92 $p = 0.026$ in paper-pencil, *Mdiff* = −1.25, $p = 0.002$ in smartphone, **Figure 3A**) and that these behaviors did not differ between the paper-pencil and smartphone conditions, *Mdiff* = 0.322, $p = 0.96$. That is, those in the smartphone and paper and pencil conditions attempted to re-engage the caregiver using positive bids during the interruption phase. To capture within-subject changes, we conducted repeated-measures ANOVAs for each condition. Positive social bids did not change across phases in the no-interruption condition, $F_{(2, 30)} = 0.2$, $p = 0.81$, ηp2 = 0.01. Positive social bids changed significantly in the paper-pencil condition across phases, $F_{(1.38, 26.12)} = 10.5$, $p = 0.001$, ηp2 = 0.36. Pairwise comparisons indicated that children showed more positive social bids during the interruption compared to the first free-play phase (*Mdiff* = 0.73, $p = 0.015$), and more positive social bids during the interruption compared to the second free-play phase (*Mdiff* = 0.92, $p = 0.006$). Likewise, positive social bids changed significantly in the smartphone condition across phases, $F_{(2, 34)} = 14.9$, $p < 0.001$, ηp2 = 0.47. Pairwise comparisons indicated that children showed more positive social bids during the interruption compared to the first free-play phase (*Mdiff* = 0.97, $p = 0.003$), and more positive social bids during the interruption compared to the second free-play phase (*Mdiff* = 1.10, $p = 0.001$).

A mixed-ANOVA on negative social bids with phase (play, interruption, play) as a within-subject factor and condition (smartphone, paper-pencil, no-interruption) as a between-subject factor revealed a significant main effects of phase, $F_{(1.30, 66.45)} = 4.2$, $p = 0.011$, ηp2 = 0.11, no significant main effect of condition, $F_{(2, 51)} = 2.5$, $p = 0.089$, ηp2 = 0.09, and no significant interaction effect, $F_{(2.61, 66.45)} = 2.0$, $p = 0.16$, ηp2 = 0.07. Bonferroni *post-hoc t*-tests indicated that children displayed marginally more negative social bids toward their mother during the interruption phase compared to first free play phase (*Mdiff* = −0.15, $p = 0.06$) (**Figure 3B**), and significantly more negative social bids during the interruption compared to the 2nd free play phase (*Mdiff* = 0.17, $p = 0.028$). The interaction effect was marginal and the pattern of results indicates that negative bids increased during the interruption phase, but did not rise to the level of statistical significance.

Prohibited behavior also changed as a function of phase, $F_{(2, 102)} = 3.9$, $p = 0.023$, ηp2 = 0.07 (**Figure 3C**). Bonferroni *post-hoc t*-tests indicated there were no significant differences in prohibited behavior during the interruption phase compared to the first free play phase (*Mdiff* = 0.11, $p = 0.070$), or between the 2nd free play phase compared to the interruption phase (*Mdiff* = −0.02, $p = 1.000$). There were no significant main effects of condition, $F_{(2, 51)} = 0.9$, $p = 0.430$, ηp2 = 0.3, and no interaction effect, $F_{(4, 102)} = 2.3$, $p = 0.065$, ηp2 = 0.08. That is, overall rates of prohibited behavior were low.

Negative affect was very low in general (see **Figure 4A**) but changed as a function of phase, $F_{(1.23, 62.60)} = 4.7$, $p = 0.026$, ηp2 = 0.09. Bonferroni *post-hoc t*-tests indicated that children displayed marginally more negative affect during the interruption phase compared to the first free play phase (*Mdiff* = 0.02, $p = 0.059$), but there was no significant difference between negative affect during the interruption compared to the 2nd free play phase (*Mdiff* = 0.02, $p = 0.096$). There were no significant main effects of condition, $F_{(2, 51)} = 0.9$, $p = 0.424$, ηp2 = 0.03, and no interaction effect, $F_{(2.46, 62.60)} = 0.8$, $p = 0.49$, ηp2 = 0.03. The overall low levels of negative affect make this pattern of results difficult to interpret.

A mixed-ANOVA on toy engagement with phase (play, interruption, play) as a within-subject factor and condition (smartphone, paper-pencil, no-interruption) as a between-subject factor revealed a significant main effects of phase, $F_{(2, 102)} = 43.8$, $p < 0.001$, ηp2 = 0.46, and condition, $F_{(2, 51)} = 15.2$, $p < 0.001$, ηp2 = 0.37. The main effects were qualified by a significant interaction between phase and condition for toy engagement, $F_{(4, 102)} = 9.6$, $p < 0.001$, ηp2 = 0.27. To disentangle the interaction, we conducted follow-up one-way between-subjects ANOVAs at each phase. These analyses showed that there was no difference between conditions in toy engagement before the interruption, $F_{(2, 51)} = 1.2$, $p = 0.314$, ηp2 = 0.04. Conditions differed during the interruption period $F_{(2, 51)} = 24.6$, $p < 0.001$, ηp2 = 0.49, and Bonferroni *post-hoc t*-tests indicated that

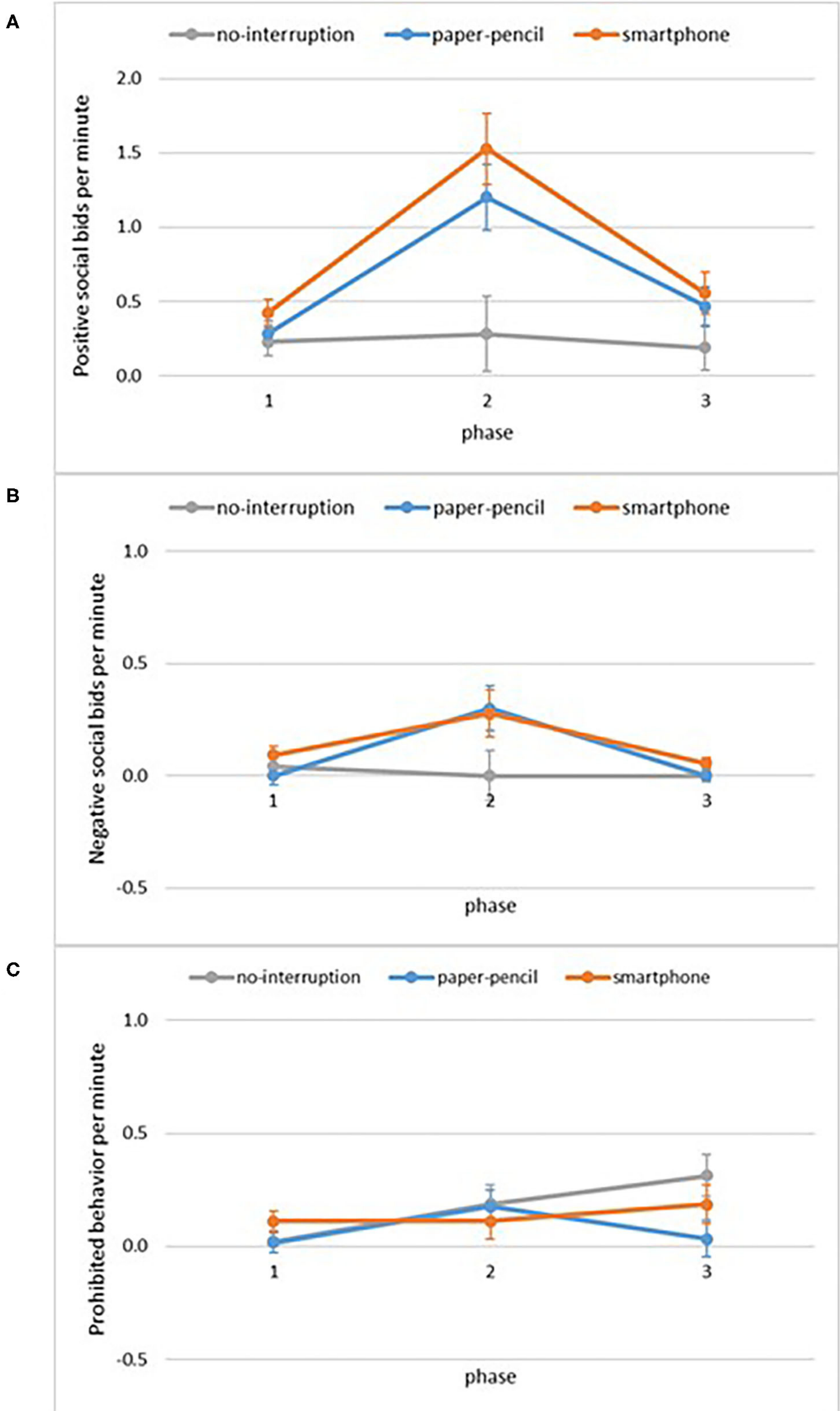


**FIGURE 3 |** Child behaviors per minute as a function of phase and condition. **(A)** Positive social bids per minute, **(B)** negative social bids per minute, **(C)** prohibited behavior per minute. Error bars are SE of M.

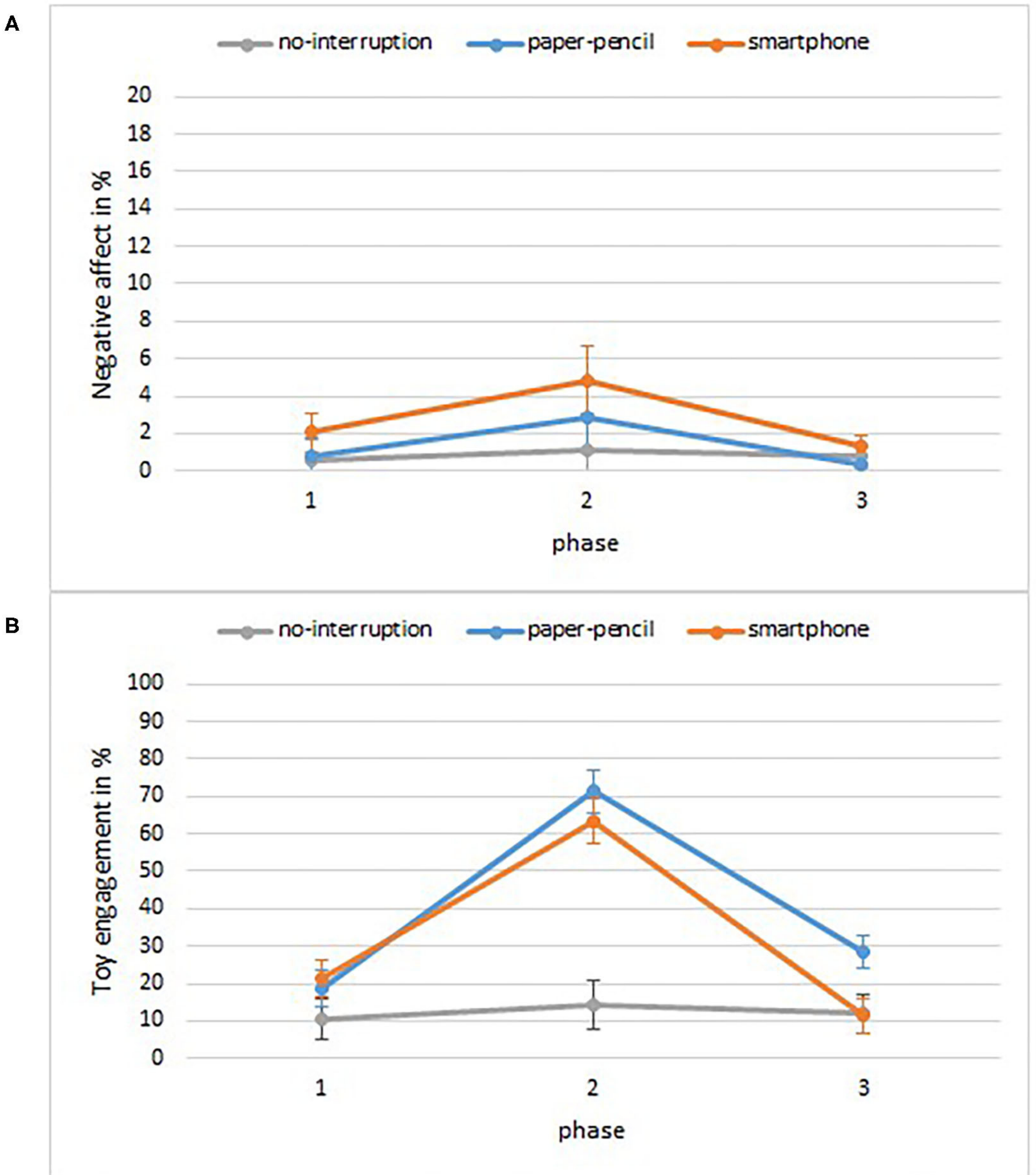


**FIGURE 4 |** Child behaviors as percentage of the time as a function of phase and condition. **(A)** Negative affect, **(B)** toy engagement. Error bars are SE of M.

children in the smartphone and paper-pencil conditions engaged with toys more compared to the no-interruption condition, $p < 0.001$ (**Figure 4B**) and that toy engagement did not differ between the paper-pencil and smartphone conditions, *Mdiff* = 0.08, $p > 0.05$. Furthermore, conditions differed after the interruption, $F_{(2, 51)} = 4.3$, $p = 0.018$, $\eta p2 = 0.15$, and Bonferroni *post-hoc t*-test indicated that children in the paper-pencil engaged with the toys more than children in smartphone condition, *Mdiff* = 0.17, $p = 0.037$, and marginally more than children in the no-interruption condition, *Mdiff* = 0.17, $p = 0.057$. To capture within-subject changes, we conducted repeated-measures ANOVAs for each condition. Toy engagement did not change across phases in the no-interruption condition, $F_{(1.44, 21.62)} = 0.2$, $p = 0.72$, $\eta p2 = 0.02$. Toy engagement changed significantly in the paper-pencil condition across phases, $F_{(2, 38)} = 31.8$, $p < 0.001$, $\eta p2 = 0.63$. Pairwise comparisons indicated that children showed more toy engagement during the interruption compared to the first free-play phase (*Mdiff* = −0.53, $p < 0.001$), and more toy engagement during the interruption compared to the second free-play phase (*Mdiff* = 0.43, $p < 0.001$). Likewise, toy engagement changed significantly in the smartphone condition across phases, $F_{(2, 34)} = 26.3$, $p < 0.001$, $\eta p2 = 0.61$. Pairwise comparisons indicated that children showed more toy engagement during the interruption compared to the first free-play phase ($Mdiff = -0.42$, $p = 0.001$), and more toy engagement during the interruption compared to the second free-play phase ($Mdiff = 0.52$, $p < 0.001$).

## Relations Between Maternal and Child Behaviors

We additionally examined how maternal and child behavior during each phase was related in each condition separately. There were no other significant associations between maternal behavior and child behavior than the ones reported here.

### Smartphone Condition

The more responsive the mothers were during the first free play, the more positive social bids the children showed during the interruption ($r = 0.58$, $p = 0.013$). The more pedagogical behavior the mother showed during the second free play, the less positive social bids the child showed ($r = -0.50$, $p = 0.034$). The more responsive a mother was during the second free play, the less prohibited behavior the child showed ($r = -0.52$, $p = 0.026$).

### Paper-Pencil Condition

The more responsive the mothers were during the first and second free play, the less toy engagement the children showed ($r = -0.59$, $p = 0.006$; $r = -0.61$, $p = 0.004$, respectively). The more pedagogical behavior the mother showed during the interruption, the less toy engagement ($r = -0.48$, $p = 0.032$) and the less negative social bids the children showed ($r = 0.48$, $p = 0.031$).

### No-Interruption Condition

The more responsive the mothers were during the first free play, the less negative affect the children showed ($r = -0.66$, $p = 0.005$).

## Relations Between Maternal and Child Behavior to Maternal Habitual Smartphone Use

Maternal habitual smartphone use as assessed via self-report was related to maternal responsiveness and pedagogical behavior and to child behaviors in each phase.

### Smartphone Condition

#### *Maternal Behavior*

The more mothers habitually check their phone per day, the less pedagogical behavior they displayed during the first free play ($r = -0.53$, $p = 0.027$, $n = 17$). Likewise, the more mothers indicated to use their smartphone during weekdays, the less pedagogical behavior they displayed during the first ($r = -0.625$, $p = 0.007$, $n = 17$) and second free play ($r = -0.63$, $p = 0.007$, $n = 17$).

#### *Child Behavior*

The more mothers habitually check their phone per day, the less negative affect the child displayed during the first free play phase ($r = -0.52$, $p = 0.034$, $n = 17$) and during the interruption ($r = -0.53$, $p = 0.029$, $n = 17$). The more mothers indicated to use their smartphone during weekdays, the more positive social bids the children displayed during the second free play ($r = 0.49$, $p = 0.045$, $n = 17$). The more mothers indicated to habitually use the smartphone when spending time with their child, the less toy engagement children showed during the first free play ($r = -0.54$, $p = 0.025$, $n = 17$).

### Paper-Pencil Condition

#### *Maternal Behavior*

Maternal responsiveness and pedagogical behavior in any phase was not related to maternal smartphone use (biggest $r = -0.22$, $p = 0.21$, $n = 18$).

#### *Child Behavior*

The more mothers habitually check their phone per day, the less negative social bids the children displayed during the interruption ($r = -0.62$, $p = 0.007$, $n = 18$). Likewise, the more mothers habitually check their phone per day, the less negative affect the child displayed during the interruption ($r = -0.65$, $p = 0.004$, $n = 18$).

### No-Interruption Condition

#### *Maternal Behavior*

The more mothers indicated to habitually use the smartphone when spending time with their child, the more pedagogical behavior they showed during the free play phase 1 ($r = 0.67$, $p = 0.018$, $n = 12$) and 2 ($r = 0.86$, $p < 0.001$, $n = 12$).

#### *Child Behavior*

Child behavior was unrelated to maternal smartphone use (biggest $r = 0.55$, $p = 0.06$, $n = 12$).

## DISCUSSION

Our findings replicate and extend those of Myruski et al. (2018). We also found that smartphone use during a free play episode can impair maternal responsiveness and pedagogical behavior. While in the Muryski study mothers were explicitly instructed to exhibit a still face when viewing a smartphone, in the current experiment parents were instructed to respond to a text and complete a questionnaire. Our findings extend those of Myruski et al. (2018) demonstrating that the type of interruption did not matter in our study: texting was not more disruptive than writing on paper. This indicates that the decrease of interaction quality is not solely a feature of the digital media itself. That is, parents and infants responded in similar ways to a digital interruption as they did to a non-digital interruption.

Our findings are consistent with prior observational studies demonstrating that mothers were less responsive and initiated fewer activities while using smartphones than when they were not using a smartphone (e.g., Radesky et al., 2014; Hiniker et al., 2015; Radesky J. et al., 2015; Abels et al., 2018; Lemish et al., 2019; Vanden Abeele et al., 2020; Wolfers et al., 2020). The present study added to this growing body of literature demonstrating that there was no difference in maternal responsiveness prior to the interruption across experimental conditions demonstrating that it was the interruption *per se* that was interfering with the quality of the interactions. Parents exhibited very few negative behaviors during the play period and infants also demonstrated relatively low levels of negative affect which did not differ as a function of experimental condition. This is in contrast to other findings where there were reports of significant increases in negative affect and boundary testing in children during parental smartphone use (Radesky et al., 2014; Myruski et al., 2018). In the present study, the lack of negative affect may be due to the fact that all parents reported that they owned smartphones and 25% of parents reported that such interruptions were typical daily events for their infants. In addition, infants were in a novel playroom and were allowed to move around freely during the interruption period while many of the infants Myruski and colleagues studied were prelocomotive (see also Kildare and Middlemiss, 2017; Myruski et al., 2018, for similar arguments). Finally, unlike Myruski et al. (2018) study where mothers were instructed to maintain a still face and mothers in the present study were simply asked to complete a questionnaire but were not told whether they could interact with the child or not. We found that most mothers monitored their infants, looking up periodically from the phone and checking in with the infants during the interruption but spontaneously exhibited periods of still face during the interruption. Furthermore, infants played with the novel toys more during the interruption and increased their positive bids for attention whereas in the Myruski study toy engagement decreased and negative bids for attention increased. The level of absorption was consistent across paper-and-pencil and smartphone conditions but in contrast to the Myruski findings, most parents periodically checked in with their infants during the interruption. Vanden Abeele et al. (2020) also suggested that many parents may have figured out how to balance their attention between responding to the infant and to the phone. After the interruption, maternal quality rapidly returned to pre-interruption levels suggesting that these short-term interruptions may not have a lasting negative impact on maternal interactional quality, at least in the context of otherwise positive parent-child interactions.

Our findings differ from observational studies which have reported that parental responsiveness was less impaired when parents were engaged in non-digital activities such as reading a newspaper at the playground (Hiniker et al., 2015; Lemish et al., 2019). However, our results may diverge because we also experimentally controlled the activity (completing a questionnaire) between the pencil-and-paper and the smartphone groups and found that mothers were equally absorbed in completing the questionnaire regardless of whether they completed it on paper or on the smartphone. Furthermore, the level of absorption in the task on average was moderate, meaning that most mothers periodically monitored what their child was doing during the interruption (see Vanden Abeele et al., 2020 for a similar finding). That is, one of the mechanisms by which smartphones may disrupt is simply by interfering with interactions or diverting attention. The smartphone and paper-pencil interruptions were able to distract the parent from the ongoing interaction. It is likely that other everyday activities disrupt the flow of parent-child interactions, e.g., writing a shopping list. That is, prior to the introduction of smartphones there were likely activities that interrupted the daily flow of interactions and importantly what we see here is that when the interruption is short then there is a rapid return to engaged interactions. The pervasive nature of smartphone notifications is likely to be more disruptive. It is possible that when mothers interact with personal media content that is more meaningful to them and when they are not being observed in a laboratory setting that they would be more absorbed and less responsive than if they were engaged in non-digital activities (see Vanden Abeele et al., 2020). Passive sensing technology has been able to determine when parents are using smartphones and researchers are beginning to map smartphone use to children's daily activities (e.g., Barr et al., 2020). Future research should vary the type of smartphone activity to examine whether media content contributes to interactional quality but also consider non-digital interruptions to play.

These findings demonstrate that infants attempt to reconnect with their mothers during free play whenever maternal attention is diverted. During the interruption, infants played with the toys more by themselves and also increased their positive bids for attention in an attempt to re-engage their mothers. This study demonstrated that it is difficult for mothers to multi-task and during interruptions when attention is absorbed by other tasks, maternal responsiveness decreases significantly. During phase 3, the 2nd free play period mothers and infants recovered quickly after a brief interruption. The findings are consistent with a large body of research on the still face effect where vocalizations also increase during the still face phase and although we did not see significant evidence of spillover as has been reported in other studies of the still face protocol (Goldstein et al., 2009), recovery occurs during the reunion phase.

There are some limitations to the current study. We randomly assigned participants to two interruption conditions (paper-and pencil or text) but provided no explicit instructions to engage in a still face. It is therefore possible that our study may simply be comparing parents' ability to divide their attention between the questionnaire and caregiving. By using this design, we may have underestimated the unique disruptive effects of smartphones that can grab, absorb and direct attention more than other forms of interaction. Another limitation of the present study and other experimental studies is a social desirability effect. That is, parents may have been more likely to respond during the texting than in an everyday setting. For example, Vanden Abeele et al. (2020) found that smartphone use changed as a function of the observer effect; disruption from smartphone use was less when parents were consented for an observational study than when they were observed in a public setting. We also corrected our reliability estimates. Finally, although the study was powered to detect medium effect sizes, the sample was small and relatively homogenous meaning we may have missed group differences and the generalizability of these findings may be limited to well-educated samples. Future research should examine larger, more diverse samples and examine how the addition of different forms of content, the salience of the content, and the frequency of notifications, changes the absorption by parents and the impact of the smartphone interruption.

The question remains as to whether there are cohort effects for infants born during the digital age. It is quite possible that interruptions due to technoference occur at a higher rate than non-digital interruptions that occurred prior to the widespread usage of mobile devices. There are reasons to consider that this might be the case. On average parents pick up their mobile devices 67 times per day (Yuan et al., 2019). Even allowing for the fact that some of this mobile media use occurs while the baby is asleep, recent research using passive sensing and examining parent reported use of mobile devices during child routines indicates that interruptions are likely to occur frequently throughout the day (Sundqvist et al., 2009; Yuan et al., 2019; Barr et al., 2020; Radesky et al., 2020). It is not yet known, however, if parental responsiveness and child reactions to interruptions will change as a function of frequency of smartphone usage. Over time, if the parent is less responsive, the infant may be less likely to attempt to re-engage the parent. Our correlational results suggest that this could be the case. It is also possible that infants will persist in their attempts to re-engage or learn to do so only when parents are not using smartphones. That is, they may learn that use of the smartphone is a cue that their mothers are unavailable and they will learn to wait to re-engage only after the interruption. The consequences of these changes to the child's proximal environment are not known but it is feasible that language development may be disrupted by frequent, intermittent parental smartphone usage. Instrumental differences in smartphone usage may be associated with outcomes. Sundqvist et al. (2021) demonstrated that increased reports of likelihood of smartphone usage during child routines were associated with poorer language in 2-year-olds. Individual differences might predict more smartphone usage. For example, Wolfers et al. (2020) found the mothers with lower maternal sensitivity were more likely to use smartphones for longer durations of time. The directionality of this finding is unclear. Research in this area will need to consider the bidirectional communication patterns between parents and infants in order to understand the impact of technology on language development and other developmental outcomes.

Some children may be differentially susceptible to interruptions due to technoference (Piotrowski and Valkenburg, 2015). Some studies have shown that children with more difficult temperaments may be more likely to be given mobile devices by their parents as a strategy to calm them down (Radesky et al., 2016b). It is possible that infants with more difficult temperaments who find it more difficult to self-regulate may also be more susceptible to negative consequences of frequent parental use of devices and interruptions to ongoing parent-child interactions. This is an empirical question that warrants further investigation. Specifically, future research should longitudinally investigate how different patterns of technoference within families across time interacts with individual infant differences, parenting quality and child responsiveness.

In conclusion, the present study adds to a small but growing body of literature showing the mobile device usage can disrupt typical parent-child interactions. The present study also demonstrates that the pattern of results was the same whether the interruption was digital or not, at least when the same type of activity is engaged in on each medium. Although future research is warranted, these findings suggest that technoference might operate in similar ways to other types of interruptions when the same type of activity is engaged in across each type of interaction.

## DATA AVAILABILITY STATEMENT

The data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Local ethics committee, Faculty of Psychology, Ruhr University Bochum. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

CK conceived the study idea. CK, RB, MH, JR, and LNi contributed conception and design of the study. MH, JR, LNi, and LNe collected data. CK performed the statistical analysis. CK, MH, and RB wrote the manuscript. All authors read and approved the submitted version.

## FUNDING

This research was supported by a grant to CK by Research School Plus at Ruhr University Bochum to invite guest scientist RB to Ruhr University Bochum for a collaboration project, and by a Caroline-Herschel Guest Professorship awarded to RB.

## REFERENCES

Abels, M., Vanden Abeele, M., van Telgen, T., and van Meijl, H. (2018). "Nod, nod, ignore: An exploratory observational study on the relation between parental mobile media use and parental responsiveness towards young children," in *The Talking Species: Perspectives on the Evolutionary, Neuronal, and Cultural Foundations of Language,* E. M. Luef and M. M. Marin, eds. (Graz: Uni-Press Verlag), 195–228.

Adamson, L., and Frick, J. (2003). The still face: A history of a shared experimental paradigm. *Infancy* 4, 451–473. doi: 10.1207/S15327078IN0404_01

Ainsworth, M. D. S., and Bell, S. M. (1974). "Mother-infant interaction and the development of competence," in *The Growth of Competence,* K. Connolly and J. Bruner, eds. (London, New York, NY: Academic Press), 97–118.

Barr, R., Kirkorian, H., Nichols, D., Radesky, J. S., Coyne, S. M., Blanchfield, O., et al. (2020). Beyond screen time: a synergistic approach to a more comprehensive assessment of family media exposure during early childhood. *Front. Psychol.* 11:1283. doi: 10.3389/fpsyg.2020.01283

Barr, R., and Linebarger, D. N. (eds.) (2017). *Media Exposure During Infancy and Early Childhood: The Effect of Content and Context on Learning and Development*. New York, NY: Springer.

Bornstein, M. H., Tamis-LeMonda, C. S., Hahn, C. S., and Haynes, O. M. (2008). Maternal responsiveness to young children at three ages: Longitudinal analysis of a multidimensional, modular, and specific parenting construct. *Dev. Psychol.* 44:867. doi: 10.1037/0012-1649.44.3.867

Dixon, S. D., LeVine, R. A., Richman, A., and Brazelton, T. B. (1984). Mother-child interaction around a teaching task: an

African-American comparison. *Child Dev.* 55, 1252–1264. doi: 10.2307/1129995

Fiese, B. H. (1990). Playful relationships: a contextual analysis of mother-toddler interaction and symbolic play. *Child Dev.* 61, 1648–1656. doi: 10.2307/1130772

George, D., and Mallery, M. (2003). *Using SPSS for Windows Step By Step: A Simple Guide and Reference.* Boston, MA: Allyn and Bacon.

Ginsburg, K. R. (2007). The importance of play in promoting healthy child development and maintaining strong parent-child bonds. *Pediatrics* 119, 182–191. doi: 10.1542/peds.2006-2697

Goldstein, M. H., Schwade, J. A., and Bornstein, M. H. (2009). The value of vocalizing: five-month-old infants associate their own noncry vocalizations with responses from adults. *Child Dev.* 80, 636–644.doi: 10.1111/j.1467-8624.2009.01287.x

Hallgreen, K. (2012). Computing inter-rater reliability for observational data: an overview and tutorial. *Tutor. Quant Methods Psychol.* 8, 23–24. doi: 10.20982/tqmp.08.1.p023

Hiniker, A., Sobel, K., Suh, H., Sung, Y.-C., Lee, C. P., and Kientz, J. A. (2015). "Texting while parenting: how adults use mobile phones while caring for children at the playground," in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI'15* (Seoul), 727–736. doi: 10.1145/2702123.2702199

Kildare, C. A., and Middlemiss, W. (2017). Impact of parents mobile device use on parent-child interaction: a literature review. *Comp. Hum. Behav.* 75, 579–593. doi: 10.1016/j.chb.2017.06.003

Konrad, C., Berger-Hanke, M., Hassel, G., and Barr, R. (2021). Does texting interrupt imitation learning in 19-month-old infants? *Infant Behav. Dev.* 62:101513. doi: 10.1016/j.infbeh.2020.101513

Landry, S. H., Smith, K. E., and Swank, P. R. (2006). Responsive parenting: establishing early foundations for social, communication, and independent problem-solving skills. *Dev. Psychol.* 42, 627–642. doi: 10.1037/0012-1649.42.4.627

Lapierre, M. A., Piotrowski, J. T., and Linebarger, D. L. (2012). Background television in the homes of US children. *Pediatrics* 130:839. doi: 10.1542/peds.2011-2581

Lemish, D., Elias, N., and Floegel, D. (2019). "Look at me!" Parental use of mobile phones at the playground. *Mobile Media Commun.* 916:1–18. doi: 10.1177/2050157919846916

Mangan, E., Leavy, J. E., and Jancey, J. (2018). Mobile device use when caring for children 0-5 years: a naturalistic playground study. *Health Prom. J. Aust.* 29, 337–343. doi: 10.1002/hpja.38

McDaniel, B. T. (2019). Parent distraction with phones, reasons for use, and impacts on parenting and child outcomes: a review of the emerging research. *Hum. Behav. Emerg. Technol.* 1, 72–80. doi: 10.1002/hbe2.139

McDaniel, B. T., and Coyne, S. M. (2016). "Technoference": the interference of technology in couple relationships and implications for women's personal and relational well-being. *Psychol. Popular Media Cult.* 5, 85–98. doi: 10.1037/ppm0000065

McDaniel, B. T., and Radesky, J. S. (2018). Technoference: parent distraction with technology and associations with child behavior problems. *Child Dev.* 89, 100–109. doi: 10.1111/cdev.12822

Myruski, S., Gulyayeva, O., Birk, S., Pérez-Edgar, K., Buss, K. A., and Dennis-Tiwary, T. A. (2018). Digital disruption? Maternal mobile device use is related to infant social-emotional functioning. *Dev. Sci.* 21:e12610. doi: 10.1111/desc.12610

Newsham, G., Drouin, M., and McDaniel, B. T. (2020). Problematic phone use, depression, and technology interference among mothers. *Psychol. Popular Media* 9, 117–124. doi: 10.1037/ppm0000220

Piotrowski, J. T., and Valkenburg, P. M. (2015). Finding orchids in a field of dandelions: understanding children's differential susceptibility to media effects. *Am. Behav. Sci.* 59, 1776–1789. doi: 10.1177/0002764215596552

Radesky, J., Kistin, C. J., Zuckerman, B., Nitzberg, K., Gross, J., Kaplan-Sanoff, M., et al. (2014). Patterns of mobile device use by caregivers and children during meals in fast-food restaurants. *Pediatrics* 133, 843–849. doi: 10.1542/peds.2013-3703

Radesky, J., Miller, A. L., Rosenblum, K. L., Appugliese, D., Kaciroti, N., and Lumeng, J. C. (2015). Maternal mobile device use during a structured parent-child interaction task. *Acad. Pediatr.* 15, 238–244. doi: 10.1016/j.acap.2014.10.001

Radesky, J., Weeks, H., Ball, R., Schaller, A., Yeo, S., Durnez, J., et al. (2020). Mobile device sampling: an unobtrusive, objective measure of child smartphone and tablet use. *Pediatrics* 146:e20193518. doi: 10.1542/peds.2019-3518

Radesky, J. S., Kistin, C., Eisenberg, S., Gross, J., Block, G., Zuckerman, B., et al. (2016a). Parent perspectives on their mobile technology use: the excitement and exhaustion of parenting while connected. *J. Dev. Behav. Pediatr.* 37, 694–701. doi: 10.1097/DBP.0000000000000357

Radesky, J. S., Peacock-Chambers, E., Zuckerman, B., and Silverstein, M. (2016b). Use of mobile technology to calm upset children associations with social-emotional development. *JAMA Pediatr.* 170, 397–399. doi: 10.1001/jamapediatrics.2015.4260

Radesky, J. S., Schumacher, J., and Zuckerman, B. (2015). Mobile and interactive media use by young children: the good, the bad, and the unknown. *Pediatrics* 135, 1–3. doi: 10.1542/peds.2014-2251

Reed, J., Hirsh-Pasek, K., and Golinkoff, R. M. (2017). Learning on hold: cell phones sidetrack parent-child interactions. *Dev. Psychol.* 53, 1428–1436. doi: 10.1037/dev0000292

Rideout, V. (2017). *The Common Sense Census: Media Use By Kids Age Zero to Eight.* San Francisco, CA: Common Sense Media, 263–283.

Sundqvist, A., Koch, F., Birberg Thornberg, U., Barr, R., and Heimann, M. (2009). *Growing Up in a Digital World.* London: Routledge. doi: 10.4324/9780203863619

Sundqvist, A., Koch, F. S., Birberg-Thornberg, U., Barr, R., and Heimann, M. (2021). Growing up in a digital world Digital media and the impact of the child's language development at two years of age. *Front. Psychol.* doi: 10.3389/fpsyg.2021.569920

Tamis-LeMonda, C. S., Bornstein, M. H., and Baumwell, L. (2001). Maternal responsiveness and children's achievement of language milestones. *Child Dev.* 72, 748–767. doi: 10.1111/1467-8624.00313

Valkenburg, P. M., Krcmar, M., Peeters, A. L., and Marseille, N. M. (1999). Developing a scale to assess three styles of television mediation: "Instructive mediation," "restrictive mediation," and "social coviewing". *J. Broadcast. Electron. Media* 43, 52–66. doi: 10.1080/08838159909364474

Vanden Abeele, M. M. P., Abels, M., and Hendrickson, A. T. (2020). Are parents less responsive to young children when they are on their phones? A systematic naturalistic observation study. *Cyberpsychol. Behav. Soc. Netw.* 23, 363–370. doi: 10.1089/cyber.2019.0472

Wagner, K., Müller, J. M., Esins, S., Romer, G., and Achtergarde, S. (2017). *Play-PAB - PLAY- Parenting Assessment Battery—German adaption of the Lab-PAB [Coder Manual].* doi: 10.23668/psycharchives.779

Wartella, E. (2019). "Smartphones and tablets and kids – oh my, oh my," in *Exploring Key Issues in Early Childhood and Technology,* ed C. Donohue (New York, NY: Routledge), 27–31. doi: 10.4324/9780429457425-5

Wolfers, L. N., Kitzmann, S., Sauer, S., and Sommer, N. (2020). Phone use while parenting: an observational study to assess the association of maternal sensitivity and smartphone use in a playground setting. *Comp. Hum. Behav.* 102, 31-38. doi: 10.1016/j.chb.2019.08.013

Yogman, M., Garner, A., Hutchinson, J., Hirsh-Pasek, K., and Golinkoff, R. M. (2018). The power of play: a pediatric role in enhancing development in young children. *Pediatrics* 142:e20182058. doi: 10.1542/peds.2018-2058

Yuan, N., Weeks, H. M., Ball, R., Newman, M. W., Chang, Y., and Radesky, J. S. (2019). How much do parents actually use their smartphones? Pilot study comparing self-report to passive sensing. *Pediatric Res.* 86, 416–418. doi: 10.1038/s41390-019-0452-2

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 12 August 2020
doi: 10.3389/fpsyg.2020.02023

# Multimedia Input and Bilingual Children's Language Learning

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The current study seeks to explore the impact of multimedia input at home on bilingual children's language outcomes. Two hundred and two Singaporean English-Mandarin kindergarteners' multimedia experience (i.e., the resources and the amount of multimedia input) and conventional language exposure (e.g., language use with family members) were investigated with a parental questionnaire. A series of English and Mandarin tests were conducted to assess children's proficiency (i.e., in receptive vocabulary, receptive grammar, verbal fluency) by standardized measures. Results demonstrated that the diversity of multimedia input is more important than the amount of multimedia input in promoting children's Mandarin language maintenance, while controlling for children's conventional language exposure, SES, and language aptitude. The number of multimedia sources is significantly and positively related to children's general Mandarin proficiency. In contrast, English multimedia exposure at home exerts little impact on children's general English proficiency. The findings indicate the unique contribution of multimedia diversity to children's early heritage language maintenance. The strong social relevance of the study is discussed at the end of the paper.

**Keywords: multimedia input, bilingual children, heritage language maintenance, input quantity, input quality**

OPEN ACCESS

***Edited by:***
*Mikael Heimann,*
*Linköping University, Sweden*

***Reviewed by:***
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***Specialty section:***
*This article was submitted to Educational Psychology, a section of the journal Frontiers in Psychology*

***Received:*** *08 June 2020*
***Accepted:*** *21 July 2020*
***Published:*** *12 August 2020*

***Citation:***
*Sun H and Yin B (2020) Multimedia Input and Bilingual Children's Language Learning. Front. Psychol. 11:2023. doi: 10.3389/fpsyg.2020.02023*

## INTRODUCTION

### Multimedia Input and Child Bilingual Language Development

Input is considered crucial in bilingual children's language development (Grüter and Paradis, 2014). The quantity and quality of input have been found to influence child bilingual's route and rate of vocabulary and grammar acquisition[1] (e.g., Paradis, 2011; Sun et al., 2018b). Researchers in child bilingualism tend to operationalize input quantity as the length of language exposure and the amount of daily communication in the given language with families, friends or in community settings (Unsworth, 2013). In terms of input quality, the emphasis has been on the richness, diversity and authenticity of input resources in children's early literacy environment (Sun, 2019). Previous studies tend to focus on the impact of active communications (e.g., with family members) on bilingual children's language development, and very few studies explore the influence of input from the multimedia perspective. We focus on the role of multimedia in children's bilingual development in the current study.

[1] We recognize that some second language/bilingual researchers make a distinction between *uninstructed* acquisition and *instructed* learning (e.g., Krashen, 1981). Nevertheless, these two terms are sometimes used interchangeably in the literature (e.g., Housen and Pierrard, 2005), which is also the approach in this paper.

The rapid emergence of multimedia such as content delivered through computers, tablets, and electronic books has substantially reshaped bilingual children's input environment (Sun et al., 2019). Thus, the conventional input assessment that addresses children's active communication with other interlocutors might not be able to holistically capture children's daily input patterns. Multimedia could be generally defined as digital technologies combining various media such as video, audio, and text options (Chandler and Munday, 2011). It has been incorporated into almost every aspect of our lives, turning children into multimedia savvy users at a young age. For instance, a US study (Rideout, 2014) showed that around 80% of the participating children use educational media that are offered on TV, computer, and mobile devices at least once a week, among whom one-third use the service every day. A similar trend could be observed in Singapore, where children below 7 years old were found to frequently use smartphones, touchscreen tablets, and laptop computers (Ebbeck et al., 2016). By investigating 1058 parents' and caregivers' views of their children's access to and time spent on multimedia devices, Ebbeck et al. (2016) demonstrated that children between 1 and 7 years of age used multimedia every day. In particular, 3-years-old spent the longest time on smartphones ($M$ = 0.6 h per day), while 5-years-old spent the longest time using touchscreen tablets ($M$ = 0.6 h per day).

Given such prevalent use of multimedia among young children, it would be pertinent to examine whether such media consumption might impact their language development. Indeed, multimedia has been found to positively influence early language learning, especially among monolingual kindergarteners (Rice et al., 1990; Singer and Singer, 1998), as well as for teenagers or adults in foreign language/bilingual settings (e.g., Cho and Krashen, 2000; Kuppens, 2010). The reason for this advantage may have to do with the dual coding theory of learning. It has been postulated that deeper learning occurs when information is presented in both the verbal (e.g., oral narration) and non-verbal modalities (e.g., dynamic visualization). The closer temporal alignment between the presentation of verbal and non-verbal information, the better the learning outcome is (e.g., Mayer, 2005). In this respect, multimedia materials provide non-verbal information that facilitates language comprehension by visualizing narrations, stories, or events in a congruent way (Jared et al., 2013; Wong and Samudra, 2019). In addition, multimedia content tend to be more engaging for children (Takacs et al., 2015), which contributes to their language learning. The bulk of research on the effect of multimedia in language learning comes from the monolingual literature, or research on older bilinguals. It remains to be seen the extent to which bilingual kindergarteners might benefit from multimedia input in their language learning.

Limited existing research suggests that in comparison to societal dominant languages, multimedia might have a more visible impact on bilingual children's heritage language learning, because such children might have limited resources to receive heritage language input from the conventional channels. Take Singapore as an example where the overall sociolinguistic environment leads to an imbalance of input for English vs. non-English languages. Since 1965, English has been taken as the societal dominant language to facilitate inter-ethnic communication and business with the world. Official heritage languages (i.e., Mandarin, Malay, and Tamil), on the other hand, have been used to transmit heritage values and maintain cultural and racial identity. In schools, heritage languages are taught only as a subject, whereas English is used as the medium of instruction. This language policy has led to a substantial change in the home language environment due to parents' utilitarian focus on English. According to Singapore Ministry of Education, 61% of children from the primary school cohort in 2011 were from English dominant families (Goh and Ng, 2015), and the percentage is probably higher based on recent large-scale investigations (e.g., Sun et al., 2018b). While children can access abundant and high-quality content in English, input for heritage languages tends to be more impoverished in quantity and quality (e.g., Sun et al., 2018b). Thus, maintenance of heritage languages in such a context poses a challenge. Given the relative lack of access to conventional, interactive forms of input in heritage languages, one might wonder whether multimedia input may play an outsized role in heritage language maintenance. Indeed, it was found that media input quantity contributed to vocabulary outcomes in heritage languages, but not in English in Singapore (Sun et al., 2018b). We continue to investigate this question in the current study where we look at both the quantity and quality dimensions (i.e., diversity of the resources) of multimedia input, for the acquisition of English and a heritage language (Mandarin Chinese) in Singapore.

## The Amount of Multimedia Input and Children's Early Language Development

Existing research focusing on multimedia as augmentations to story narration has generally shown that the amount of multimedia input is positively related to vocabulary acquisition. A meta-analysis study (Takacs et al., 2015) drawing on data from 2147 children in 43 studies found that technology-enhanced storybooks conferred a small, but significant additional benefit on expressive vocabulary and story comprehension. Importantly, the analysis conducted in that study revealed that multimedia was particularly beneficial for "disadvantaged" children including those from bilingual, immigrant backgrounds, low socioeconomic status (SES) families, and those with other at-risk characteristics. However, the focus of the meta-analysis in Takacs et al. (2015) was deliberately narrow – only studies that included (oral) story narrations were selected for analyses. While this was necessary to enable a valid comparison with the traditional book reading experience, it also meant that studies that looked at the general, incidental effects of multimedia on language and literacy were not included. We look at some of those studies below.

Studies on the incidental effects of multimedia on language and literacy among monolingual children appear to show that results depend on the age. For example, Singer and Singer (1998) found that preschoolers who had viewed ten preselected episodes of Barney and Friends showed significant vocabulary gains. Another study (Rice et al., 1990) found that children who had been frequent viewers of *Sesame Street* performed significantly better on vocabulary tests at age 5 than children in a comparison group. On the other hand, studies focusing on younger monolinguals (around 3 years of age and below) did not yield positive results for the effects of multimedia exposure (e.g., Alloway et al., 2014; Taylor et al., 2018). For example, in a study on 131 British children aged 6–36 months, Taylor et al. (2018) found no effect of screen time (TV or mobile devices) on the vocabulary knowledge of the children as measured by parental reports. Alloway et al. (2014) likewise relied on parental reports as a measure of 30 British toddlers' vocabulary and failed to detect any effects of TV watching on children's language development.

In bilingual and foreign language settings, the effects of multimedia exposure on incidental vocabulary learning are likewise mixed. Kuppens (2010) looked at incidental foreign language learning (English) among Flemish Dutch-speaking pupils (around 11 years old). These pupils had never been formally taught English in their school curriculum, but had access to a wide range of English-language media in their daily life. It was found that subtitled TV/movies, and computer games had significant effects on translation scores between Dutch and English for these students. In addition, the more time spent on those multimedia resources, the better their translation scores were. In heritage maintenance, Cho and Krashen (2000) reported that for ethnic-Korean adults who had arrived in the United States at an early age, watching television in Korean (regardless of the program) was a significant predictor of self-reported Korean language proficiency. Sun et al. (2020) likewise found that the amount of heritage language media input at home was a significant predictor of Singaporean heritage learners' receptive vocabulary. On the other hand, Scheele et al. (2010) did not find any significant correlation between the frequency of watching educational TV program in the heritage language and vocabulary development in Moroccan-Dutch and Turkish-Dutch 3-years old. Another study showing null results was Patterson (2002) who found that television viewing did not predict vocabulary size for either Spanish or English in the bilingual toddlers (around 2 years of age) they studied. The results of these studies seem to mirror those from the monolingual literature in showing that older children were more likely to benefit from multimedia exposure than younger children.

## The Resources of Multimedia Input and Children's Language Development

In addition to the role of input amount, it is also relevant to look at the issue of the quality of multimedia in predicting language outcome. Broadly, this question relates to the issue of input quality in language learning which can be defined as "variation in experience with native-speaker input, rich and complex input gained through activities like reading" (Paradis, 2011, p. 217). Researchers have found that input quality is important for bilinguals' language and literacy acquisition. For example, Scheele et al. (2010) looked at enriching home language activities such as reading, story-telling, and educational TV among Moroccan-Dutch and Turkish-Dutch families in the Netherlands. Their study found a significant correlation between these quality-oriented activities in the L2 (Dutch) and L2 vocabulary outcomes. Paradis (2011) operationalized the notion of input quality in terms of mothers' self-assessed proficiency (in L2 English), mothers' education, and richness of the English environment outside school. Her research revealed that richness of the English environment was a significant predictor for vocabulary scores of her 169 child bilingual participants. Sun et al. (2020)'s research on Singaporean children's receptive vocabulary included measures on input quality such as book reading, and their analyses showed that those were significant predictors of these 457 children's receptive vocabulary growth.

We also take up the issue of the quality of input in children's multimedia exposure. Prior research has touched on the issue of different sources of enriching language activities (e.g., reading, story-telling, TV/movies). In addition, there is recent though limited evidence suggesting that the notion of variety in a given literacy activity contributes to learning outcomes. In a study on book-sharing interactions, Luo et al. (2020) examined the role of book variety in literacy outcomes of children from low-income, ethnic-minority homes in the United States. In the study, mothers of the children were asked to report whether they read each of 10 pre-specified types of books to their children, in addition to indicating the total number of books available at home. Those 10 types of books were divided into two categories for further analyses: concept books (number, colors, letters, shapes, and opposite concepts) and narrative books (daily activities, family relationships or friendships, religious or cultural beliefs, folk tales, and humor). The study found significant effects of book variety for both categories. Namely, the variety of narrative books explained children's narrative contributions during book-sharing interactions whereas the variety of concept books predicted children's referential contribution. The authors concluded by recommending a "varied diet of literacy resources" for literacy development (p. 229). Following this finding, we zoom in on the topic of multimedia exposure and explore the question whether the diversity of different types of multimedia alone contributes to early bilingual language acquisition, over and above the overall quantity of multimedia exposure. Specifically, parents were asked to indicate whether children were exposed to six sources of multimedia input: TV programs, Videos, Audio, Materials demonstrated via electronic devices, e-books, and computer games. We would like to find out whether being exposed to different varieties of these multimedia alone accounts for their language outcome. The rationale behind our thinking is that different types of multimedia may typically use different kinds of lexicon and grammar structures. For example, TV programs might expose children more to colloquial language and informal lexicon, whereas e-books are likely to contain more sophisticated vocabulary and grammar. The more variety of multimedia exposure therefore leads to a wider range of language input for the child. To the best of our knowledge, this question has not been directly addressed in the literature on multimedia exposure, and we would like to pursue it in the current study.

## Other Influential Factors in Bilingual Language Acquisition

A set of factors reflecting learners' specific capability for language learning have also been found to influence bilingual children's language learning (Carroll and Sapon, 2002). These factors are collectively known as language aptitude, and include components such as phonological short-term memory and non-verbal intelligence. Each of these contributes to bilingual children's language learning in different ways (e.g., Knell et al., 2007; Alexiou, 2009; Paradis, 2011). Short-term memory facilitates word articulation and semantic memory by helping children retain the novel sequence of the phonological properties of a language (Gathercole and Baddeley, 1989; Paradis, 2011). Non-verbal intelligence enables a bottom-up approach to linguistic tasks whereby children are able to infer and reorganize structures and patterns (Hakuta and Diaz, 1985; Daller and Ongun, 2018).

Social-economic (SES) has also been found to affect bilingual children's language. Usually measured through maternal education level and household income, SES has been shown to significantly predict bilingual children's vocabulary and grammar acquisition (Blom et al., 2012; Sun et al., 2018b). This can be illustrated by the investment model, as the time and effort the parents spend on their children are equivalent to the number of potential avenues for promoting children's language and cognitive development (Dickinson and Tabors, 2001; Hartas, 2011).

## The Current Study

The current study intends to explore the relationship between multimedia input and children's bilingual language outcomes. In the current paper, multimedia exposure refers to TV programs, videos (e.g., movies via DVD player), audios (e.g., songs via CD player), ebooks, computer games, and other materials demonstrated via E-devices (e.g., apps on iPad). Before proceeding to the questions of the current study, it is important to provide a brief sketch of the overall linguistic environment for the child participants in the current study. As mentioned above, our children are heritage language learners in Singapore where English together with three ethnic languages (Mandarin Chinese, Malay and Tamil) function as official languages. Nevertheless, the predominance of English in various domains of life, including education, government, and inter-ethnic communication (e.g., Bokhorst-Heng, 1999) has resulted in a situation unfavorable to the acquisition and maintenance of heritage languages. Specifically, as described in Sun et al. (2018b), the linguistic environment in Singapore is considered input-poor for heritage languages as a result of the comparative lack of exposure to these languages in various spheres of life. In such a situation, the quantity and quality of input plays a differential role for the learning of heritage languages vs. the societal dominant language (English), as already demonstrated in prior research (e.g., Paradis, 2011; Sun et al., 2018b). With this in mind, there are two specific hypotheses we would make for our current study:

1 Multimedia input has a larger effect on children's Mandarin learning than on English learning. It is because Mandarin has much less amount and resources of input from the conventional channels than that of English, and multimedia input could be an important supplement for children's Mandarin exposure at home. Moreover, children's heritage language may be weaker than their societal dominant language, and the features of multimedia input may scaffold children's vocabulary and grammar learning in the weaker language development to a larger extent.
2 Both the number of resources and the amount of multimedia input are crucial in children's language acquisition, as the former might provide the children with a higher quality of input (e.g., the diverse vocabulary) and the latter may offer children larger quantity of language exposure.

# MATERIALS AND METHODS

## Participants

We recruited two hundred and two young English-Chinese bilingual preschoolers in Kindergarten 1 (4–5 years old; 89 boys and 112 girls) from 21 preschools in Singapore to participate in this study. The participants were recruited based on information provided by teachers and parents. The two selection criteria for participation were: firstly, children should be Mandarin-English bilingual language learners. Participants exposed to more than two languages at home or recent immigrant children from China were excluded[2]. Secondly, there should be no history of developmental delays or impairment. Children varied in social-economic status, but most of them were from middle-class families, with their family income well above the relative poverty line of the country (> S$2500, Donaldson et al., 2013). The average monthly household income was between S$7500 and S$7999. The parental questionnaire contained 20 income options, ranging from "Below 1,000" to "10,000 and over," with S$500 increment for each higher level ($M$ = 15.01, $SD$ = 5.07, *range* = 0–19). On average, parents' highest level of education was a polytechnic diploma or bachelor's degree (e.g., mother's education; $M$ = 5.34, $SD$ = 1.28, *range* = 2–8, ranging from "No qualification" to "Doctorate degree").

## Data Collection and Measures

The first author of this paper obtained ethics clearance from the University's institutional review board. Consent was obtained from parents through forms disseminated at kindergartens. Prior to test administration, children also provided their assent to complete the tasks. Children's English and Mandarin competencies (i.e., vocabulary and grammar) and cognitive capacities were assessed with standardized measures, while a parental questionnaire was used to collect information related to their bilingual environment at home. The sections below provide further information about the measures and the questionnaire in the study.

[2]The children in the current study were early bilinguals, who have been exposed to both English and Chinese at home simultaneously or sequentially from birth. We excluded recent immigrants from China because such children are probably monolingual Mandarin speakers and their language experience would be substantially different from the rest of the population in our sample.

### English and Mandarin Vocabulary Breadth

To measure children's English and Mandarin receptive vocabulary, we used the Bilingual Language Assessment Battery (BLAB) (Rickard-Liow et al., 2013), a standardized test modeled after the Peabody Picture Vocabulary Test II (Dunn and Dunn, 2007). The auditory-picture matching task was developed locally and has been reported to have good reliability in the context of Singapore within the original bilingual norming sample (Rickard-Liow et al., 2013). During the assessment, children were presented with four pictures while listening to recorded words in the program. They were then asked to select one picture out of the four that best conveyed the understanding of the word presented to them. The assessment consisted of 3 practice trials and 80 test trials in total.

### English and Mandarin Vocabulary Depth

Children's productive vocabulary depth was assessed via a verbal fluency task. Participants were asked to name as many English and Mandarin words as they could within a general theme in 1 min. The chosen topics included food and animals, as previous studies have shown their effectiveness in testing child bilinguals' verbal fluency (e.g., Schwartz et al., 2012; Sun et al., 2018a). One point was awarded for an appropriate word. Higher scores indicate greater vocabulary depth in children.

### English and Mandarin Grammar

The English Test for Reception of Grammar Version 2 (TROG; Bishop, 2003) and the Mandarin Grammar Receptive Test (MGRT; Sun, 2019) were used to assess children's receptive grammar knowledge. Similar to the procedures in the BLAB, children were presented with four images and a spoken sentence at the same time. Their task was to select one image out of the four pictures based on their understanding of the sentence heard. There were 3 practice trials and 60 test trials in total. Both tests have demonstrated good external validity and internal reliability.

### Non-verbal Intelligence

The Ravens Colored Progressive Matrices (CPM) test (Raven and Rust, 2004) was administered as a non-verbal measure of children's general cognitive ability, and consists of three sections (A, AB, B) containing twelve items each. Children were provided with an incomplete puzzle and asked to choose one out of six pieces to complete the puzzle. The items are arranged to assess the consistency in the children's reasoning using analogy and inference skills. The Ravens CPM test has been extensively used across a variety of settings worldwide as a culture-neutral instrument of non-verbal intelligence.

### Phonological Working Memory

The digit span and non-word repetition sub-tests of the Comprehensive Test of Phonological Processing (CTOPP; Wagner et al., 1999) were administered to measure phonological short-term memory. The two tests comprise a list of digits or non-words in English, and participants were asked to repeat and pronounce what they heard on the computer. There were 21 and 18 trials respectively for each subtest, and each subsequent trial increased in difficulty as the length of the digits and non-words increased in length. The tests were terminated after five consecutive incorrect responses.

### Parental Questionnaire

We administered a parental questionnaire that included items adapted from existing related studies to explore children's conventional language exposure and literacy environment (Sun et al., 2016). Compared with the prior questionnaire, the current version was mainly concerned with children's bilingual input environment at home. The questionnaire focused on children's media usage (i.e., amount and diversity of multimedia input) and conventional language input at home. Children's multimedia type and amount have been estimated by the total hours and numbers of sources that children were exposed in TV programs, videos, audios, eBooks, and computer games via digital devices per week. Home language input and output were measured by the amount of time family members and friends interacted with children in English and Mandarin. Children's cumulative input has been estimated with their onset age to steadily receive English and Mandarin exposure. For home literacy environment, parents were asked about the number of English and Mandarin books at home using a scale ranging from 0 to 6 (0 = None, 1 = 1–10, 2 = 10–30, 3 = 30–60, 4 = 60–90, 5 = 90–120, 6 = More).

## Data Analysis

The authors used IBM SPSS AMOS 25 to build up structural equation modeling (SEM) for the postulated relationships in the two hypotheses. SEM refers to a modeling technique that allows the evaluation of multiple correlational and causal assumptions simultaneously. It has been widely applied in sociology, psychology, linguistics, and other social sciences to explore complex associations. According to the literature (Klem, 2000), four indexes are crucial to the evaluation of the model fit, including Chi-square, comparative fit index (CFI), Tucker and Lewis's fit index (TLI), and the root mean square error of approximation (RMSEA). A non-significant Chi-square indicates a good model fit as it implies that the theoretical model and the data-driven model are not significantly different. Nevertheless, as Chi-square is sensitive to sample size, researchers may end up with a significant $p$-value for Chi-square easily. In contrast, TLI and CFI values are less affected by sample size. Higher TLI and CFI values (= 0.9) and lower RMSEA values (=0.06) indicate a good model fit (Kenny and McCoach, 2003). Approximately 3.76% of data were missing mainly due to parent's overlooking of a survey item or children's absence on the testing day due to illness. The authors used the Full-Information Maximum Likelihood method in AMOS to estimate the missing values.

# RESULTS

## Descriptive Statistics and Bivariate Correlations

**Table 1** presents the descriptive statistics of 202 children's home language environment (i.e., multimedia input and conventional language input), social-economic status (i.e., mother's education level, and household income), language aptitude (i.e., phonological short-term memory, and non-verbal intelligence), and bilingual language skills (i.e., vocabulary breadth, vocabulary depth, and grammar). The results [i.e., the standard deviation (SD) and range figures in **Table 1**] indicate that group-wise, children's bilingual home language environment and learning outcomes varied substantially. Take children's multimedia time as an example, some children could receive as much as 92 h of English input per week, while some children have no English multimedia input at all. The substantial variation among children's learning environment and language proficiency yielded high SD figures (e.g., the SD of children's multimedia time is 17.22). Children's bilingual language environment and outcomes are not only different from each other, but also within each child's dual languages. Paired sample *t*-tests demonstrated that Singaporean children's English environment is significantly and systematically better than their Mandarin environment. Except for the onset age of having steady English and Mandarin input at home, children have significantly more English input than Mandarin input from multimedia and family members. They have a significantly larger number of multimedia resources and books in English than in Mandarin. They also use English significantly more often with their family members. Regarding children's language outcomes, their English vocabulary breadth, vocabulary depth, and grammar were substantially better than their skills in Mandarin. The dominance of English in children's language environment and outcomes keep in line with the previous findings (e.g., Sun et al., 2018b), confirming our assumption of the unbalanced situation of children's bilingual language learning in Singapore. As home input and output were highly correlated in English and Mandarin languages respectively (i.e., $r$ = 0.874 in English, $r$ = 0.879 in Mandarin), we averaged home input and output in each language and used it to reflect the frequency of family members' and children's interaction in that language.

## Multimedia Input and Early Mandarin Language Skills

Mandarin vocabulary breadth, vocabulary depth, and receptive grammar were used to create the latent "Mandarin" factor, and CFA was performed to measure the fitness of the latent factor. The results of maximum likelihood estimation indicated that the assumption for the latent factor holds, $X^2(3) = 253.610$, $p < 0.001$, CFI = 1, TLI = 1, RMSEA = 0.00, as CFI, TLI, and RMSEA were consistent with the cutoff model-fit criteria recommended by previous studies (e.g., Kenny and McCoach, 2003), indicating a reasonable factor structure of our model.

The association between children's Mandarin language environment and their Mandarin outcomes (i.e., vocabulary and grammar) have been demonstrated in **Table 2**. Children's general Mandarin proficiency was predicted by the multimedia exposure in Mandarin language at home (i.e., multimedia type, and multimedia time), conventional exposure in Mandarin language at home (i.e., the average hours of Mandarin use between family members and the child per day, children's onset age of having steady Mandarin input, and the number of Mandarin books at home), and individual differences in familial

**TABLE 1** | Descriptive statistics and paired *t*-tests of the bilingual language environment and learning outcomes.

| | English | | | Mandarin | | | Paired *t*-test | |
|---|---|---|---|---|---|---|---|---|
| | N | *M* (*SD*) | Range | *N* | *M* (*SD*) | Range | *t* | *p* |
| Multimedia type | 201 | 2.27 (1.17) | 0–6 | 201 | 1.26 (1.31) | 0–6 | 10.49 | 0.00 |
| Multimedia time | 196 | 23.01 (17.22) | 0–92 | 199 | 10.62 (13.75) | 0–56 | 8.70 | 0.00 |
| Home input | 199 | 3.01 (2.30) | 0–13.71 | 201 | 2.39 (2.17) | 0–12 | 2.60 | 0.01 |
| Home output | 198 | 2.57 (2.02) | 0–11.89 | 199 | 2.04 (2.09) | 0–9.6 | 2.32 | 0.02 |
| Onset age | 199 | 16.43 (14.47) | 0–61 | 202 | 16.89 (14.82) | 0–61 | −0.57 | 0.57 |
| Book number | 201 | 2.53 (1.34) | 0–6 | 202 | 1.94 (1.33) | 0–6 | 6.76 | 0.00 |
| Vocabulary breadth | 180 | 43.41 (8.05) | 24–64 | 191 | 34.68 (9.99) | 7–61 | 9.67 | 0.00 |
| Vocabulary depth | 182 | 14.83 (5.02) | 0–31 | 189 | 7.43 (5.05) | 0–25 | 15.01 | 0.00 |
| Grammar | 180 | 41.31 (15.99) | 0–70 | 189 | 35.97 (11.07) | 9–57 | 8.89 | 0.00 |
| Mother education | 200 | 5.18 (1.29) | 2–8 | | | | | |
| Household income | 198 | 14.25 (5.57) | 2–20 | | | | | |
| Phonological memory | 189 | 19.90 (4.51) | 6–31 | | | | | |
| Non-verbal intelligence | 181 | 20.17 (4.88) | 8–33 | | | | | |

*Multimedia Type, the numbers of multimedia resources that children obtain English and Mandarin input per week; Multimedia Time, the numbers of hours that children spend on multimedia in English and Mandarin per week; Home Input, the numbers of hours that family members on average speak to children in English and Mandarin per day; Home Output, the numbers of hours on average that children speak to family members in English and Mandarin per day; Onset Age, the ages that children start to receive consistent and significant exposure to English and Mandarin; Book Number, the numbers of English and Mandarin books at home on a 1–7 point scale; Vocabulary Breadth, English and Mandarin receptive vocabulary size measured by BLAB; Vocabulary Depth, English and Mandarin productive vocabulary fluency; Grammar, English and Mandarin receptive grammar measured by MGRT and TROG; Mother Education, mothers' highest educational level; Household Income, monthly family income on a 1–20 increasing point scale; Phonological Memory, short-term phonological memory score based on digit span and non-word repetition; Non-verbal Intelligence, non-verbal IQ score as a measure of analytic reasoning using Raven's (Sun et al., 2016).*

**TABLE 2 |** Results of structural equation modeling on Mandarin language outcomes.

| | Path | *B* | *SE* | β | C.R. | *P* |
|---|---|---|---|---|---|---|
| Multimedia language environment | Man. Multimedia Type – > Mandarin | 1.24 | 0.56 | 0.18 | 2.20 | 0.03* |
| | Man. Multimedia time– > Mandarin | −0.06 | 0.05 | −0.09 | −1.09 | 0.28 |
| Conventional language environment | Man. Home use – > Mandarin | 1.14 | 0.30 | 0.26 | 3.83 | *** |
| | Man. Onset age – > Mandarin | −0.14 | 0.05 | −0.19 | −3.00 | ** |
| | Man. Book number – > Mandarin | 1.52 | 0.45 | 0.23 | 3.40 | *** |
| Other control factors | Mother education – > Mandarin | 0.33 | 0.51 | 0.05 | 0.64 | 0.53 |
| | Household income– > Mandarin | 0.04 | 0.12 | 0.02 | 0.30 | 0.76 |
| | Phonological memory – > Mandarin | 0.66 | 0.13 | 0.33 | 5.09 | *** |
| | Non–verbal intelligence – > Mandarin | 0.41 | 0.12 | 0.23 | 3.44 | *** |
| Mandarin latent factor | Mandarin – > Man. Vocabulary breadth | 1.00 | | 0.89 | | |
| | Mandarin – > Man. Vocabulary depth | 0.41 | 0.04 | 0.72 | 11.15 | *** |
| | Mandarin – > Man. Grammar | 1.06 | 0.08 | 0.84 | 13.45 | *** |

****p < 0.001, **p < 0.01, *p < 0.05.* $X^2(18) = 29.738$, *p = 0.04, CFI = 0.98, TLI = 0.913, RMSEA = 0.057. B refers to estimate of unstandardized regression coefficients/weights, SE refers to approximate standard error, β refers to estimate of standardized regression coefficients/weights, and C.R. refers to critical ratio (t-value). Interested readers may refer to Finch et al. (2016) for details of the terminologies.*

**TABLE 3 |** Results of structural equation modeling on English language outcomes.

| | Path | B | SE | β | C.R. | P |
|---|---|---|---|---|---|---|
| Multimedia language environment | Eng. Media type – > English | −0.29 | 0.43 | −0.05 | −0.67 | 0.50 |
| | Eng. Media time – > English | 0.04 | 0.03 | 0.09 | 1.16 | 0.25 |
| Conventional language environment | Eng. Home use – > English | 0.52 | 0.23 | 0.16 | 2.22 | 0.03* |
| | Eng. Onset age – > English | −0.07 | 0.04 | −0.13 | −1.84 | 0.07 |
| | Eng. Book number – > English | 0.50 | 0.36 | 0.10 | 1.38 | 0.17 |
| Other control factors | Mother education – > English | 0.43 | 0.41 | 0.08 | 1.05 | 0.30 |
| | Household income – > English | 0.03 | 0.10 | 0.03 | 0.34 | 0.73 |
| | Phonological memory – > English | 0.56 | 0.11 | 0.38 | 5.33 | *** |
| | Non-verbal intelligence – > English | 0.58 | 0.10 | 0.43 | 5.99 | *** |
| English latent factor | English – > Eng. vocabulary breadth | 1.00 | | 0.82 | | |
| | English – > Eng. vocabulary depth | 0.34 | 0.06 | 0.45 | 5.63 | *** |
| | English – > Eng. grammar | 1.87 | 0.20 | 0.78 | 9.35 | *** |

****p < 0.001, *p < 0.05.* $X^2(18) = 21.344$, *p = 0.262, CFI = 0.991, TLI = 0.962, RMSEA = 0.03. B refers to estimate of unstandardized regression coefficients/weights, SE refers to approximate standard error, β refers to estimate of standardized regression coefficients/weights, and C.R. refers to critical ratio (t−value). Interested readers may refer to Finch et al. (2016) for details of the terminologies.*

social-economic status and language aptitude (i.e., mother's educational level, household income, phonological memory, and non-erbal intelligence). The results indicated that it is the number of multimedia resources but not the amount of multimedia input in Mandarin that significantly predicted children's better Mandarin outcomes. Diverse multimedia input was positively and significantly related to children's general Mandarin skills. Conventional environmental factors, such as Mandarin input and output in the current family environment, the onset age of having steady Mandarin input, and the number of Mandarin books at home, were also positively and significantly associated with children's general Mandarin proficiency. Besides the multimedia and conventional language input at home, children's language aptitude mattered. Children with better short-term phonological memory and non-verbal intelligence tended to have better Mandarin proficiency. The SEM model explained 47% of the variance in children's Mandarin proficiency, with good model-fit statistics [$X^2(18) = 29.738$, $p = 0.04$, CFI = 0.98, TLI = 0.913, RMSEA = 0.057].

## Multimedia Input and Early English Language Skills

Similar to Mandarin language measures, English vocabulary breadth, vocabulary depth, and receptive grammar were used to create a latent "English" factor. The fitness of the latent factor has been examined with CFA, and the model fits are satisfying [$X^2(3) = 127.891$, $p < 0.001$, CFI = 1, TLI = 1, RMSEA = 0.00].

The relationship between children's English language input (via multimedia and conventional exposures) and their English skills has been summarized in **Table 3**. Children's general English proficiency was predicted by their home English multimedia use (i.e., type and amount), conventional exposures related to English input at home (i.e., use with family members, age of onset, and the number of books in English), and other control variables (i.e., mother's educational level, household income, phonological awareness, and non-verbal intelligence). Different from the Mandarin SEM results, neither the type nor the amount of English multimedia input significantly predicted children's general English proficiency. Children's English interaction with family members mattered. The more hours per day they used English, the better the children's general English skills were. Besides, children's language aptitude (i.e., phonological awareness and non-verbal intelligence) also significantly predicted children's English language outcomes. In total, the model explained 51% of the variance in children's general English proficiency. The model fits are consistent with the cutoff criteria recommended in the literature (i.e., CFI = 0.991, TLI = 0.962, RMSEA = 0.03).

## DISCUSSION

The current study examined how multimedia language input might influence English-Mandarin bilingual children's dual language skills, controlling for children's conventional language input factors at home (i.e., language use, age of onset, and literacy environment), children's family SES (i.e., mother's educational level, and household income), and language aptitude (i.e., phonological short-term memory and non-verbal intelligence). Two specific hypotheses were raised based on the literature and the bilingual language environment in Singapore. We hypothesized that (1) children's Mandarin learning (i.e., heritage language) might benefit more from multimedia exposure than their English learning (i.e., societal dominant language), and (2) both the number of multimedia resources and the amount of multimedia input would be significantly associated with children's Mandarin learning. Our results confirmed the first hypothesis. It was children's Mandarin performance but not English performance (i.e., language outcome factors based on children's Mandarin/English vocabulary breadth, vocabulary depth, and grammar) that significantly related to children's multimedia input. The contribution of multimedia input to children's Mandarin language performance is unique, which is on top of the variance explained by conventional home language exposure and children's language aptitude. In terms of our second hypothesis, we were able to confirm half of the assumption, as only the number of multimedia resources in Mandarin was significantly associated with children's Mandarin performance. Our results contradicted some previous findings (e.g., Kuppens, 2010) that demonstrates the significance of multimedia quantity (operationalized as multimedia time in the current study) on children's early language acquisition. In the following sections, we discuss our findings in relation to the two hypotheses respectively.

### The Differential Effects of Multimedia Input on Bilingual Children's Language Learning

Previous studies found that Singapore children's bilingual input environment is not balanced (Dixon et al., 2012; Sun et al., 2018b). They have an input-rich English environment while a relatively input-poor heritage language environment, at both the input quantity and input quality levels (Sun et al., 2018b). The results of the paired *t*-tests in our study were in line with the existing studies, and confirmed the advantage of children's English environment in family-child interactions and literacy resources at home. In such a situation, multimedia offered children an important channel to receive additional language exposure, and this extra input might substantially promote children's heritage language outcome (as in the current study). In contrast, children have ample English input from various interlocutors at home and in the community; therefore, the additional input from multimedia may exert much less influence on children's English learning outcome, as the conventional environment has already provided children with the "critical mass" of input to develop their English language skills properly (Sun et al., 2018b).

Multimedia may not only increase children's input quantity in heritage language, but also provide them with more comprehensive input thanks to the features of multimedia. Previous studies have shown that learners' prior knowledge is crucial as it determines how learners would process the information by linking the unknown with their existing knowledge. Information that engages multiple channels might be beneficial for novice learners but redundant for expert learners according to The Expertise Reversal Principle (Kalyuga et al., 2012). Learners with higher language skills may more efficiently process the input, thus additional information presented in the multimedia material may be redundant and cause cognitive overload (Mayer, 2009). For learners with lower language skills, the animated and interactive language input might provide children with additional contextual cues to extract semantic and syntactic information from the input. Take storybook reading as an example. It is one of the most popular activities among children, and is assumed to provide a meaningful context for children to acquire unfamiliar words and grammar (Weizman and Snow, 2001). Nonetheless, children with limited language knowledge (e.g., Mandarin language learners in the current study) may benefit less from the reading activities, due to the gap between their language skills and those required for processing the narration. They may fail to derive the meaning of unknown words and grammar from the verbal context and consequently have difficulties in figuring out the story plots (Verhallen and Bus, 2010). Well-designed animated eBooks hold good promise for children's emergent literacy in this case, as such books can stimulate readers' visual, auditory and even kinesthetic senses to comprehend a story and unfamiliar language via the congruence between non-verbal sources (motion pictures, images, sound, and music) and the narration (Sun et al., 2019), as predicted by the dual coding theory of learning. The "enhanced" message could scaffold learners to pick up the target information more easily and establish a coherent mental representation. In the current study, children's Mandarin skills are significantly lower than their English skills in all three aspects we have measured (vocabulary breadth, $t = -9.67$, $p < 0.001$; vocabulary breadth, $t = -15.01$, $p < 0.001$; grammar, $t = 8.89$, $p < 0.001$). Therefore, they might benefit from multimedia-powered Mandarin input to facilitate their language learning.

### The Number of Resources and Amount of Multimedia Input and Child Mandarin Learning

The exploration of the second hypothesis further narrows down the effective components of the multimedia input. Contrary to our prediction, only the number of resources but not the amount of multimedia input has been found to be significantly related to children's general Mandarin competence. The non-significance of multimedia input *per se* might be due to the mismatch between children's current language level and the complexity of some of the content presented via multimedia. Researchers have noted that certain conditions need to be met for multimedia resources (e.g., educational TV programs) to exert a positive effect on child language development, including (1) the match of the language in the program with child's linguistic abilities; (2) children's maturation in cognition (i.e., older than a toddler); and (3) the match of the content of the program with children's comprehension level (Rice, 1983). The majority of studies that found the significant effects of multimedia quantity were based on experiments (e.g., Kuppens, 2010), and the language materials they have used were carefully selected to match participants' current language ability. In contrast, the current study is an observational study and the participants have the freedom to choose whatever materials are available to them at home. Their multimedia input might be out of their zone of proximal language development, being beyond or below their proficiency level. Moreover, the materials could be more entertainment-oriented than education-oriented, resulting in a situation where the increased amount of language input leads to no substantial language improvement.

A larger number of resources, on the other hand, increased the chance of matching the multimedia input with children's Mandarin proficiency level. Moreover, the diverse resources (e.g., games, eBooks, educational programs, and movies) provided children with rich vocabulary and linguistic structures to promote language building. Such language input could provide children sufficient language examples, which facilitates language entrenchment and abstraction (Lieven, 2019). Encountering the various types of exemplars in diverse contexts allows children to recognize the analogies between constructions (Bybee, 2006) and promote children's language learning. In other words, a larger number of multimedia resources could offer bilingual children more authentic, rich, and complex heritage language input, which the children lack in conventional language settings.

## CONCLUSION

Multimedia is widely used in early childhood nowadays, and the current study focused on the effectiveness of the amount and number of resources of multimedia input on early bilingual language acquisition. The study found a differential effect on children's societal dominant language and the heritage language. Multimedia exerted little influence on the former and showed significant effects on the latter for the English-Mandarin bilinguals in the current study. Simply increasing the quantity of multimedia input would not promote children's heritage language learning, as it was the diversity of multimedia resources that has been found to significantly affect children's Mandarin learning. Our finding is assumed to be important for multilingual societies like Singapore, where bilingualism is the foundation for its education. Parents in these countries usually prefer to speak the societal language to their children at home due to utilitarian concerns. They would probably rely on schools to develop children's heritage language. Schools, on the other end, are busy with accommodating children with significantly different language proficiency levels in the same class. Teachers must work hard to optimize the limited instructional hours (40 min to 1 h per day on average) to provide children with good language input. Our findings provide another solution: a diversity of multimedia materials may be taken as supplementary input to the conventional sources (e.g., home and school), for effective early heritage language development. Tutorials should be provided to parents, to facilitate their multimedia selection and usage with their children.

There are four major limitations of the study. First, this is a cross-sectional study; therefore, only the relationship between multimedia input and children's English and Mandarin language skills could be inferred. Future studies could follow the participants longitudinally and examine possible variations in the trajectory of the relations. Second, the current study only considers two general aspects of multimedia input, and future studies might further explore the effects of the specific features of multimedia (e.g., interactive questions, dictionaries, and music) on bilingual children's dual language learning. Third, the current study has only tested three aspects of children's vocabulary and grammatical skills, and future studies might employ an in-depth approach to assess children's dual language proficiency. For instance, children's vocabulary skills should not only be examined with labeling tasks but also with word description tasks to reflect their vocabulary depth. Last, the elicitation of home language input quantity and quality could be improved, as the parental survey could only generally reflect the home language environment and therefore not necessarily accurate. Future researchers could use the language diary approach (De Houwer and Bornstein, 2003) or Environmental assessing technology (e.g., LENA) to more precisely capture children's language exposure with different interlocutors (e.g., with parents vs. with peers) and in different modalities (with interlocutors vs. using multimedia).

## DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because: the data could not be shared due to PDPA. Requests to access the datasets should be directed to HS, he.sun@nie.edu.sg.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the IRB-2017-04-019, Nanyang Technological

University Institutional Review Board. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

HS designed the work, analyzed the data, and interpreted the results. HS and BY wrote the manuscript together. Both authors contributed to the article and approved the submitted version.


## FUNDING

This work was supported by grants OER 13/16 HS and OER 05/17 KYH.

## ACKNOWLEDGMENTS

We would like to thank Lou Jieying and Au Yong Shi Lin for their help with data collection and discussion.


## REFERENCES


Alexiou, T. (2009). "Young learners' cognitive skills and their role in foreign language vocabulary learning," in *Early Learning of Modern Foreign Languages: Processes and Outcomes*, ed. M. Nikolov (Clevedon: Multilingual Matters), 46–61. doi: 10.21832/9781847691477-006

Alloway, T. P., Williams, S., Jones, B., and Cochrane, F. (2014). Exploring the impact of television watching on vocabulary skills in toddlers. *Early Child. Educ. J.* 42, 343–349. doi: 10.1007/s10643-013-0618-1

Bishop, D. (2003). *Test for Reception of Grammar*, 2nd Edn. London: Pearson Assessment.

Blom, E., Paradis, J., and Duncan, T. S. (2012). Effects of input properties, vocabulary size, and L1 on the development of third person singular – s in child L2 English. *Lang. Learn.* 62, 965–994. doi: 10.1111/j.1467-9922.2012.00715.x

Bokhorst-Heng, W. D. (1999). "Bilingual education and the dialectics of national integration," in *Proceedings of Georgetown University Round Table on Languages and Linguistics*, eds J. E. Alatis and A.-H. Tan (Washington, DC: Georgetown University Press), 356–370.

Bybee, J. L. (2006). From usage to grammar: the mind's response to repetition. *Language* 82, 711–733. doi: 10.1353/lan.2006.0186

Carroll, J. B., and Sapon, S. (2002). *Modern Language Aptitude Test: Manual. N.* Bethesda, MD: Second Language Testing, Inc.

Chandler, D., and Munday, R. (2011). *A Dictionary of Media and Communication*. Oxford: OUP.

Cho, G., and Krashen, S. D. (2000). The role of voluntary factors in heritage language development: how speakers can develop the heritage language on their own. *ITL Int. J. Appl. Linguist.* 127, 127–140. doi: 10.1075/itl.127-128.06cho

Daller, M., and Ongun, Z. (2018). The threshold hypothesis revisited: bilingual lexical knowledge and non-verbal IQ development. *Int. J. Biling.* 22, 675–694. doi: 10.1177/1367006917690835

De Houwer, A., and Bornstein, M. (2003). "Balancing on the tightrope: language use patterns in bilingual families with young children," in *Presented at the Fourth International Symposium on Bilingualism*, Tempe, AZ.

Dickinson, D. K., and Tabors, P. O. (2001). *Beginning Literacy with Language: Young Children Learning at Home and School. P.H.* Baltimore, MA: Brookes Publishing Company.

Dixon, L. Q., Zhao, J., Quiroz, B. G., and Shin, J. Y. (2012). Home and community factors influencing bilingual children's ethnic language vocabulary development. *Int. J. Bilingual.* 16, 541–565. doi: 10.1177/1367006911429527

Donaldson, J. A., Loh, J., Mudaliar, S., Kadir, M. M., Wu, B. Q., and Yeoh, Y. L. (2013). Measuring poverty in Singapore: frameworks for consideration. *Soc. Space* 6, 58–66.

Dunn, L. M., and Dunn, D. M. (2007). *Peabody Picture Vocabulary Test*, 4th Edn. Minneapolis: Pearson.

Ebbeck, M., Yim, H. Y. B., Chan, Y., and Goh, M. (2016). Singaporean parents' views of their young children's access and use of technological devices. *Early Child. Educ. J.* 44, 127–134. doi: 10.1007/s10643-015-0695-4

Finch, W., Immekus, J., and French, B. (2016). *Applied Psychometrics Using SPSS and AMOS*. Charlotte, N.C: Information Age Publishing, Inc.

Gathercole, S. E., and Baddeley, A. D. (1989). Evaluation of the role of phonological STM in the development of vocabulary in children: a longitudinal study. *J. Memo. Lang.* 28, 200–213. doi: 10.1016/0749-596X(89)90044-2

Goh, Y. S., and Ng, C. W. (2015). Hard truths about Chinese language policy and planning in Singapore. *Glob. Chin.* 1, 267–279.

Grüter, T., and Paradis, J. (eds) (2014). *Input and Experience in Bilingual Development*. Amsterdam: John Benjamins Publishing Company.

Hakuta, K., and Diaz, R. M. (1985). The relationship between degree of bilingualism and cognitive ability: a critical discussion and some new longitudinal data. *Child. Lang.* 5, 319–344.

Hartas, D. (2011). Families' social backgrounds matter: socio-economic factors, home learning and young children's language, literacy and social outcomes. *Br. Educ. Res. J.* 37, 893–914. doi: 10.1080/01411926.2010.506945

Housen, A., and Pierrard, M. (2005). "Investigating instructed second language acquisition," in *Investigations in Instructed Second Language Acquisition*, eds A. Housen and M. Pierrard (Berlin: Mouton de Gruyter), 1–27.

Jared, D., Poh, R. P. Y., and Paivio, A. (2013). L1 and L2 picture naming in Mandarin–English bilinguals: a test of bilingual dual coding theory. *Bilingualism* 16, 383–396. doi: 10.1017/S1366728912000685

Kalyuga, S., Rikers, R., and Paas, F. (2012). Educational implications of expertise reversal effects in learning and performance of complex cognitive and sensorimotor skills. *Educ. Psychol. Rev.* 24, 313–337. doi: 10.1007/s10648-012-9195-x

Kenny, D. A., and McCoach, D. B. (2003). Effect of the number of variables on measures of fit in structural equation modeling. *Struct. Equa. Model. Multidis. J.* 10, 333–351. doi: 10.1207/S15328007SEM1003_1

Klem, L. (2000). "Structural equation modeling," in *Reading and Understanding MORE Multivariate Statistics*, ed. P. R. Yarnold (Washington, DC: American Psychological Association).

Knell, E., Haiyan, Q., Miao, P., Yanping, C., Siegel, L. S., Lin, Z., et al. (2007). Early english immersion and literacy in Xi'an. China. *Modern Lang. J.* 91, 395–417. doi: 10.1111/j.1540-4781.2007.00586.x

Krashen, S. (1981). *Second Language Acquisition and Second Language Learning*. Oxford: Pergamon.

Kuppens, A. H. (2010). Incidental foreign language acquisition from media exposure. *LearnMedia Technol.* 35, 65–85. doi: 10.1080/17439880903561876

Lieven, E. (2019). "Input, interaction and learning in early language development," in *Learning Through Language: Towards an Educationally Informed Theory of Language Learning*, eds V. Grover, P. Uccelli, M. Rowe, and E. Lieven (Cambridge, MA: Cambridge University Press), 19–30. doi: 10.1017/9781316718537.003

Luo, R., Tamis-LeMonda, C. S., and Mendelsohn, A. L. (2020). Children's literacy experiences in low-income families: the content of books matters. *Read. Res. Q.* 55, 213–233. doi: 10.1002/rrq.263

Mayer, R. E. (2005). "Principles for reducing extraneous processing in multimedia learning: coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principles," in *The Cambridge Handbook of Multimedia Earning*, ed. R. E. Mayer (New York, NY: Cambridge University Press), 279–315. doi: 10.1017/cbo9781139547369.015

Mayer, R. E. (2009). *Multimedia Learning*, 2nd Edn. New York, NY: Cambridge University Press, doi: 10.1017/CBO9780511811678

Paradis, J. (2011). The impact of input factors on bilingual development: quantity versus quality. *Linguist. Approaches Biling.* 1, 67–70. doi: 10.1075/lab.1.1.09par

Patterson, J. L. (2002). Relationships of expressive vocabulary to frequency of reading and television experience among bilingual toddlers. *Appl. Psycholinguist.* 23, 493–508. doi: 10.1017/S0142716402004010

Raven, J., and Rust, J. (2004). *Coloured Progressive Matrices and Crichton Vocabulary Scale*. London: Pearson.

Rice, M. (1983). The role of television in language acquisition. *Dev. Rev.* 3, 211–224. doi: 10.1016/0273-2297(83)90030-8

Rice, M. L., Huston, A. C., Truglio, R., and Wright, J. C. (1990). Words from "Sesame Street": learning vocabulary while viewing. *Dev. Psychol.* 26, 421–428. doi: 10.1037/0012-1649.26.3.421

Rickard-Liow, S. J., Sze, W. P., and Lee, L. C. (2013). *Bilingual Language Assessment Battery (BLAB) Manual*. Singapore: National University of Singapore,.

Rideout, V. (2014). "Learning at home: families' educational media use in America," in *Joan Ganz Cooney Center at Sesame Workshop. Joan Ganz Cooney Center at Sesame Workshop. 1900 Broadway*, New York, NY, 10023.

Scheele, A. F., Leseman, P. P. M., and Mayo, A. Y. (2010). The home language environment of monolingual and bilingual children and their language proficiency. *Appl. Psycholinguist.* 31, 117–140. doi: 10.1017/S0142716409990191

Schwartz, M., Moin, V., and Leikin, M. (2012). Lexical knowledge development in the first and second languages among language-minority children: the role of bilingual versus monolingual preschool education. *Int. J. Biling. Educ. Biling.* 15, 549–571. doi: 10.1080/13670050.2011.650332

Singer, D., and Singer, J. (1998). "Barney & friends as entertainment and education: evaluating the quality and effectiveness of a television series for preschool children," in *Research Paradigms, Television, and Social Behavior*, eds J. Asamen and G. Berry (Thousand Oaks, CA: Sage Publications), 205–367.

Sun, H. (2019). Home environment, bilingual preschooler's receptive mother tongue language outcomes, and social-emotional and behavioral skills: one stone for two birds? *Front. Psychol.* 10:1640. doi: 10.3389/fpsyg.2019.01640

Sun, H., Loh, J. Y., and Charles, A. C. (2019). Motion and sound in animated storybooks for preschooler's total fixation time and mandarin language learning: an eye-tracking study with Singaporean bilingual children. *AERA Open* 5, 1–19. doi: 10.1177/2332858419848431

Sun, H., Ng, S. C., O'Brien, B. A., and Fritzsche, T. (2020). Child, family, and school factors in bilingual preschoolers' vocabulary development in heritage languages. *J. Child Lang.* 47, 1–27. doi: 10.1017/S0305000919000904

Sun, H., Steinkrauss, R., Tendeiro, J., and de Bot, K. (2016). Individual differences in very young children's English acquisition in China: internal and external factors. *Bilingual. Lang. Cogn.* 19, 550–566. doi: 10.1017/s1366728915000243

Sun, H., Steinkrauss, R., Wieling, M., and de Bot, K. (2018a). Individual differences in very young Chinese children's English vocabulary breadth and semantic depth: internal and external factors. *Int. J. Biling. Educ. Bilingual.* 21, 405–425. doi: 10.1080/13670050.2016.1178706

Sun, H., Yin, B., Amsah, F., and O'Brien, B. A. (2018b). Differential effects of internal and external factors in early bilingual vocabulary learning: the case of Singapore. *Appl. Psycholinguist.* 39, 383–411. doi: 10.1017/S014271641700039X

Takacs, Z. K., Swart, E. K., and Bus, A. G. (2015). Benefits and pitfalls of multimedia and interactive features in technology-enhanced storybooks: a meta-analysis. *Rev. Educ. Res.* 85, 698–739. doi: 10.3102/0034654314566989

Taylor, G., Monaghan, P., and Westermann, G. (2018). Investigating the association between children's screen media exposure and vocabulary size in the UK. *J. Child. Media* 12, 51–65. doi: 10.1080/17482798.2017.1365737

Unsworth, S. (2013). Assessing the role of current and cumulative exposure in simultaneous bilingual acquisition: the case of Dutch gender. *Bilingualism* 16, 86–110. doi: 10.1017/S1366728912000284

Verhallen, M. J. A. J., and Bus, A. G. (2010). Low-income immigrant pupils learning vocabulary through digital picture storybooks. *J. Educ. Psychol.* 102, 54–61. doi: 10.1037/a0017133

Wagner, R., Torgesen, J. K., and Rashotte, C. (1999). *Comprehensive Test of Phonological Processing*. Austin, TX: Pro-Ed.

Weizman, Z. O., and Snow, C. E. (2001). Lexical input as related to children's vocabulary acquisition: effects of sophisticated exposure and support for meaning. *Dev. Psychol.* 37, 265–279. doi: 10.1037/0012-1649.37.2.265

Wong, K. M., and Samudra, P. G. (2019). L2 vocabulary learning from educational media: extending dual-coding theory to dual-language learners, computer assisted language learning. *Comput. Assis Lang. Learn.* doi: 10.1080/09588221.2019.1666150


**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 05 November 2020
doi: 10.3389/fpsyg.2020.570068

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# Children's Reality Status Judgments of Digital Media: Implications for a COVID-19 World and Beyond

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OPEN ACCESS

***Edited by:***
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***Specialty section:***
*This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology*

***Received:*** *06 June 2020*
***Accepted:*** *12 October 2020*
***Published:*** *05 November 2020*

***Citation:***
*Hassinger-Das B, Dore RA, Aloisi K, Hossain M, Pearce M and Paterra M (2020) Children's Reality Status Judgments of Digital Media: Implications for a COVID-19 World and Beyond. Front. Psychol. 11:570068. doi: 10.3389/fpsyg.2020.570068*

Even prior to the COVID-19 crisis, one of the children's most common screen activities was using the video-sharing platform YouTube, with many children preferring YouTube over television. The pandemic has significantly increased the amount of time many children spend on YouTube—watching videos for both entertainment and education. However, it is unclear how children conceptualize the people they see on YouTube. Prior to the pandemic, children 3–8 years old ($N$ = 117) were recruited to participate. Children were told that they would see pictures taken from videos and answer questions about them. Children saw three physical photos with the same image of a man and a bird and were told that the photo was (a) from a video on the experimenter's phone, (b) from a video on television, or (c) from a video on YouTube. They were asked whether the person in the photo was real or not real, which video would be best for learning, and which video they would prefer to watch. Findings indicated that children were marginally less likely to believe that people on YouTube are real than people in a video on a phone, with no difference between beliefs about people on YouTube and television. Notably, these beliefs were similar across the age range tested here. Across all ages, children preferred to watch YouTube more than phone videos and believed that YouTube possessed greater educational value than both phone and television videos.

**Keywords: YouTube, television, mobile phone, reality status, digital media**

## INTRODUCTION

By the end of March 2020, school closures during the coronavirus disease 2019 (COVID-19) pandemic affected almost 90% of the world's student learners (Mokhtar and Gross, 2020). As a result, online learning modalities have become a commonplace, even for the youngest of children. This rise in the use of virtual tutoring, educational apps, videoconference classrooms, and YouTube lessons has radically shifted the educational landscape, and these changes may not yield to business-as-usual any time soon—if ever.

Yet, even before COVID-19, children were increasingly using a variety of screen devices on a regular basis. Prepandemic, children's time using mobile devices had tripled from 2013 to 2017 (Common Sense Media, 2017)—with children under eight using screens for almost 3 h per day. This incredible, widespread international adoption of devices in the homes of children and families has been complemented, at the same time, by similar growth in child-directed content, such as apps and streaming video.

## Preference for YouTube

One of the children's most common screen activities is using the video-sharing platform YouTube on mobile devices and smart televisions, with many children preferring YouTube over television (Ofcom, 2016). During the COVID-19 pandemic, caregivers noted that YouTube was children's most commonly used video platform, with over 78% of children watching (ParentsTogether Foundation, 2020). This aligns with research from 2018 where Smith et al. (2018) from the Pew Research Center reported that 81% of United States parents allowed their children under age 11 to watch videos on YouTube. For younger children, 4- to 8-year olds spend approximately 17% of their screen time per day on online video platforms such as YouTube (Common Sense Media, 2017).

Much more so than television, there is an incredible variety of content available on YouTube. For example, YouTube content includes episodes of regular television shows, clips of children and adults playing video games, and music videos. But because the platform allows for user-generated content, children can also watch videos of their friends making slime or baking a cake and now perhaps videos of their teachers reading a storybook or teaching a math lesson. Among children who watch videos online, learning videos emerge as the most-watched category, with 64% of parents reporting that their children watch them often or watch them sometimes (Common Sense Media, 2017). This percentage has likely increased during the pandemic as many teachers and early childhood care providers, as well as authors and celebrities, are now providing YouTube storybook readings and educational videos to support out-of-school instruction (Li and Lalani, 2020). While YouTube has emerged as a popular learning tool for young children, it remains unclear how children conceptualize what they see on YouTube, given that it exists on a platform that contains such diverse content. The importance of investigating this phenomenon has only increased due to the increase in the use of YouTube during the pandemic (Lukovitz, 2020).

## Television Reality Status Judgments

The majority of previous research in this area has focused on adults' understanding of the reality of television content, while less is known about children's judgments (e.g., Hall, 2003; Busselle and Bilandzic, 2008). Some studies suggest that 5-year olds take a somewhat all-or-nothing view of television—believing that everyone on television is not real (Wright et al., 1994)—whereas 7-year olds are somewhat better at distinguishing between different types of programs (e.g., news vs. a cartoon). Research also shows a developmental pattern for children's judgments about the reality of television—where 3- to 4-year olds are more likely than older children to view television pictures as real objects (Flavell et al., 1990) and to confuse characters and the actors portraying them (Goldstein and Bloom, 2015). Work by Li et al. (2015) also found that 4-year olds often underestimate the reality status of real events in videos. Even though they were able to tell that fantastical events were not real, these children also often claimed that real events could not actually happen.

More recent research has shown that children 5–7 years of age are likely to make reality status judgments of television clips with equal accuracy compared with adults, yet behavioral and neuropsychological data demonstrate significant discrepancies (Li et al., 2019). Children took longer periods of time before making a decision about reality status, and output from functional near-infrared spectroscopy (fNIRS) revealed greater activation of the prefrontal cortex for children. Therefore, the authors argued that reality status judgments require increased cognitive resources for children as compared with adults. As in their earlier work (Li et al., 2015), Li et al. (2019) argued that children use their personal experiences with real-life events to make reality judgments, as evidenced by increased activity in the part of the brain associated with working memory and retrieval of memories.

## Digital Media as a Source of Information

Children's media literacy—or their ability to employ critical thinking to develop individual judgments about the value of media content (Silverblatt and Eliceiri, 1997)—affects how they view digital media as a source of information. Media literacy often increases with age as children gain more experience with various forms of media (Huston and Wright, 1983). Children may also receive school- or home-based instruction regarding how to evaluate media messages.

Researchers have argued that children's judgments shed light on how they learn from television and other digital media (Bonus and Mares, 2019). Studies show that children are less likely to learn from television when they judge that a show's content is not real (Mares and Sivakumar, 2014)—suggesting that understanding how children view the reality status of other digital media may have implications for their educational potential. Yet, it is unclear whether these findings also apply to YouTube as a source of information. In many ways, children's evaluations of information and reality status of media from television and online video platforms, such as YouTube, may be similar. Indeed, no differences were found when exploring preschool children's responses to video advertising on television versus YouTube (Vanwesenbeeck et al., 2020). Relatedly, children were observed to learn and interact with television and YouTube videos in similar ways, including actively applying information they learned to real-world contexts and sharing learned information with others (Dugan et al., 2010). However, given YouTube's unique properties of containing both mass-produced and user-generated content, there may also be important differences in how children process and conceptualize content on this popular platform.

## The Present Study

Children like watching YouTube, and the platform's popularity has grown greatly since its introduction in 2005. Yet, unlike television, little research has examined children's reality status beliefs about YouTube content. In one qualitative study, Martínez and Olsson (2019) found that 9- to 12-year-old children moved between identifying a YouTuber as a paid celebrity influencer (less real) versus as a young girl (more real), but there is no research to our knowledge that has examined perceptions of the reality status of people on YouTube in younger children. Additionally, little is known about how children view YouTube as a source of information and as an educational resource.

As a result, the current study asks how different media formats (YouTube video, television, and video on a phone) affect 3- to 8-year-olds' reality status judgments, preferences for videos, and beliefs about the educational value of videos. We hypothesized that children would be more likely to believe that a person in a video from the experimenter's phone was real compared with a person in a video from television and that these judgments would be more distinct for older children. Given the limited evidence, we did not have a specific hypothesis regarding YouTube; rather, we asked the research question: How do children view the reality status of people in a YouTube video? We also explored children's preferences for videos from these sources and beliefs about the educational value of the videos but did not have specific hypotheses for these outcomes.

## MATERIALS AND METHODS

The study design and hypotheses were preregistered on the Open Science Framework and may be accessed at the following link: https://osf.io/wrsbz. The study was powered to detect medium-sized effects ($d = 0.5$).

### Participants

Participants ($N$ = 117 children, 53.8% female, 61.5% white; $N$ = 101 caregivers; 93.1% mothers, 34.2% college graduates) were recruited at two children's museums in the United States, one in the Northeast and one in the Midwest (see **Table 1** for more demographic information). All children between the ages of 3 and 8 years who were able to see, hear, and understand the stimuli in English were eligible to participate (10.2% of the sample also spoke additional languages—5.1% Spanish; 5.1% other languages). Caregivers were asked to complete a questionnaire about children's exposure to digital media, types of apps they use, videos/shows they watch, platforms they use to watch, and other related questions. Results indicated that for the children whose caregivers completed the question ($N$ = 93), children in the sample watch between 0 and 240 min of television/YouTube per day, with 32.1% of that time dedicated to YouTube. Caregivers reported that out of the total time that their child watches television, they watch television with their child 74.7% of the time on average, while they only watch YouTube with their children 47.0% of the time that their child watches YouTube overall.

**TABLE 1** | Demographics of the sample.

| | **% of total sample** |
|---|---|
| **Age groups** | |
| 3–4-year olds | 17.1 |
| 5–6-year olds | 51.3 |
| 7–8-year olds | 31.6 |
| **Gender** | |
| % male | 46.2 |
| % female | 53.8 |
| **Caregiver** | |
| Mother | 94 |
| Father | 6 |
| Other relative | 1 |
| **Mother's education** | |
| % high school | 10.3 |
| % some college | 14.5 |
| % college graduate | 34.2 |
| % graduate degree | 27.4 |
| % no answer | 13.7 |
| **Child's ethnic background** | |
| % Asian/Pacific Islander | 2.6 |
| % African American | 8.5 |
| % Latinx | 6 |
| % White | 61.5 |
| % Other | 1.7 |
| % Multiracial | 1.7 |
| % No answer | 3.4 |
| **Children's language exposure** | |
| % English | 100 |
| % English and Spanish | 5.1 |
| % English and other language (not Spanish or Mandarin/Cantonese) | 5.1 |

**FIGURE 1** | Stimuli image used in the study (with television corner icon). Image of trees and bird: Photographer Robin Moore/used under license from Shutterstock.com. Image of person: Photographer Roman Samborskyi/ used under license from Shutterstock.com.

### Procedure

#### Reality Status Judgments

To assess children's reality status judgments, the research team created an 8 × 10 physical photo with an image of a person that children would likely identify as male along with a nature background featuring a sky, a tree, and a bird (see **Figure 1**). This composition was chosen because 46% of children 0–8 years of age often/sometimes watch YouTube videos about animals (Common Sense Media, 2017), and popular children's television shows, such as *Sesame Street* and *Wild Kratts*, feature male animals and male adult characters. Birds are also a type of animal that all children in the sample would have seen in real life, given that birds are common in urban, suburban, and rural areas. Additionally, the image also looked like it could have been taken from a video from someone's phone. The same image was altered to include an icon in the upper left corner representing the media type (YouTube logo, image of a flat screen television, or an image of a smartphone; see **Figure 1** for the image with the television icon). The order in which the experimenter presented the three physical photos representing the three mediums (YouTube, television, phone) was counterbalanced.

xyl The experimenter explained to the children that they were going to look at some pictures taken from videos and answer some questions related to those videos (see **Supplementary Materials** for the full study protocol). First, the experimenter laid out the three physical photos one at a time, stating with each photo where it came from—YouTube, television, or experimenter's phone—while referencing the icon in the upper left corner denoting the photo's source. Then, the experimenter pointed to the first photo (the order of which was counterbalanced across participants) and asked children whether they thought the person in the picture was real or not real. Then, children were asked how confident they were about this judgment (not sure at all, a little bit sure, very sure). Real/not real judgments and confidence ratings were used to create a belief score for each media format from −3 (very sure that it is not real) to +3 (very sure that it is real). Finally, children were asked an open-ended justification question about why they thought that the person was real or not real.

### Beliefs About Educational Value

Next, children were asked questions about their desire to learn from the videos. First, the experimenter told the children that all of the videos are about birds and reminded them which platform each physical photo was from. Then, the experimenter asked the children which video they thought would be the best for learning about birds. Then, their first choice was removed and they were asked, of the remaining two, which they thought would be best for learning about birds. Then children were asked a justification question about why they thought their first choice would be best for learning about birds and why their last choice would not be as good to learn from. A score was created for each media format, denoting whether that format was selected as a child's first (1), second (0), or third (−1) choice.

### Preference

The same sequence as beliefs about educational value was used to ask children about their preference— which video the child would want to watch the most and why.

### Justifications Coding

The authors generated a coding scheme for the children's responses to the three justification questions: reality status, educational value, and preference (see **Table 2**). Then, the lead author trained a research assistant to complete all of the coding. Thirty-two percent of the data were double coded for reliability, and any discrepancies between the lead author and the research assistant were discussed and resolved.

# RESULTS

## Reality Status Judgments

### How Does Media Format Affect Children's Reality Status Judgments?

To answer this question, we first checked for effects of medium order on children's responses; children's reality status judgments did not differ based on which of the three mediums they were asked about first ($p > 0.165$). We then conducted a one-way repeated measures ANOVA to compare the effect of age group, gender, media format, and the medium that children saw first on children's reality status judgments. We were particularly interested in the interaction between media format and the medium that children saw first to determine whether the medium they were presented first differentially affected how the children responded to the three media formats. This interaction was non-significant ($p = 0.313$). Age group and gender were also not significant predictors or part of any significant interaction effects ($p > 0.183$) so they were dropped from the analysis.[1] There was a main effect of media format, $F(2,344) = 5.61$, $p = 0.004$, $\eta_p^2 = 0.032$—showing that, as predicted, children were more likely to believe that the person in the phone video was real ($M = 0.47$) compared with the person from television ($M = -0.59$, $p = 0.004$). Children's belief in the person from YouTube fell in between ($M = -0.34$), lower than the phone video ($p = 0.044$) and not significantly different from television ($p = 1.00$; see **Figure 2**)[2]. The age by condition interaction was not significant, indicating that our hypothesis was not supported: younger children seem to understand the differences between the media formats similarly to older children, with no apparent developmental change.

We further examined whether the mean score for each medium was significantly different from 0. Phone was significantly above 0, $t(114) = 2.00$, $p = 0.024$, and television was significantly below 0, $t(116) = 2.51$, $p = 0.006$, but YouTube did not significantly differ from 0, $t(115) = 1.47$, $p = 0.071$, suggesting that whereas children are likely to believe phone videos are real and television videos are not, there is less certainty about the status of YouTube videos.

### How Do Children Justify Their Reality Status Judgments?

**Figure 3** depicts children's justifications for their reality status judgments by medium. For phone and television, children's most popular justification was based on the physical characteristics of the person in the video (physical-person), such as, "He can't be that tall." (23.1% for phone and 26.5% for television). Although physical-person justifications were also prevalent for YouTube (24.8%), the most frequent justification was supplying fact or

[1]Gender and medium that children saw first were not a significant predictor for any of the other analyses presented here ($p > 0.313$), so they were dropped from all subsequent analyses and will not be discussed further.

[2]All factors, factor interactions, and *post hoc* comparisons described in this manuscript were corrected for type I error using the Bonferroni correction.

**TABLE 2 |** Coding scheme for open-ended responses.

| Category | Definition | Examples |
|---|---|---|
| Physical-person | The comment is about the physical nature of the person. | "His shirt is green."; "He looks funny." |
| Physical-non-person | The comment is about something else in the picture or about the physical picture itself. | "The bird on the tree is small."; "The picture looks blurry." |
| Medium-subjective | An opinion on the medium (YouTube, television, and phone). | "I think YouTube is the best because I like it the best." |
| Medium objective | A fact/description of the medium. | "YouTube is good to learn from because real people put videos on there." |
| Device | A comment made about the actual device as opposed to the medium. | "I don't use the phone because the screen is too small." |
| Definitional | The comment is directly addressing the definition of the question (different for each question) or restating the medium. | "I think the guy is real because he looks real."; "Because it's on television." |
| Personal reference | The comment references something from their personal life. | "I have seen this guy before"; "He looks like my uncle." |
| Feelings about photo | Any subjective comments about how the photo makes them feel. | "The photo makes me happy." |
| Comment on the photo itself | Any comment referencing the photo itself without adding additional information. | "Because it's a picture." |
| Reality status (only coded for preference question) | Comment about the reality status of that medium. | "I like to watch YouTube because it is real."; "I do not like to watch television because it is not real." |
| Educational information (only coded for preference question) | Comment about the educational quality of the medium. | "I like to watch YouTube because I can learn the most from it." |
| I don't know | Child stated that they did not know why they chose their answer. | "I don't know." |
| Does not fit/miscellaneous | The comment does not fit into any of the previous categories. | |

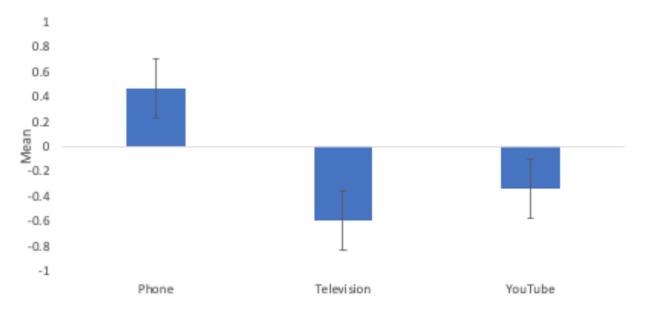


**FIGURE 2 |** Children's reality status judgments by medium.

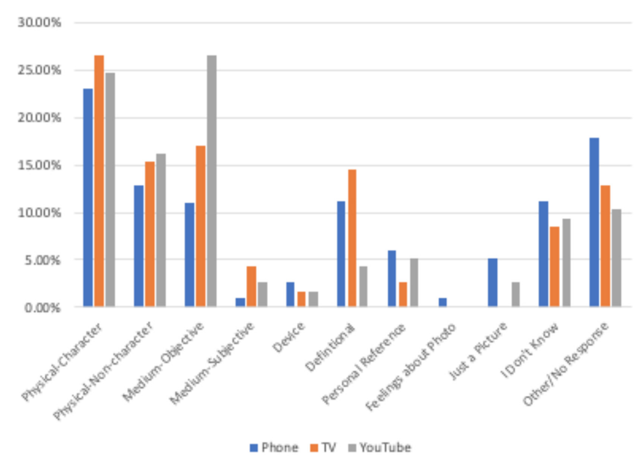


**FIGURE 3 |** Percentage of children providing each justification by medium.

description of the medium (medium-objective) as a justification (26.5%), such as, "YouTubers are actually in real life, and they report on real things that really happen."

Next, we conducted a series of one-way ANOVAs to examine the effect of age group and medium on each justification category. Belief score was dropped from these models, because there were no significant main effects of or interactions involving children's reality status judgments on their justifications, $p > 0.06$, suggesting that children's justifications did not differ based on whether they believed the person was real or not real. For medium-objective, there were effects of both medium, $F(2,350) = 3.16$, $p = 0.044$, $\eta_p^2 = 0.018$, and age group, $(2,350) = 8.28$, $p < 0.001$, $\eta_p^2 = 0.046$. Children gave this type of justification more often for YouTube (26.5%) than phone (11%, $p = 0.040$) but not significantly more than television (17.1%, $p = 0.387$). Additionally, both 5- and 6-year olds (18.9%, $p = 0.007$) and 7- and 8-year olds (26.1%), $p < 0.001$, gave this type of justification more than 3- and 4-year olds (1.7%). The age group by medium interaction was not significant, suggesting that the differences by medium were consistent across the age range.

Children were more likely to provide definitional justifications [directly addressing the definition of the question, such as, "I think he is real, because he looks, $F(2,350) = 3.78$, $p = 0.024$, $\eta_p^2 = 0.022$]. There was also a significant effect of age group for physical-non-person—a comment about something else in the picture or about the physical picture itself, such as, "The bird on the tree is small," $F(2,350) = 4.29$, $p = 0.014$, $\eta_p^2 = 0.024$, with 7- and 8-year olds (22.5%) giving this type of justification more often than 5- and 6-year olds (10%, $p = 0.011$) with 3- and 4-year olds in the middle (15%), regardless of medium. There was a significant age group × medium interaction for feelings about the video, $F(2,350) = 2.49$, $p = 0.043$, $\eta_p^2 = 0.028$, with only 3- and 4-year olds providing this justification, and only for phone (5%). Additionally, the youngest children justified their responses with, "I don't know," (16.7%) more than 7- and 8-year olds (4.5%), $p = 0.032$, $F(2,350) = 3.45$, $p = 0.033$, $\eta_p^2 = 0.020$. Similarly, 3- and 4-year olds gave no response or responses outside the coding scheme more frequently (23.3%) than 5- and 6-year olds (10.6%), $p = 0.039$, $F(2,350) = 3.12$, $p = 0.045$, $\eta_p^2 = 0.018$. There were no significant differences based on age group, medium, or the interaction between the two for the other justifications, $p > 0.06$. **Figures 4–6** depict the use of justifications by age group for each medium separately.

## Beliefs About Educational Value

### How Does Media Format Affect Children's Beliefs About the Educational Value of Videos?

Again, a one-way repeated measures ANOVA was conducted to compare the effect of media format on children's beliefs about the educational value of videos, while also investigating the effects of age group. The outcome was an educational value score, ranging from −1 to 1 representing whether the child chose each medium first, second, or third. There was a significant main effect of medium, $F(2,340) = 5.82$, $p = 0.003$, $\eta_p^2 = 0.034$, with children regardless of age perceiving higher educational value for YouTube ($M = 0.24$) than phone ($M = -0.09$, $p = 0.014$) and television ($M = -0.11$, $p = 0.008$). There was no significant effect of age group ($p = 0.981$) or interaction between age group and medium ($p = 0.118$).

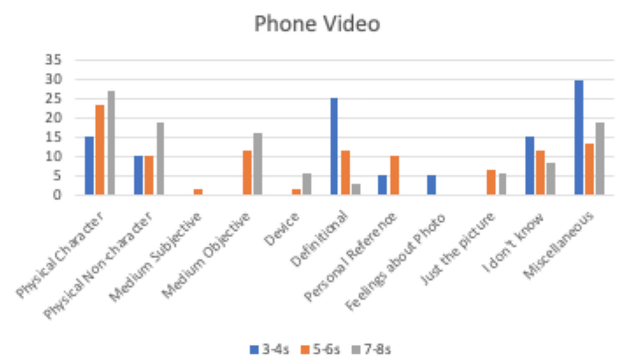


**FIGURE 4 |** Percentage of children by age group providing each justification for the phone video.

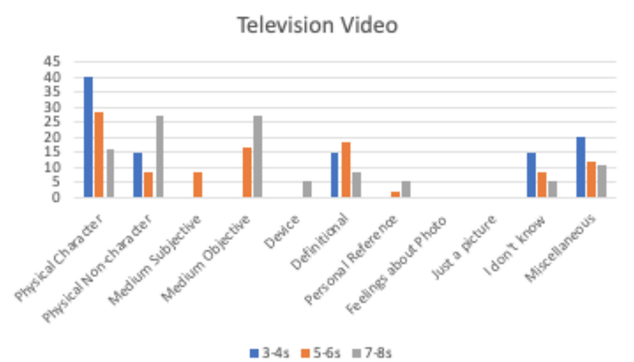


**FIGURE 5 |** Percentage of children by age group providing each justification for the television video.

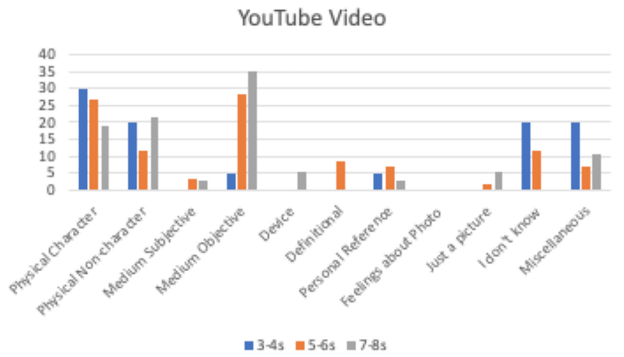


**FIGURE 6 |** Percentage of children by age group providing each justification for the YouTube video.

#### *How do children justify their beliefs about a medium's educational value?*

Across mediums, children most frequently justified their educational value choice by supplying facts or descriptions of the medium (medium-objective; phone: 31%, television: 53.1%, and YouTube: 33.3%). Next, we conducted a series of one-way ANOVAs to examine the effect of age group and first medium chosen for educational value on each justification category. There was a significant interaction between age group and first medium chosen for the physical-non-person justification, $F(2,116) = 3.13$, $p = 0.011$, $\eta_p^2 = 0.129$, with younger children providing this type of justification more than older children, except for phone—where 5- and 6-year olds (80%) gave this type of justification more than both younger and older children (3–4 s: 20%; 5–6 s: 22.2%). For medium-objective, there was a significant main effect of age group, $F(2,116) = 14.58$, $p < 0.001$, $\eta_p^2 = 0.216$, which was driven by 7- and 8-year olds (67.6%) giving this justification more often than 3- and 4-year-olds (0%, $p < 0.001$) and 5- and 6-year olds (31.7%, $p = 0.007$). The youngest children (25%) gave no answer or a justification that did not fit the coding scheme more frequently than 5- and 6-year olds (5%, $p = 0.006$) and 7- and 8-year olds (8.1%, $p = 0.004$), $F(2,116) = 5.09$, $p = 0.008$, $\eta_p^2 = 0.088$. There were no significant individual predictors or interactions for the other justification categories ($p > 0.06$).

Similarly, across all three medium types, children were most likely to justify their third choice (that a video was not as good to learn from) based on providing facts or descriptions of the medium (medium-objective), phone = 21.1%; television = 29.5%, YouTube = 51.6%. We then conducted a series of one-way ANOVAs to examine the effect of age group and last choice medium preference on each justification category. There was a significant effect of age group for medium-objective, with 7- and

8-year olds (56.8%) selecting this justification more often than both 3- and 4-year olds (10%, $p = 0.004$) and 5- and 6-year olds (26.7%, $p = 0.047$). No significant individual predictors or interactions emerged for any of the other justification categories ($p > 0.06$).

### How Do Children's Beliefs About Educational Value Relate to Reality Status Judgments?

We conducted a regression model predicting children's beliefs about educational value from age group, medium, belief score, and their interactions. There were no significant predictors or interactions ($p > 0.107$).

## Preference

### How Does Media Format Affect Children's Preferences for Videos?

To answer this question, a one-way repeated measures ANOVA was conducted to compare the effect of age group and media format on children's preferences. Age group was not a significant predictor nor was it part of a significant interaction with medium ($p > 0.10$) so it was dropped from the analysis. There was a main effect for media format, $F(2,347) = 8.41$, $p < 0.001$, $\eta_p^2 = 0.047$, showing that children were more likely to prefer to watch YouTube ($M = 0.22$, $p = 0.001$) and television ($M = 0.03$, $p = 0.049$) than phone video ($M = -0.25$). There were no significant differences in preference between television and YouTube ($p = 0.292$).

#### *How do children justify their medium preferences?*

For first-choice preference, children who chose the phone video justified their selection most frequently by giving a fact or some element of description about the medium, such as, "Sometimes you can find all sorts of stuff on the phone, some of it is true and you can learn a lot from that stuff" (medium-objective; 23.5%), whereas children who preferred the television or YouTube video most frequently justified their choice using an opinion about the medium (medium-subjective; television: 27.5%; YouTube: 32.2%).

We then conducted a series of one-way ANOVAs to examine the effect of age group and first-choice medium preference on each justification category. There were no main effects or interactions with medium ($p > 0.06$), but there were some age effects. Regarding the medium-objective justification, there was a significant main effect of age group, $F(2,115) = 5.46$, $p = 0.005$, $\eta_p^2 = 0.093$, which was driven by 7- and 8-year olds (37.8%) giving this justification more often than 3- and 4-year olds (0%, $p = 0.021$) with 5- and 6-year olds falling in between (18.3%). There was also a significant main effect of age group for the Educational Information justification—or comments based on the educational quality of the medium, such as, "I prefer YouTube, because I can learn from it," $F(2,115) = 4.03$, $p = 0.021$, $\eta_p^2 = 0.070$. Here, 7- and 8-year olds (13.5%) were more likely to use this justification than 5- and 6-year olds (1.7%, $p = 0.035$) and 3- and 4-year olds (0%, $p = 0.050$). There were no significant individual predictors or interactions for the other justification categories ($p > 0.06$).

Similarly, across all three medium types, children most frequently justified their decision that a video was their least favorite by providing facts or descriptions of that medium (medium-objective; phone = 17.6%; television = 15.4%, YouTube = 30.8%). We conducted a series of one-way ANOVAs to examine the effect of age group and last choice medium preference on each justification category. For both definitional, such as, "He is real, because he looks real," $F(2,115) = 2.99$, $p = 0.022$, $\eta_p^2 = 0.101$, and just a photo—or comments about how it is just a photograph and not an actual video—justifications, $F(2,115) = 2.99$, $p = 0.022$, $\eta_p^2 = 0.101$, there were significant age group by medium interactions. Only 3- and 4-year olds used these two justifications (and only for television, 16.7% for definitional, 16.7% for just a photo) for these questions—no other age groups used them for any medium. No significant individual predictors or interactions emerged for any of the other justification categories, $p > 0.06$.

### How Does Children's Preference for a Particular Format Relate to Reality Status Judgments?

We conducted a regression model predicting children's preference from their reality status judgments, age group, medium, and their interaction. Children's belief scores significantly predicted their preferences, $b = 0.491$, $t(6) = 2.23$, $p = 0.026$, with children having a greater preference for videos that they believed to be more real ($r = 0.111$, $p = 0.002$). There were no significant predictors or interactions, $p > 0.152$.

### How Does Children's Preference Relate to Their Belief About Educational Value?

Finally, we conducted a regression model predicting children's beliefs about educational value from age group, preference, and their interactions. Preference significantly predicted children's beliefs about a medium's education value, $b = 0.46$, $t(6) = 2.54$, $p = 0.011$, meaning that children believed a medium had more educational value when they also had a greater preference for it ($r = 0.507$, $p < 0.001$). No other predictors or interactions were significant, $p > 0.500$.

# DISCUSSION

The goal of this study was to examine how different media formats affect children's reality status judgments, preferences, and beliefs about videos' educational value. The COVID-19 pandemic has accelerated children's use of YouTube for both entertainment and educational purposes. As a result, research investigating how children conceptualize the people they view on YouTube is even more imperative than ever. Are these people real—like caregivers and friends? Or are they not real—like people on television?

## Reality Status Judgments

As we predicted, children recognized that the phone video was more likely to be real than television, suggesting that they understood and followed our procedure and questions. YouTube fell in between phone and television, confirming the idea that YouTube may be a murkier area for children to understand reality status, perhaps given the diverse content on the platform. That it was not rated as more real than television suggests that children may default to believing screen content is not real (Woolley and Ghossainy, 2013) and may not fully appreciate YouTube's intermediate status.

Wright et al. (1994) noted that children use form and context clues to help them determine the reality status of television. In this study, we coded children's reality status justifications using 11 different categories that focused on similar areas—as well as others—to determine why children made their judgments. Interestingly, children tended to justify their reality status judgments for YouTube by referring to objective characteristics of the medium more than for either television or phone. This finding, along with YouTube's intermediate status in children's reality status scores, suggests that children may find YouTube a more complex medium and thus are really thinking about features of the medium itself to make their judgments. Judgments for television and phone may seem more obvious to children and thus make it more difficult for them to verbalize their justifications. Furthermore, neither children's reality status judgments nor their use of this type of justification changed with age suggesting that children's basic understanding of the reality status of YouTube does not develop significantly across this large age range—even the youngest children in our sample (3- and 4-year olds) demonstrated a familiarity with the platform and made similar judgments about its reality status as 7- and 8-year olds. This highlights that even young preschoolers are familiar with YouTube and are able to make similar judgments about it as children more than twice their age.

## Beliefs About Educational Value

Regardless of age, children perceived greater educational value in YouTube as compared with both phone and television. This is striking, given the plethora of educational content available on television and the diverse content present on YouTube. It is not clear why children see YouTube as a better learning source. Perhaps differences in the content children view on YouTube accounts for the finding, such as how-to-videos, which are watched by 38% of 0–8-year olds (Common Sense Media, 2017) and can help children learn all kinds of things—from rollerblading to math problems. It might be that we see children's beliefs about YouTube's educational value increase even further due to the COVID-19 pandemic, since many educators have been posting videos to support children's at-home learning. Future research should obtain more detailed information about children's viewing habits to assess this possibility.

It was also striking that there were no age-related differences regarding the educational value of the various media. Previous television research suggests that older children are better at recognizing the nuances of television programs, with some being real and some not (Wright et al., 1994), which may result in a clearer understanding of learning potential. Yet, we found that children made similar choices regardless of age. It may be that YouTube—in its novelty—cleaves less closely to traditional distinctions in reality versus non-reality and educational value, which leads to weaker societal beliefs about its purpose. Though, when considering children's justifications of educational value, the oldest children overwhelmingly chose medium-objective reasons to justify their beliefs. This suggests that they may have a more advanced grasp on the nature of the various media types, which is in line with expected age-related differences.

Additionally, children's reality status judgments did not predict their beliefs about a medium's educational value. This lack of relation between children's assessment of reality status with their judgments about educational value is aligned with Hawkins (1977) finding that younger children believed that television characters were more real than their older peers, but they did not endorse statements about the educational utility of television, such as, "Watching police officers on television helps me understand the police I might meet." However, this finding is somewhat surprising given research by Mares and Sivakumar (2014) and Bonus and Mares (2019) showing that children are less likely to learn from television when they judge that a show's content is not real. It may be the case that children's judgments of educational value and their actually ability to learn from media content do not always go hand in hand. Future research should explore both learning and perceptions of educational value together, as our results did show children's perceptions of educational value were linked to their preference and interest in watching the video.

## Preference

Perhaps not surprisingly, regardless of age, children preferred YouTube and television over phone videos, suggesting that children make assumptions about the quality or interest level of videos based on platform. Notably, children preferred to watch videos that they believed were real. This finding appears to align with previous research about children's distinctions between reality and fantasy. As early as the preschool years, children are able to identify the difference between real and fantastical people and characters (Skolnick and Bloom, 2006). They are also able to attribute necessary human functions, such as needing to eat, to real people and not to fantastical ones (Sharon and Woolley, 2004). In general, children possess some amount of disbelief about fantastical contexts, which might result in not preferring to watch them (see also Lillard and Taggart, 2019).

Interestingly, for children's last choice preference, only 3- and 4-year olds gave just a picture justifications—and only for television. Comments about the picture itself, such as, "It's just a picture," may represent children's inability to look beyond the image presented to them to see the medium that is being represented. This is in line with research by Flavell et al. (1990), which suggests that 3-year olds view images from television as real objects, while older children are able to understand these images are representations of objects.

Importantly, preference positively predicted educational value for all media, suggesting that children may be more interested in videos that offer to-be-learned content on these platforms. This is notable given the demonstrated value of educational media content in promoting children's skills (e.g., Mares and Pan, 2013; Hurwitz, 2018). Although entertainment media is popular among children, our findings suggest that when content is matched, children prefer videos that they can learn from. Research with storybooks also suggests that children might prefer to interact with media that help them learn new information. When preschool children were read two matched books—one with detailed causal information such as why animals behave and look in certain ways—and another that simply described animals and their behaviors, Shavlik et al. (2020) found that children preferred the causally rich storybook, perhaps because they found it more engaging.

## Limitations

One limitation of the current study is the lack of racial/ethnic diversity in the sample (61.5% white children). There was greater socioeconomic diversity present within the sample, but ideally, the sample would contain a larger percentage of children from underrepresented populations. This may be important because African–American and Latinx children spend more time using mobile media compared with white children (Rideout, 2017) and thus may have higher exposure to YouTube content, which may influence perceptions.

Another limitation might have been the image used as the study stimuli. The image was very deliberately created—a male-appearing person was chosen because approximately 62% of YouTube users/creators are male (Drazovic, 2019), and a bird was selected as the animal in the image since children from rural, suburban, and urban environments all encounter birds in the course of their everyday lives. This procedure was extensively pilot tested to ensure that children were able to attend to the format of the video instead of just focusing on the image itself, and only one child commented that the images for all three media types were the same. Additionally, 82% of children made comments based on medium, which strongly suggests that they were able to attend to the different platforms presented. However, because we only test one type of image, generalizability may be limited and results may not extend to other types of videos.

Another limitation is that our study asked about children's perceptions of reality status and educational potential, rather than assessing their learning from different mediums. Yet, research shows that preschool-age children are less likely to learn from television when they judge that content is not real (Mares and Sivakumar, 2014), so exploring the relation between children's reality status judgments and their beliefs about educational value may be valuable for furthering our understanding of this phenomenon. Future studies should investigate how children are actually able to learn from YouTube videos, as opposed to only measuring how much they believe they can learn from them, and explore links to their reality status judgments.

It is also likely that children do not conceptualize the differences between media types in the same way that adults do. They may be motivated primarily to find the content that they enjoy watching and not care about the platform on which they can view that content. That being said, results did show that children's preference did positively predict educational value for all media, suggesting that children may in fact be most interested in videos that offer educational content—no matter what the platform.

Furthermore, we used a laboratory-based procedure and researcher-created image to maximize experimental control, but we may have missed important elements of children's YouTube viewing experience by controlling content across platforms.

# CONCLUSION

As a result of the COVID-19 pandemic, many early childhood and K–12 schools moved to online instruction with only a few days' notice. Video conference class meetings and YouTube videos of lessons and storybook readings supplanted classroom instruction and radically changed the educational landscape across the globe (Li and Lalani, 2020). However, research is lacking on how children conceptualize people that they view on YouTube. This study aimed to describe how children aged 3–8 make judgments about media's reality status, determine their preferences, and reason about videos' educational value. Results suggest that YouTube does occupy a unique space in children's media landscape. Children are more likely to see YouTube content as educational, which might help them learn more from educational content on the platform.

Media literacy curricula will do well to include information specific to YouTube and other online video platforms, given their popularity among children in recent years. In the context of the current pandemic and with the possibility of future spikes, online learning modalities are likely to be a part of children's educational experiences for months and years to come. Knowledge regarding the power of YouTube for education will help educators and caregivers make informed decisions for children's success.

# DATA AVAILABILITY STATEMENT

The datasets generated for this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://osf.io/n37z6/?view_only=87a1fc1c161548f9a289270a6b3c751c.

# ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Pace University IRB and The Ohio State University IRB. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

# AUTHOR CONTRIBUTIONS

BH-D led the design the study, conducted data analysis, and led the writing of the manuscript. RD helped to design the study and consulted on analyses and helped to write the manuscript. KA conducted all of the justifications coding and helped to write the manuscript. MH and MPe conducted data collection and assisted in writing the manuscript. MPa conducted data collection and helped to design the coding scheme for the justifications. All authors contributed to the article and approved the submitted version.

## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.570068/full#supplementary-material

## REFERENCES


Bonus, J. A., and Mares, M.-L. (2019). Learned and remembered but rejected: preschoolers' reality judgements and transfer from sesame street. *Commun. Res.* 46, 375–400. doi: 10.1177/0093650215609980

Busselle, R. W., and Bilandzic, H. (2008). Fictionality and perceived realism in experiencing stories: a model of narrative comprehension and engagement. *Commun. Theory* 18, 255–280. doi: 10.1111/j.1468-2885.2008.00322.x

Common Sense Media (2017). *The Common Sense Census: Media use by Kids Age Zero to Eight*. San Francisco, CA: Common Sense Media.

Drazovic, Z. (2019). *YouTube Stats for Marketers*. Available online at: https://www.rivaliq.com/blog/youtube-stats-for-marketers/ (accessed June 1, 2020).

Dugan, T. E., Stevens, R., and Mehus, S. (2010). "From show, to room, to world: a cross-context investigation of how children learn from media programming," in *Proceedings of the 9th International Conference of the Learning Sciences*, eds K. Gomez, L. Lyons, and J. Radinsky (Chicago IL: International Society of the Learning Sciences), 992–999.

Flavell, J. H., Flavell, E. R., Green, F. L., and Korfmacher, J. E. (1990). Do young children think of television images as pictures or real objects? *J. Broadcast. Electron. Media* 34, 399–419. doi: 10.1080/08838159009386752

Goldstein, T. R., and Bloom, P. (2015). Is it oscar-worthy? Children's metarepresentational understanding of acting. *PLoS One* 10:e0119604. doi: 10.1371/journal.pone.0119604

Hall, A. (2003). Reading realism: audiences' evaluations of the reality of media texts. *J. Commun.* 53, 624–641. doi: 10.1111/j.1460-2466.2003.tb02914.x

Hawkins, R. P. (1977). The dimensional structure of children's perceptions of television reality. *Commun. Res.* 4, 299–320. doi: 10.1177/009365027700400304

Hurwitz, L. B. (2018). Getting a read on ready to learn media: a meta-analysis review of effects on literacy. *Child Dev.* 90, 1754–1771. doi: 10.1111/cdev.13043

Huston, A. C., and Wright, J. C. (1983). "Children's processing of television: the informative functions of formal features," in *Children's Understanding of Television: Research on Attention and Comprehension*, eds J. Bryant and D. R. Anderson (San Diego, CA: Academic Press), 35–68.

Li, C., and Lalani, F. (2020). *The COVID-19 Pandemic has Changed Education Forever. This is How*. Cologny: World Economic Forum.

Li, H., Boguszewski, K., and Lillard, A. S. (2015). Can that really happen? Children's knowledge about the reality status of fantastical events in television. *J. Exp. Child Psychol.* 139, 99–114. doi: 10.1016/j.jecp.2015.05.007

Li, H., Liu, T., Woolley, J., and Zhang, P. (2019). Reality status judgements of real and fantastical events in children's prefrontal cortex: an fNIRS study. *Front. Hum. Neurosci.* 13:444. doi: 10.3389/fnhum.2019.00444

Lillard, A. S., and Taggart, J. (2019). Pretend play and fantasy: what if montessori was right? *Child Dev. Perspect.* 13, 85–90. doi: 10.1111/cdep.12314

Lukovitz, K. (2020). *Pandemic-Driven Kid-Related Video Boom: Even DIYs are Diving in*. New York, NY: Media Post.

Mares, M.-L., and Sivakumar, G. (2014). "Vámonos means go, but that's made up for the show": reality confusions and learning from educational TELEVISION. *Dev. Psychol.* 50:2498. doi: 10.1037/a0038041

Mares, M., and Pan, Z. (2013). Effects of *Sesame Street*: a meta-analysis of children's learning in 15 countries. *J. Appl. Dev. Psychol.* 34, 140–151. doi: 10.1016/j.appdev.2013.01.001

Martínez, C., and Olsson, T. (2019). Making sense of YouTubers: how swedish children construct and negotiate the YouTuber Misslisibell as a girl celebrity. *J. Child. Media* 13, 36–52. doi: 10.1080/17482798.2018.1517656

Mokhtar, F., and Gross, S. (2020). *Should Schools Close to Fight Virus? these Places Say No*. New York, NY: Bloomberg News.

Ofcom (2016). *Children and Parents: Media Use and Attitudes Report*. London: Ofcom.

ParentsTogether Foundation (2020). *Survey Shows Parents Alarmed as Kids' Screen Time Skyrockets During COVID-19 Crisis*. Available online at: https://parents-together.org/survey-shows-parents-alarmed-as-kids-screen-time-skyrockets-during-covid-19-crisis/ (accessed September 28, 2020).

Rideout, V. (2017). *The Common Sense Census: Media Use by Kids Age Zero to Eight*. San Francisco, CA: Common Sense Media.

Sharon, T., and Woolley, J. D. (2004). Do monsters dream? Young children's understanding of the fantasy/reality distinction. *Br. J. Dev. Psychol.* 22, 293–310. doi: 10.1348/026151004323044627

Shavlik, M., Bauer, J. R., and Booth, A. (2020). Children's preference for causal information in storybooks. *Front. Psychol.* 11:666. doi: 10.3389/fpsyg.2020.00666

Silverblatt, A., and Eliceiri, E. M. E. (1997). *Dictionary of Media Literacy*. Westport, CT. Greenwood Press.

Skolnick, D., and Bloom, P. (2006). What does batman think of SpongeBob? Children's understanding of the fantasy/fantasy distinction. *Cognition* 101, B9–B18. doi: 10.1016/j.cognition.2005.10.001

Smith, A., Toor, S., and van Kessel, P. (2018). *Many Turn to Youtube for Children's Content, News, How-To Lessons*. Washington, D.C: Pew Research Center.

Vanwesenbeeck, I., Hudders, L., and Ponnet, K. (2020). Understanding the YouTube generation: how preschoolers process television and YouTube advertising Advance online publication. *Cyberpsychol. Behav. Soc. Netw.* 23, 426–432. doi: 10.1089/cyber.2019.0488

Woolley, J. D., and Ghossainy, E. M. (2013). Revisiting the fantasy-reality distinction: children as naïve skeptics. *Child Dev.* 84, 1496–1510. doi: 10.1111/cdev.12081

Wright, J. C., Huston, A. C., Reitz, A. L., and Piemyat, S. (1994). Young children's perceptions of television reality: determinants and developmental differences. *Dev. Psychol.* 30, 229–239. doi: 10.1037/0012-1649.30.2.229


**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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ORIGINAL RESEARCH
published: 09 September 2020
doi: 10.3389/fpsyg.2020.02224

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# Characteristics of Children's Media Use and Gains in Language and Literacy Skills

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Media use could be detrimental to children's language and literacy skills because it may displace other language-enhancing activities like shared reading and caregiver-child interactions. Furthermore, the extent to which children use media with adults (joint media engagement), the extent to which they use interactive media (apps/games), and the time of the day and week during which media use occurs may attenuate any negative effects. The current study examines the relation between characteristics of children's media use and gains in first graders' language and literacy skills. Children ($N = 488$) completed direct assessments of language and literacy skills in the spring of kindergarten and the spring of first grade. Parents reported how many hours children used both interactive and non-interactive media during different times of the day on the most recent weekday and weekend day and responded to items about the extent to which they engage with their children during media use. A quadratic relationship between media use and language gains showed that a moderate amount of media use was related to larger language gains, whereas high use was related to smaller gains. For literacy, an interaction between media use and joint media engagement showed a small negative effect of media use at low levels of joint media engagement and little to no relation between media use and literacy gains at higher levels of joint media engagement. Children's language and literacy skills were not predicted by either the proportion of media time that was spent with apps/games or morning and weekday media use. These results show that moderate amounts of media use may not be a negative influence on children's developing language skills, whereas high levels may displace other language-enhancing activities. Additionally, joint media engagement may play an important buffering role in the relation between media use and early literacy skills, aligned with current recommendations encouraging co-viewing.

**Keywords: media, language, literacy, co-viewing, joint media engagement, interactivity**



***Edited by:***
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***Specialty section:***
*This article was submitted to Developmental Psychology, a section of the journal Frontiers in Psychology*

***Received:*** *04 June 2020*
***Accepted:*** *10 August 2020*
***Published:*** *09 September 2020*

***Citation:***
*Dore RA, Logan J, Lin T-J, Purtell KM and Justice L (2020) Characteristics of Children's Media Use and Gains in Language and Literacy Skills. Front. Psychol. 11:2224. doi: 10.3389/fpsyg.2020.02224*

## INTRODUCTION

Popular press coverage often highlights studies showing associations between how many hours of "screen time" children are exposed to and negative outcomes, potentially fueling concerns among parents and caregivers about their children's use of media and technology. One domain that has been investigated in prior research is the relation between media use and language development.

Indeed, several studies have found that media exposure during toddlerhood or preschool is associated with lower language development in subsequent years. Clarke and Kurtz-Costes (1997) found that preschoolers' TV viewing was negatively associated with several domains of school readiness. Similarly, Pagani et al. (2013) found that every additional hour that children watched TV at 29 months of age was associated with 11% lower vocabulary scores at 65 months of age. However, findings are inconsistent, with other research finding no association between media exposure and language development. Patterson (2002) examined expressive vocabulary size and television watching among 21- to 27-month old bilingual toddlers and found that TV watching was not associated with vocabulary size in either language. Schmidt et al. (2009) found similar results for TV viewing at 6 months, 1 year, and 2 years and vocabulary skills at 3 years. More recently, Taylor et al. (2017) reported on an upper-socioeconomic status (SES) sample of children in the United Kingdom and found that TV and mobile device use was not predictive of children's vocabulary skills for children between 6 and 36 months of age. Notably, in both of these studies time spent being read to was associated with language (although only for 6- to 18-month-olds in Taylor et al.), suggesting that the variability in children's vocabulary scores was meaningful and associated with other characteristics of the home environment. Together, the only consistent finding in this literature is inconsistency, suggesting that studies may be leaving out critical factors that may help explain discordant findings; some of these factors are speculated on below and tested in the current research. This represents a critical gap in our understanding and precludes the development of evidence-informed recommendations.

In the current study, we investigate four hypotheses that might explain these mixed findings. First, we assess the possibility that there are nonlinear relations between media use and children's skill gains. Our prior research has demonstrated that any (weak) relations between media use and language development are best represented as a threshold effect rather than a straightforward linear relation, such that increases from small to moderate amounts of media use are not related to children's skill gains, whereas larger amounts of media use are related to lower gains (Dore et al., in press). Studies testing only for linear relations may miss meaningful associations that manifest as quadratic relations. Here, we use a continuous measure of children's media use that should be more sensitive to potential associations and test both linear and quadratic relations to uncover possible associations with children's skill gains.

A second hypothesis that might explain mixed findings in this domain is that media use has differential effects on language and literacy development depending on the extent to which it disrupts other beneficial activities. This idea is grounded in Vygotsky's theory of language development, highlighting the idea that language acquisition is embedded in social interaction and that talk that is contingent and responsive to children's verbalizations and actions should support language development (Vygotsky, 1962; Bruner, 1983). Thus, time spent with media could be detrimental to the children's language skills because it may *displace* language-enhancing activities. For example, Vandewater et al. (2006) found that time spent watching TV was negatively related to time spent with parents and siblings, as well as creative play.

Following this research, media use may have a negative effect on language growth only to the extent that it inhibits caregiver-child interaction and caregiver language input. In other words, joint media engagement may moderate the association between children's media use and language skills. Joint media engagement refers to experiences in which caregivers and children use the same media at the same time, are involved in the content together, and are prompted by what they are seeing to interact with each other and bring more meaning to what they are watching or doing (Stevens and Penuel, 2010; Takeuchi and Stevens, 2011; Guernsey and Levine, 2015; see Dore and Zimmermann, 2020, for a review). When parent-child joint media engagement is frequent, children's development may be more positive because the media experience does not replace contingent caregiver-child interaction but instead extends it to a new context. Some research has found that the negative association between preschoolers' television exposure and a standardized measure of language development is entirely explained by accounting for adult-child conversations, suggesting that joint media engagement may influence language (Zimmerman et al., 2009). Indeed, there is no relation between infants' media exposure (television, videos/DVDs, movies, and games) and a standardized measure of language development when caregivers report frequent joint media engagement (Mendelsohn et al., 2010). Additionally, Strouse et al. (2013) found that children understood a story and learned new words better when their parents were trained to use joint media engagement while viewing an educational video by pausing and asking their child questions about the content. Thus, to the extent that caregivers use media with their children and engage in conversation around media, any negative effects on language development may be attenuated. Joint media engagement is variable across families (Connell et al., 2015) and is thus a possible hidden moderator of media on language trajectories. Thus, we predict that joint media engagement will moderate the association between media use and children's language gains, such that any negative association between media use and language will be attenuated when joint media engagement is high.

Notably, although considerable research has investigated the role of media in young children's language development, less focus has been placed on early literacy skills. This is critical, because early literacy skills are a major predictor of later reading performance (National Early Literacy Panel, 2008). Indeed, language and literacy skills are intricately related during the early school years and work together to influence reading ability (Snow, 1991; Snow et al., 1995; Torppa et al., 2010). As with language development, the displacement hypothesis suggests that media use may take the place of activities like shared storybook reading, which are linked to the development of children's early literacy skills. Indeed, Khan et al. (2017) found that children's TV viewing was negatively related to the frequency of parent-child reading. However, any relation between media use and literacy development may also be moderated by joint media engagement, as adults can support children's literacy learning from educational TV when they scaffold the interaction by asking children questions and providing feedback (e.g., Reiser et al., 1984). Recent research by Hutton et al. (2020) also supports an association between media use and literacy skills. The researchers created a new composite measure designed to align with the American Academy of Pediatrics' recommendations for young children's media use. The parent report measure contained 15 items assessing access to screens, frequency of use, media content, and caregiver-child co-viewing (akin to joint media engagement). Parents of preschoolers completed the measure and children complete a standardized measure of core emergent literacy skills. Results showed that the media measure was negatively related to emergent literacy skills, although the composite nature of the assessment makes it impossible to determine the specific role of joint media engagement as opposed to other aspects of children's media use (i.e., quantity and content). A more nuanced understanding of how both the quantity of children's media use and joint media engagement relate to both language and literacy skills will provide a broader lens through which to consider the role of media in child development. As with language skills, we hypothesize that there may be a negative, quadratic relation between media use and literacy gains and a moderating effect of joint media engagement, such that any negative association between media use and literacy will be attenuated when joint media engagement is high.

A third hypothesis to explain mixed findings related to the effects of media use on children's language and literacy skills is the extent to which the media is interactive. Digital games and apps may be more supportive of language and literacy development than non-interactive media use, as they are interactive and responsive to the child's actions in a way that a television show is not (Sheehan and Uttal, 2016). Indeed, existing research focuses primarily on television use, whereas an increasing amount of children's media use comes from interactive media like apps and games on mobile devices. It is possible that children learn better from touchscreens, as learning is enhanced when children are actively engaged in an activity (Hirsh-Pasek et al., 2015). Joint attention and serve-and-return interactions are important for word learning (Tomasello and Farrar, 1986; Bloom et al., 1987) and apps mimic some of those features – for example, by providing labels immediately after children touch an object or responding to incorrect responses with an appropriate hint.

However, mixed findings emerge when this idea is tested empirically. Some research finds that preschoolers readily learn new information from apps on touchscreen devices (Huber et al., 2016) and that toddlers who use more interactive media (apps/games) learn new information better from media in general, suggesting that experiences with interactivity may have shown them that media can be responsive and a reliable source of information (Kirkorian and Choi, 2016). Yet, other studies show that preschoolers learned less from playing an interactive game than when passively watching a video of gameplay (Aladé et al., 2016; Schroeder and Kirkorian, 2016) or that the effect of interactivity depends on children's age or sex (Choi and Kirkorian, 2016; Kirkorian et al., 2016; Russo-Johnson et al., 2017). These studies have primarily focused on lab-based learning tasks (e.g., finding the location of a hidden object) and little research to our knowledge has examined how media interactivity relates to language and literacy development. We hypothesize that media interactivity will moderate the association between media use and language and literacy development, such that any negative association between media use and language and literacy will be attenuated when media interactivity is high.

A fourth hypothesis is that the time of the day and week during which media use occurs could influence the relation between media use and language development. Recent studies have suggested that fantastical television (Lillard et al., 2015) and noneducational cartoons (Huber et al., 2018) may inhibit children's executive function skills and if children use these media immediately prior to school, it may disrupt opportunities for learning. Furthermore, following from the displacement hypothesis, the types of activities that are displaced by media use may differ for weekdays and weekends, such that more language-enhancing activities are displaced during the week, whereas weekend media use may be likely to displace less constructive activities. If true, these hypotheses would suggest that when more of children's media use occurs in the morning before school and on the weekdays, language and literacy development may be more negatively affected than when media use occurs during other times the day and week.

We focus on children transitioning from kindergarten to first grade because research on media and language has focused primarily on children under 3 years of age (see Linebarger and Vaala, 2010, for a review) and there is relatively less evidence for the role of media in language and literacy development among older children. Children in this age range are gaining more advanced vocabulary and language skills, as well as beginning to learn to read and gain important early literacy skills (Farkas and Beron, 2004). It is vitally important to understand predictors of these skills among children during the early elementary years, given the role of these skills in predicting reading achievement (e.g., Blachman, 1984). Media use is also higher in this age range than during early childhood (Rideout, 2017), perhaps partially because of less restrictive recommendations from the American Academy of Pediatrics for older children (AAP Council on Communications and Media, 2016). Thus, this period may be an ideal time for interventions to reduce media use or influence its content and context. Understanding the role of media use in development for children in this age range is important to inform future developmentally-specific recommendations.

Importantly, we measure and control for several demographic factors that may be related to both media use (or characteristics of media use) and language and literacy gains, as relations between media and children's outcomes are often attenuated by including proper control variables (e.g., Orben and Przbylski, 2019). By controlling for these variables, we will have greater confidence that any relations between media use and language and literacy development are unique and meaningful associations.

In all, the current study addresses four research questions: (1) To what extent is the quantity of children's media use associated with gains in the language and literacy skills of children from kindergarten to first grade? *We hypothesize that there will be quadradic, rather than linear, associations between media use and language and literacy skills, such that media use is only negatively associated with skill gains at high levels.* (2) To what extent does the degree of joint media engagement moderate the association between the quantity of media use and gains in language and literacy skills? *We hypothesize that joint media engagement will moderate the association between media use and children's language and literacy gains, such that any negative association between media use and language and literacy will be attenuated when joint media engagement is high.* (3) To what extent does the interactivity of the media moderate the association between the quantity of media use and gains in language and literacy skills? *We hypothesize that media interactivity will moderate the association between media use and children's language and literacy gains, such that any negative association between media use and language and literacy will be attenuated when media interactivity is high.* (4) To what extent is morning and weekday media use associated with gains in language and literacy skills? *We hypothesize that when more of children's media use occurs in the morning before school and on the weekdays, language and literacy gains may be smaller than when media use occurs during other times the day and week.*

**TABLE 1** | Descriptive statistics for all study variables.

| Continuous variables | Mean | *SD* |
|---|---|---|
| WJ Picture Vocabulary (K) | 473.8 | 10.2 |
| WJ Picture Vocabulary (first) | 480.4 | 9.7 |
| WJ Letter-Word Identification (K) | 401.8 | 30.1 |
| WJ Letter-Word Identification (first) | 446.1 | 30.8 |
| Weekly media use in hours | 23.5 | 13.2 |
| Joint media engagement score | 26.8 | 5.9 |
| **Factors** | **Percentage (%)** | |
| **Mother's education** | | |
| Less than high school diploma | 11.3 | |
| High school diploma or GED | 41.4 | |
| Associate's degree | 16.0 | |
| Bachelor's degree | 21.4 | |
| Graduate or professional degree | 9.9 | |
| **Number of adults in the home** | | |
| One | 11.1 | |
| Two | 73.6 | |
| More than two | 15.2 | |
| **Child's race** | | |
| White | 74.1 | |
| Hispanic or Latino | 14.3 | |
| Black or African-American | 4.0 | |
| Asian | 3.1 | |
| Multiple races | 10.4 | |
| Other | 8.4 | |

# MATERIALS AND METHODS

## Participants

Participating teachers in a large school district in Ohio received financial incentives as part of the larger study and all children in their classrooms were recruited. Of those asked to participate in preschool, 64.5% consented. Data from the spring of kindergarten and the spring of first grade year are reported in the current study[1].

Of the children whose parents consented for them to participate, approximately 55.4% of families (representing 488 children) responded to the survey items about child media use to be included in the current analysis[2]. Thus, data from 488 children (53.2% males) primarily between 6 and 8 years of age ($M$ = 84.9, $SD$ = 4.4) are included. See **Table 1** for sample demographics.

## Procedures

We used two time points from the larger longitudinal project to address our research questions: the spring of kindergarten and the spring of first grade. Children's language and literacy skills were directly assessed in the spring of kindergarten and the spring of first grade. In the spring of first grade only, caregivers reported on children's media use, as well as other child and family demographics characteristics.

### Quantity of Child Media Use

Parents were asked how long their child spent using two types of media ("Watching any kind of video including TV, movies or short clips on any type of device" and "Using apps or games on any type of electronic device") during three different time periods (the most recent weekday before school, the most recent weekday after school, and the most recent weekend day). For each time period, there were eight response options from "None" to "More than 3 h" with intervening options in half an hour increments. To create a total weekly media score, any response of "More than 3 h" was coded as 4 h and these items were aggregated by multiplying the weekday score by 5 and the weekend score by 2 and summing. Outliers were winsorized by replacing values that were more than three *SD*s above the mean with that value; 1.6% of the data were replaced in this manner.

### Joint Media Engagement

To assess joint media engagement, we created a new measure informed by existing scales of caregiver mediation based on particular content (e.g., Rasmussen et al., 2016), focused exclusively on television viewing (e.g., Valkenburg et al., 1999; Nathanson et al., 2013), or exclusively examining co-use with children (e.g., Rideout, 2017). Thus, our measure assesses the extent to which adults use media with the child and the extent

[1]Seven children were retained in kindergarten during the second year of testing.
[2]In line with studies showing that low-SES and minority families are underrepresented in research (Myers et al., 1992; Gross et al., 2001), this sub-sample had higher maternal education ($\chi2$ = 42.8, $p$ < 0.0001), fewer single-adult homes ($\chi2$ = 13.1, $p$ = 0.01), and more White families than the full sample ($\chi2$ = 52.3, $p$ < 0.0001), suggesting that even when these families consented to being part of the study they were less likely to return the survey and/or respond to survey items.

to which adults talk to the child about media. Responses are on a 6-point scale from strongly disagree to strongly agree.

Confirmatory factor analyses revealed that three items did not load with the rest of the items in the scale and were removed for analyses. All other items loaded at 0.438 or above, comparative fit index (CFI) = 0.852, root mean square error of approximation (RMSEA) = 0.169, $\chi^2 < 0.001$, and standardized root mean square residual (SRMR) = 0.088. Of the final items, one asks about co-viewing, one asks about distracted co-viewing (caregiver is in the room but engaged in another task), three ask about conversation during media use (two reverse scored), and two ask about discussing media after use. These seven items were summed to create a joint media engagement score. See **Table 2** for the final items.

**TABLE 2** | Joint media engagement items.

| Item | |
|---|---|
| 1. | It is usually in the same room as me or another adult. |
| 2. | I am not sure whether they are watching videos or using apps/games.* |
| 3. | I comment on or ask my child questions about what is happening. |
| 4. | I do not interrupt him/her to talk about what he/she is doing or watching.* |
| 5. | We do not talk much about what he/she is doing or watching.* |
| 6. | I bring up what he/she saw or did in other conversations. |
| 7. | We talk about it beforehand. |

*Reverse scored.

### Interactivity of the Media

The quantity items described above were used to create a variable representing how much children use interactive (using apps/games regardless of device) vs. non-interactive media (watching video and regardless of device). Specifically, we created proportion scores by dividing the time children spent with apps/games by their total media time.

### Language Skills

To assess language skills, children completed the Picture Vocabulary subtest of the *Woodcock Johnson Test of Achievement-III* (WJ-III; Woodcock et al., 2007) in the spring of kindergarten and the spring of first grade. The initial items of the subtest require children to choose the picture that fits the named word for the initial items, and then later items require children to provide names for each picture (44 items total). Six consecutive correct items are needed to establish test basal and six consecutive incorrect responses terminate the test. Reliability was adequate (0.80) and W-scores were used to examine student growth.

### Literacy Skills

To assess literacy skills, children completed the Letter-Word Identification subtest of the *Woodcock Johnson Test of Achievement-III* (WJ-III; Woodcock et al., 2007) in the spring of kindergarten and the spring of first grade. This subtest (76 items total) requires children to identify individual letters and then read individual words of increasing difficulty. Six consecutive correct items are needed to establish test basal and six consecutive incorrect responses terminate the test. Reliability was adequate (0.94) and W-scores were used to examine student growth.

# RESULTS

## Preliminary Analyses

We first report descriptive statistics related to children's media use. According to parent report, children used media for a mean of 23.5 h per week ($SD = 13.2$) or over 3 h per day ($M = 3.36$).

On our scale for joint media engagement, responses could range from 0 to 35, with higher scores representing more joint media engagement. The mean joint media engagement score total was 26.8 ($SD = 6.01$), $N = 467$. Although the distribution was negatively skewed, scores from 0 to 35 were represented in the data.

The mean media interactivity proportion was 40.5% ($SD = 17.1$), suggesting more video watching than app/game use. These scores ranged from 0 to 1, indicating that some children used all videos and no apps/games, whereas other children used all apps/games and no video.

In relation to time of day and week, 59.8% of children were reported to use media before school in the morning and 97.7% were reported to use media on weekdays after school. On average, children used media for almost 1 h before school in the morning ($M = 0.95$, $SD = 1.36$) and over 3 h on weekdays ($M = 3.11$, $SD = 2.30$). Parents reported that 99.0% of children used media on the most recent weekend day.

## Association Between the Quantity of Media Use and Children's Language and Literacy Gains

To address our first research question, we conducted multilevel regression models accounting for classroom variance. To assess changes in children's language and literacy skills, children's first-grade scores were dependent variables and the models controlled for kindergarten scores in both language and literacy. The models also controlled for age, gender, race, mother's education, and number of adults in the household, as these may be related to both media use and language and literacy gains.

For language skills, media use did not predict gains in the linear model ($p = 0.33$). However, results showed a quadratic relation ($B = -13.9$, $p = 0.03$) showing that children who use a moderate amount of media have the largest language gains, whereas both the lowest and the highest levels of media use are associated with smaller language gains, see **Table 3**; **Figure 1**. For the models predicting literacy, neither linear nor quadratic effects were significant ($ps > 0.35$).

## Joint Media Engagement as a Moderator of Associations Between Media Use and Children's Language and Literacy Gains

To address our second research question, we conducted models adding joint media engagement as a moderator of the association between media quantity and children's skill gains.

**TABLE 3** | Predicting language gains: results of multilevel regression model ($N$ = 419).

| Predictor | *B* | *SE* | *p* |
|---|---|---|---|
| Intercept | 171.2 | 16.0 | <0.0001*** |
| Baseline language | 0.60 | 0.04 | <0.0001*** |
| Baseline literacy | 0.04 | 0.01 | 0.0001** |
| Media use | 6.33 | 6.63 | 0.34 |
| Media use$^2$ (quadratic) | −13.94 | 6.57 | 0.03* |
| Gender | −0.08 | 0.64 | 0.90 |
| Age | 0.07 | 0.07 | 0.32 |
| Race (White) | 2.81 | 0.96 | 0.004** |
| Mother's education | 0.01 | 0.29 | 0.96 |
| Number of adults in household | −0.80 | 0.50 | 0.11 |

*Outcome is Picture Vocabulary W-scores. *p < 0.05; **p < 0.01; ***p < 0.001.*

**TABLE 4** | Predicting literacy gains: results of multilevel regression model ($N$ = 419).

| Predictor | *B* | *SE* | *p* |
|---|---|---|---|
| Intercept | 119.96 | 48.2 | 0.01* |
| Baseline literacy | 0.77 | 0.03 | <0.0001*** |
| Baseline language | 0.07 | 0.11 | 0.55 |
| Media use | −0.66 | 0.33 | 0.05* |
| Gender | 1.50 | 1.79 | 0.40 |
| Age | −0.11 | 0.20 | 0.59 |
| Race (White) | 1.22 | 2.94 | 0.68 |
| Mother's education | 2.29 | 0.84 | 0.007** |
| Number of adults in household | −0.82 | 1.4 | 0.56 |
| Media use × Joint media engagement | 0.03 | 0.01 | 0.02* |

*Outcome is Letter-Word W-scores. *p < 0.05; **p < 0.01; ***p < 0.001.*

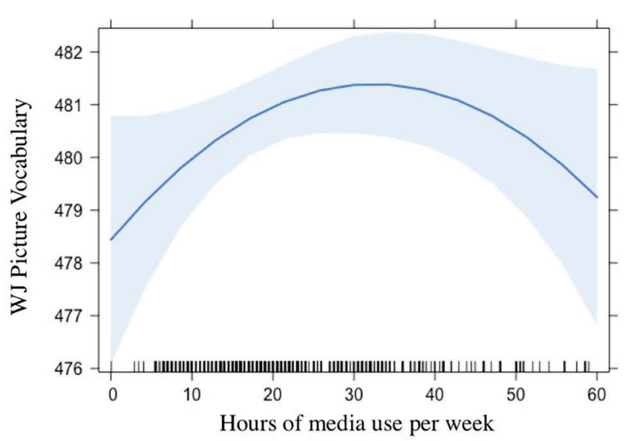


**FIGURE 1** | Association between weekly media use and language gains. Each vertical line along the X-axis represents one child.

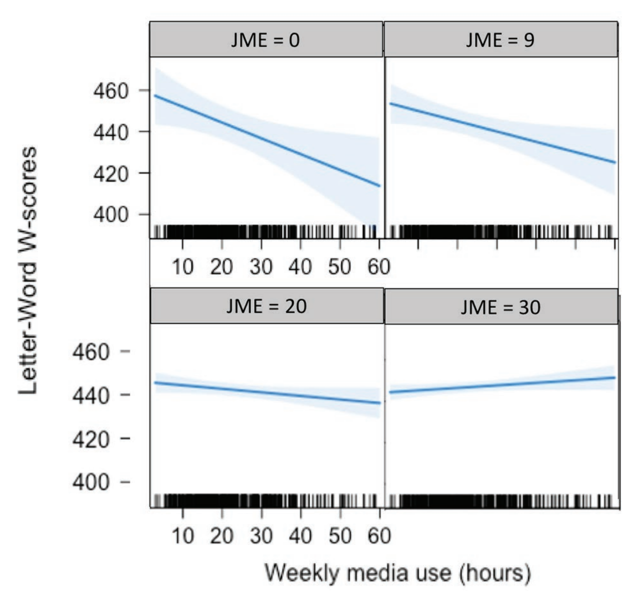


**FIGURE 2** | Association between weekly media use and literacy gains, moderated by joint media engagement (JME). Each panel represents a different level of joint media engagement score, starting from a low score of 0 on the top left, going to a high score of 30 on the bottom right.

First, we examined whether joint media engagement moderated the relation between media use and skill gains. When predicting language, the interaction was not significant in either the linear or the quadratic models ($ps > 0.23$).

For the models predicting literacy, there was a significant interaction between media use and joint media engagement ($B = 0.03$, $p = 0.02$), showing a small negative effect of media use at low levels of joint media engagement and little to no relation between media use and literacy gains at higher levels of joint media engagement, see **Table 4**; **Figure 2**.

## Interactivity of the Media as a Moderator of Associations Between Media Use and Children's Language and Literacy Gains

To address our third research question, we conducted models adding the proportion of children's media use that interactive media (apps/games) as a moderator of the association between media quantity and children's skill gains. There were no interactions between media use and the proportion of children's interactive media use for either language or literacy ($ps > 0.48$).

## Association of Morning and Weekday Media Use and Children's Language and Literacy Gains

To address our fourth research question, we conducted models parallel to those for research question one but predicting language and literacy gains from the quantity of children's morning media and, separately, from quantity of children's weekday media use. There were not significant associations between morning ($ps > 0.13$) and weekday ($ps > 0.54$) media use for either language or literacy skills.

# DISCUSSION

These results shed light on media use and children's language and literacy skills. We found that for language, the effect of media use differed by the level of use: children who used a moderate amount of media had the largest language gains, whereas both the lowest and the highest levels of media use are associated with smaller language gains. Our results for literacy showed that the association with media use depended on joint media engagement, such that when joint media engagement was low, media use was negatively related to literacy gains, but at high levels of joint engagement, this relation was not present. However, counter to our predictions, the relation between media use and language was not moderated by joint media engagement, and there was no main effect of media use on literacy gains. Furthermore, interactivity of the media and morning and weekday media use were not associated with either language or literacy gains.

Descriptively, our results showed that children used over 3 h of media per day on average. This level of usage is in line with a previous nationally representative survey showing that children between five and eight used almost 3 h of media per day on average (Rideout, 2017). The slightly higher use in our sample may be due to several factors, including our more nuanced methodology for asking about media use during different times of day.

Our first research question focused on the association between media use and children's language and literacy skill gains. The quadratic relation between media quantity and language skills runs counter to the idea that any amount of media use is detrimental for development. Our results showed that children who had a moderate amount of weekly media use were likely to have higher language gains than children who had no or very little weekly media use. This finding may reflect the potential educational value of some programs (e.g., Mares and Pan, 2013) or the idea that media can expose children to new vocabulary and concepts in a similar way to children's picture books (Lavigne et al., 2015; Montag et al., 2015). However, at higher levels, increased media use had a negative relation with children's language gains, which is in line with social interaction theories of language development (Vygotsky, 1962; Bruner, 1983) and prior suggestions that media use can replace other valuable language-enhancing activities (e.g., Vandewater et al., 2006; Khan et al., 2017). This finding is an important extension of prior research in this domain, which has demonstrated mixed results with some studies finding negative linear associations between media use and children's language skills (e.g., Clarke and Kurtz-Costes, 1997; Pagani et al., 2013) whereas others find no relation (e.g., Patterson, 2002; Schmidt et al., 2009; Taylor et al., 2017). By ignoring potential quadratic relations, these prior studies may be missing a meaningful association, potentially explaining conflicting findings.

Literacy gains, on the other hand, appeared to differ based on the extent to which caregivers reported engaging with children during media use. When joint media engagement was low, media use was negatively related to literacy gains, perhaps because it replaced activities that are more likely to focus on literacy skills, like shared reading. However, at high levels of joint engagement, this relation was non-significant, perhaps because parents who use media with children are likely to use opportunities within media to provide practice with literacy skills, in line with research suggesting that such joint engagement can support children's learning (Reiser et al., 1984; Strouse et al., 2013). One might expect that joint media engagement is acting as a proxy for general parenting quality or home environment, such that any association is not due to media use specifically but instead shows that higher quality parenting or home environment is associated with literacy gains. However, in a supplementary analysis, we found no main effect of joint media engagement on literacy gains, suggesting that an association between joint media engagement and general parenting quality or home environment outside of media use is unlikely to explain the relation.

These contrasting results beg the question of why our first hypothesis was not supported for literacy (i.e., there was no main effect of media use on literacy gains) and our second hypothesis was not supported for language (i.e., joint media engagement did not moderate the association between media use and children's language gains). Although these disparate findings were not predicted, we have several speculations that may explain these results. First, our measure of joint media engagement was positively skewed, with most caregivers reporting engaging in these behaviors at moderate to high levels. For these children, there was little to no relation between media use and literacy gains. Thus, a paucity of data points at the low end of the distribution, where an association does emerge, may have precluded our ability to detect a main effect of media use on gains in children's literacy skills across the year. Second, there is more growth in literacy skills than in language skills across first grade, meaning that there was less variability to predict in language skills and thus, lower power to see a potential moderation effect even though the main effect emerged. However, it is also possible that this finding represents a true null effect, indicating that, counter to prior research with infants and preschoolers (Zimmerman et al., 2009; Mendelsohn et al., 2010), joint media engagement does not support language development for children during the early elementary years, perhaps because there are additional influences on these skills that contribute more variance (e.g., school and peers). Future research would do well to investigate skill gains over longer developmental periods and attempt to develop more sensitive measures of joint media engagement.

It was also somewhat surprising that children's language and literacy skills were not predicted by the proportion of media time that was spent with apps/games, the indicator of interactivity of the media in this study. This finding runs counter to theoretical approaches suggesting that children may learn more from interactive media (Sheehan and Uttal, 2016) and ideas in the popular press that interactive screen time may be more beneficial for development than video. However, at least for overall media exposure and for language and literacy skills, interactive and non-interactive media seem to have similar relationships with skill gains. Results may differ for educational media (Hirsh-Pasek et al., 2015) or for apps and games that include developmentally appropriate guidance, like scaffolded feedback (Callaghan and Reich, 2018), which better mimic the serve-and-return interactions that are important for language learning (Bloom et al., 1987).

Similarly, there was no relation between children's media use in the mornings before school or on weekdays and children's language and literacy gains. Although prior research has shown that certain types of media can have immediate impacts on executive function skills (Lillard et al., 2015; Huber et al., 2018), which may disrupt learning, our data does not allow us to determine what types of media children were using in the morning before school or what academic content (i.e., literacy, math, etc.) they were exposed to immediately upon their arrival at school. This finding, in combination with the finding that weekday media use was not differentially associated with children's skill gains, suggests that it is the overall quantity of children's media use that is related to language and literacy skills, not use at any specific time of the day or week.

Our primary findings have several important implications for media use among young children. First, they suggest that moderate amounts of media use are not detrimental, and may even be beneficial for language growth, at least by the first grade year. Although this finding does not indicate that increasing media use should be recommended over established language-promoting activities like book reading, it does suggest that when left to their own devices, families who limit media use to extremely low levels may not be replacing that time with other enriching activities. It may be more reasonable for interventions and recommendations to focus on shifting the quality of children's media use by increasing educational content, rather than decreasing the overall quantity, at least for children who receive moderate levels of media use. Importantly, these data do show a negative relation between high levels of media use and children's language gains. For these children, interventions to decrease media use and replace it with more enriching activities could be warranted. This distinction highlights the value of conducting screening and differentiating recommendations to families based on their existing media use.

Our findings also suggest that joint media engagement may play an important buffering role in the relation between media use and children's early literacy skills, in line with recent research (Hutton et al., 2020). The American Academy of Pediatrics recommendations include a focus on co-using media with children (AAP Council on Communications and Media, 2016) and other research has shown that co-use can enhance positive effects (e.g., Strouse et al., 2013) and buffer negative effects of media (Nathanson et al., 2002). These findings support this recommendation and suggest that joint media engagement may be helpful for limiting negative effects of media use on children's developing literacy skills.

Despite its strengths, there are several limitations to this study. First, both language and literacy are complex constructs and were measured here through single standardized measures. Future research should expand the measures that are used to more comprehensively understand the relation between media and multiple facets of language and literacy development. Furthermore, media use was reported by parents, whose responses may be limited by memory challenges and/or social desirability, as is common in this literature (see Madigan et al., 2020). Future studies would do well to include more objective measures of children's media exposure, such as ecological momentary assessment or passive device tracking. Additionally, our measure of joint media engagement was self-reported by caregivers and asked about general approaches to media use in the home rather than specific instances of joint media engagement. We took this approach because we expected that instances of joint media engagement might be relatively rare and hard to capture. However, it would be beneficial for additional research to use alternative methods of assessing joint media engagement, such as observation. Notably, although we examined gains across a school year to avoid some of the limitations of studies using only one time point, these relations are still correlational and do not justify causal conclusions. Rigorous correlational research using multiple time points can justify possible targets for interventions, which could then provide causal evidence for the relations between these variables.

The current study makes several important contributions to the literature in this area. By accounting for non-linear relations and taking into consideration the characteristics of media use, the current results begin to provide a more nuanced understanding of the relation between media use and language and literacy development. Our results demonstrate the importance of going beyond linear associations and understanding possible buffers of the role of children's media use on child development.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors upon request, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Ohio State University Institutional Review Board. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

LJ, KP, T-JL, and JL contributed to conceptualization of the larger project and obtained funding. RD and JL contributed to the conceptualization of the current study and conducted data analyses. RD drafted the work. JL, LJ, KP, and T-JL contributed to editing and revising and gave final approval of the version to be submitted.

## FUNDING

The research reported here was supported by Institute for Education Sciences, through grant R305N160024 awarded to The Ohio State University (Justice). The opinions expressed are those of the authors and do not represent views of the Institute or National Center for Education Research.

## ACKNOWLEDGMENTS

We would like to thank the research team, staff, and families without whom this research would not have been possible.

## REFERENCES

AAP Council on Communications and Media (2016). Media and young minds. *Pediatrics* 138:e20162591. doi: 10.1542/peds.2016-2591

Aladé, F., Lauricella, A. R., Beaudoin-Ryan, L., and Wartella, E. (2016). Measuring with Murray: touchscreen technology and preschoolers' STEM learning. *Comput. Hum. Behav.* 62, 433–441. doi: 10.1016/j.chb.2016.03.080

Blachman, B. A. (1984). Relationship of rapid naming ability and language analysis skills to kindergarten and first-grade reading achievement. *J. Educ. Psychol.* 76, 610–622. doi: 10.1037/0022-0663.76.4.610

Bloom, K., Russell, A., and Wassenberg, K. (1987). Turn taking affects the quality of infant vocalizations. *J. Child. Lang.* 14, 211–227. doi: 10.1017/s0305000900012897

Bruner, J. (1983). Play, thought, and language. *Peabody J. Educ.* 60, 60–69.

Callaghan, M. N., and Reich, S. M. (2018). Are educational preschool apps designed to teach? An analysis of the app market. *Learn. Media Technol.* 43, 280–293. doi: 10.1080/17439884.2018.1498355

Choi, K., and Kirkorian, H. L. (2016). Touch or watch to learn? Toddlers' object retrieval using contingent and noncontingent video. *Psychol. Sci.* 27, 726–736. doi: 10.1177/0956797616636110

Clarke, A. T., and Kurtz-Costes, B. (1997). Television viewing, educational quality of the home environment, and school readiness. *J. Educ. Res.* 90, 279–285. doi: 10.1080/00220671.1997.10544584

Connell, S. L., Lauricella, A. R., and Wartella, E. (2015). Parental co-use of media technology with their young children in the USA. *J. Child. Media* 9, 5–21. doi: 10.1080/17482798.2015.997440

Dore, R. A., and Zimmermann, L. (2020). "Coviewing, scaffolding, and children's media comprehension" in *The International encyclopedia of media psychology*. eds. J. Van den Bulck, D. Ewoldsen, M. Mares and E. Scharrer (Wiley).

Farkas, G., and Beron, K. (2004). The detailed age trajectory of oral vocabulary knowledge: differences by class and race. *Soc. Sci. Res.* 33, 464–497. doi: 10.1016/j.ssresearch.2003.08.001

Gross, D., Julion, W., and Fogg, L. (2001). What motivates participation and dropout among low- income urban families of color in a prevention intervention? *Fam. Relat.* 50, 246–254. doi: 10.1111/j.1741-3729.2001.00246.x

Guernsey, L., and Levine, M. H. (2015). *Tap, click, read: Growing readers in a world of screens*. San Francisco, CA: John Wiley and Sons.

Hirsh-Pasek, K., Zosh, J. M., Golinkoff, R. M., Gray, J. H., Robb, M. B., and Kaufman, J. (2015). Putting education in "educational" apps: lessons from the science of learning. *Psychol. Sci. Public Interest* 16, 3–34. doi: 10.1177/1529100615569721

Huber, B., Tarasuik, J., Antoniou, M. N., Garrett, C., Bowe, S. J., Kaufman, J., et al. (2016). Young children's transfer of learning from a touchscreen device. *Comput. Hum. Behav.* 56, 56–64. doi: 10.1016/j.chb.2015.11.010

Huber, B., Yeates, M., Meyer, D., Fleckhammer, L., and Kaufman, J. (2018). The effects of screen media content on young children's executive functioning. *J. Exp. Child Psychol.* 170, 72–85. doi: 10.1016/j.jecp.2018.01.006

Hutton, J. S., Dudley, J., Horowitz-Kraus, T., DeWitt, T., and Holland, S. K. (2020). Associations between screen-based media use and brain white matter integrity in preschool-aged children. *JAMA Pediatr.* 174:e193869. doi: 10.1001/jamapediatrics.2019.3869

Khan, K. S., Purtell, K. M., Logan, J., Ansari, A., and Justice, L. M. (2017). Association between television and parent-child reading in the early home environment. *J. Dev. Behav. Pediatr.* 38, 521–527. doi: 10.1097/DBP.0000000000000465

Kirkorian, H. L., and Choi, K. (2016). Associations between toddlers' naturalistic media experience and observed learning from screens. *Infancy* 22, 271–277. doi: 10.1111/infa.12171

Kirkorian, H. L., Choi, K., and Pempek, T. A. (2016). Toddlers' word learning from contingent and noncontingent video on touch screens. *Child Dev.* 87, 405–413. doi: 10.1111/cdev.12508

Lavigne, H. J., Hanson, K. G., and Anderson, D. R. (2015). The influence of television coviewing on parent language directed at toddlers. *J. Appl. Dev. Psychol.* 36, 1–10. doi: 10.1016/j.appdev.2014.11.004

Lillard, A. S., Li, H., and Boguszewski, K. (2015). Television and children's executive function. *Adv. Child Dev. Behav.* 48, 219–248. doi: 10.1016/bs.acdb.2014.11.006

Linebarger, D. L., and Vaala, S. E. (2010). Screen media and language development in infants and toddlers: an ecological perspective. *Dev. Rev.* 30, 176–202. doi: 10.1016/j.dr.2010.03.006

Madigan, S., McArthur, B. A., Anhorn, C., Eirich, R., and Chistakis, D. (2020). Associations between screen use and child language skills: a systematic review and meta-analysis. *JAMA Pediatr.* 174, 1–11. doi: 10.1001/jamapediatrics.2020.0327

Mares, M. -L., and Pan, Z. (2013). Effects of Sesame Street: a meta-analysis of children's learning in 15 countries. *J. Appl. Dev. Psychol.* 34, 140–151. doi: 10.1016/j.appdev.2013.01.001

Mendelsohn, A., Brockmeyer, C. A., Dreyera, B. P., Fiermana, A., Berkule-Silbermana, S., and Tomopoulosa, S. (2010). Do verbal interactions with infants during electronic media exposure mitigate adverse impacts on their language development as toddlers? *Infant Child Dev.* 19, 577–593. doi: 10.1002/icd.711

Montag, J. L., Jones, M. N., and Smith, L. B. (2015). The words children hear: picture books and the statistics for language learning. *Psychol. Sci.* 26, 1489–1496. doi: 10.1177/0956797615594361

Myers, H., Alvy, K., Arrington, A., Richardson, M., Marigna, M., Huff, R., et al. (1992). The impact of a parent training program on inner-city African-American families. *J. Community Psychol.* 20, 132–147. doi: 10.1002/1520-6629(199204)20:2<132::AID-JCOP2290200204>3.0.CO;2-Z

Nathanson, A. I., Sharp, M. L., Aladé, F., Rasmussen, E. E., and Christy, K. (2013). The relation between television exposure and theory of mind among preschoolers. *J. Commun.* 63, 1088–1108. doi: 10.1037/a0035714

Nathanson, A. I., Wilson, B. J., McGee, J., and Sebastian, M. (2002). Counteracting the effects of female stereotypes on television via active mediation. *J. Commun.* 52, 922–937. doi: 10.1111/j.1460-2466.2002.tb02581.x

National Early Literacy Panel (2008). *Developing early literacy: Report of the National Early Literacy Panel*. Washington, DC: National Institute for Literacy. Available at: https://lincs.ed.gov/publications/pdf/NELPReport09.pdf (Accessed August 27, 2020).

Orben, A., and Przybylski, A. K. (2019). The association between adolescent well-being and digital technology use. *Nat. Hum. Behav.* 3, 173–182. doi: 10.1038/s41562-018-0506-1

Pagani, L. S., Fitzpatrick, C., and Barnett, T. A. (2013). Early childhood television viewing and kindergarten entry readiness. *Pediatr. Res.* 74, 350–355. doi: 10.1038/pr.2013.105

Patterson, J. L. (2002). Relationships of expressive vocabulary to frequency of reading and television experience among bilingual toddlers. *Appl. Psycholinguist.* 23, 493–508. doi: 10.1017/S0142716402004010

Rasmussen, E. E., Shafer, A., Colwell, M. J., White, S., Punyanunt-Carter, N., Densley, R. L., et al. (2016). Relation between active mediation, exposure to Daniel Tiger's Neighborhood, and US preschoolers' social and emotional development. *J. Child. Media* 10, 443–461. doi: 10.1080/17482798.2016.1203806

Reiser, R. A., Tessmer, M. A., and Phelps, P. C. (1984). Adult-child interaction in children's learning from "Sesame Street." *Educational Communication and Technology* 32, 217–223. doi: 10.1007/BF02768893

Rideout, V. (2017). *The common sense census: Media use by kids age zero to eight*. San Francisco, CA: Common Sense Media.

Russo-Johnson, C., Troseth, G., Duncan, C., and Mesghina, A. (2017). All tapped out: Touchscreen interactivity and young children's word learning. *Front. Psychol.* 8:578. doi: 10.3389/fpsyg.2017.00578

Schmidt, M. E., Rich, M., Rifas-Shiman, S. L., Oken, E., and Taveras, E. M. (2009). Television viewing in infancy and child cognition at 3 years of age in a US cohort. *Pediatrics* 123, e370–e375. doi: 10.1542/peds.2008-3221

Schroeder, E. L., and Kirkorian, H. L. (2016). When seeing is better than doing: preschoolers' transfer of STEM skills using touchscreen games. *Front. Psychol.* 7:1377. doi: 10.3389/fpsyg.2016.01377

Sheehan, K. J., and Uttal, D. H. (2016). Children's learning from touch screens: a dual representation perspective. *Front. Psychol.* 7:1220. doi: 10.3389/fpsyg.2016.01220

Snow, C. E. (1991). The theoretical basis for relationships between language and literacy in development. *J. Res. Child. Educ.* 6, 5–10. doi: 10.1080/02568549109594817

Snow, C. E., Tabors, P. O., Nicholson, P. A., and Kurland, B. F. (1995). SHELL: oral language and early literacy skills in kindergarten and first-grade children. *J. Res. Child. Educ.* 10, 37–48. doi: 10.1080/02568549509594686

Stevens, R., and Penuel, W. R. (2010). Studying and fostering learning through joint media engagement. Paper presented at the Principal Investigators Meeting of the National Science Foundation's Science of Learning Centers, Arlington, VA.

Strouse, G. A., O'Doherty, K., and Troseth, G. L. (2013). Effective coviewing: preschoolers' learning from video after a dialogic questioning intervention. *Dev. Psychol.* 49, 2368–2382. doi: 10.1037/a0032463

Takeuchi, B. L., and Stevens, R. (2011). The new coviewing: designing for learning through joint media engagement. Available at: http://www.joanganzcooneycenter.org/wp-content/uploads/2011/12/jgc_coviewing_desktop.pdf (Accessed August 27, 2020).

Taylor, G., Monaghan, P., and Westermann, G. (2017). Investigating the association between children' s screen media exposure and vocabulary size in the UK. *J. Child. Media* 12, 51–65. doi: 10.1080/17482798.2017.1365737

Tomasello, M., and Farrar, M. J. (1986). Joint attention and early language. *Child Dev.* 57, 1454–1463. doi: 10.2307/1130423

Torppa, M., Lyytinen, P., Erskine, J., Eklund, K., and Lyytinen, H. (2010). Language development, literacy skills, and predictive connections to reading in Finnish children with and without familial risk for dyslexia. *J. Learn. Disabil.* 43, 308–321. doi: 10.1177/0022219410369096

Valkenburg, P. M., Krcmar, M., Peeters, A. L., and Marseille, N. M. (1999). Developing a scale to assess three styles of television mediation: "Instructive mediation," "restrictive mediation," and "social coviewing." *J. Broadcast. Electron. Media* 43, 52–66. doi: 10.1080/08838159909364474

Vandewater, E. A., Bickham, D. S., and Lee, J. H. (2006). Time well spent? Relating television use to children's free-time activities. *Pediatrics* 117, e181–e191. doi: 10.1542/peds.2005-0812

Vygotsky, L. S. (1962). *Thought and language*. Cambridge, Massachusetts: MIT Press.

Woodcock, R. W., McGrew, K. S., and Mather, N. (2007). Woodcock-Johnson tests of achievement, (WJ-III ACH). Rolling Meadows, IL: Riverside.

Zimmerman, F. J., Gilkerson, J., Richards, J. A., Christakis, D. A., Xu, D., Gray, S., et al. (2009). Teaching by listening: the importance of adult-child conversations to language development. *Pediatrics* 124, 342–349. doi: 10.1542/peds.2008-2267

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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ORIGINAL RESEARCH
published: 25 January 2021
doi: 10.3389/fpsyg.2020.576940

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# 2-Year-Olds Learning From 2D Media With and Without Parental Support: Comparing Two Forms of Joint Media Engagement With Passive Viewing and Learning From 3D

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OPEN ACCESS

**Edited by:**
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**Specialty section:**
*This article was submitted to
Developmental Psychology,
a section of the journal
Frontiers in Psychology*

**Received:** *27 June 2020*
**Accepted:** *29 December 2020*
**Published:** *25 January 2021*

**Citation:**
*Heimann M, Hedendahl L, Ottmer E, Kolling T, Koch F-S, Birberg Thornberg U and Sundqvist A (2021) 2-Year-Olds Learning From 2D Media With and Without Parental Support: Comparing Two Forms of Joint Media Engagement With Passive Viewing and Learning From 3D. Front. Psychol. 11:576940. doi: 10.3389/fpsyg.2020.576940*

The study investigates to what degree two different joint media engagement (JME) strategies affect children's learning from two-dimensional (2D)-media. More specifically, we expected an instructed JME strategy to be more effective than a spontaneous, non-instructed, JME strategy. Thirty-five 2-year old children saw a short video on a tablet demonstrating memory tasks together with a parent. The parents were randomized into two groups: One group ($N = 17$) was instructed to help their child by describing the actions they saw on the video while the other group ($N = 18$) received no specific instruction besides "do as you usually do." The parents in the instructed group used significantly more words and verbs when supporting their child but both groups of children did equally well on the memory test. In a second step, we compared the performance of the two JME groups with an opportunistic comparison group ($N = 95$) tested with half of the memory tasks live and half of the tasks on 2D without any JME support. Results showed that the JME intervention groups received significantly higher recall scores than the no JME 2D comparison group. In contrast, the three-dimensional (3D) comparison group outperformed both JME groups. In sum, our findings suggest that JME as implemented here is more effective in promoting learning than a no JME 2D demonstration but less so than the standard 3D presentation of the tasks.

**Keywords: digital media, joint media engagement, learning, memory, deferred imitation**

## INTRODUCTION

Over the last decades, digital media has become seamlessly integrated in the life of families, a societal change that impacts children's early experiences. The studies conducted so far tell us that young children, especially if 36 months or younger, seem to have a harder time learning from media than from real life events (Barr, 2010; Barr and Linebarger Nichols, 2017;

Strouse and Samson, 2021) but also that excessive screen time at an early age might influence a child's development negatively (Madigan et al., 2019). However, research also suggests that how parents interact with their children is important for language and cognitive development (Barr, 2019). Although parents own use of technology might interfere with children's learning by limiting parent-child interactions (McDaniel and Radesky, 2018; Sundqvist et al., 2020), other studies suggest that parents can facilitate children's learning if they take an active and supportive part in their child's use of digital media (Zack and Barr, 2016; Barr, 2019; Padilla-Walker et al., 2020). The idea that parental support might ameliorate learning from digital media is the basis of this study in which parents were instructed to employ one of two different interactive strategies in order to support their 2-year-old child's learning from information provided on a tablet.

A specific form of how parents may support learning from digital media is when parents view media content together with their child in order to support the child's learning and/or understanding of the content at hand (e.g., Courage, 2017; Padilla-Walker et al., 2020). Although previously labeled co-viewing (Ewin et al., 2020), a more precise, up-to-date, and informative label is joint media engagement (JME) which, as Barr (2019, p. 343) states, "occurs when people interact around media together to scaffold learning." Exactly when and how JME is effective is, however, not clear. According to Ewin et al.'s recent review, it is relatively common for parents to attempt some kind of JME strategy such as prompting, cognitive scaffolding, or various dialogical strategies. They further suggest that many parents seem to transfer their knowledge on how to deal with traditional TV-viewing to the new digital media environment. The successfulness of these strategies depends, however, on factors such as parental skills, educational level, socio-economic status (SES), and ethnicity. Another factor that Ewin et al. (2020) brings up is that sometimes the media in itself hinder the parent's attempt to create a JME situation when watching together with a young child. This is because the content sometimes creates such a heightened engagement that it becomes difficult for a parent to "break in" in order to create a dialog. Although comprehensive, the review also makes it obvious that much research is still lacking, the papers covered in the review are unevenly spread both culturally and geographically. About half of the studies comes from North America, about a fifth from Europe and only one single study represents Scandinavia (Norway).

The current study investigates if a specific JME instruction to parents leads to better learning from two-dimensional (2D)-media than when parents are allowed to choose spontaneously how to interact with their child as measured by how much the children remember of a video demonstration of a deferred imitation test presented on a tablet. Deferred imitation (DI) requires forming, storing, and later retrieving information of an observed behavior and is often described as a pre-verbal measure of episodic declarative memory (e.g., Meltzoff, 1988; Heimann and Meltzoff, 1996; Jones and Herbert, 2006; Kolling et al., 2010; Lukowski and Bauer, 2014). Today, DI is an established method to study memory and learning in children with no or very limited verbal ability (Meltzoff, 1988; Barr et al., 1996).

Deferred imitation has been successfully used to examine how children acquire and remember knowledge from screens (e.g., Barr and Wyss, 2008; Myers et al., 2017). Research has shown that toddlers often have a slower learning curve when learning from digital media than from real events or actions. In addition, they also show difficulty to transfer what they have learned from 2D to three-dimensional (3D) or the other way around, a phenomenon referred to as a *transfer* or *video deficit* (Kirkorian, 2018; Barr, 2019; Strouse and Samson, 2021) usually assumed to be most evident among children younger than 3 years (Barr and Brito, 2014; Moser et al., 2015; Courage, 2017; Barr, 2019). In a review covering the video deficit among children 0–6 years old, Strouse and Samson (2021) conclude that the effect seems to decrease as children grow older, but it is uncertain exactly when and if it will vanish completely. About two-thirds of the studies in the review represent North America, only 14% is European and only one comes out of Scandinavia (Sweden). For children below 36 months, Strouse and Samson report that the observed averaged effect size ($g$) was about three times larger than for children older than 3. They also report that the effect varies with the domain studied. As example, object retrieval tasks showed the strongest deficit ($g = -1.00$) while studies focusing on imitation displayed an effect that was about half as strong ($g = -0.58$). The deficit can probably be explained, at least partly, by factors restraining young children's ability to interpret and process information, foremost limitations in their perceptual abilities (Barr, 2019), as well as a lack of memory flexibility (Barr and Brito, 2014). In addition, young children's lack of symbolic understanding is most likely also part of the explanation for the transfer deficit. Problem with symbolic understanding also influence young children's ability to transfer knowledge from books to the real 3D world (e.g., Simcock et al., 2011; Brito et al., 2012). Pictures are symbolic artifacts and it takes considerable time for a child to understand that an object shown on a video is identical with a real-world object. This has been shown by DeLoache (2004) who also have demonstrated that a shift in symbolic understanding occurs sometime between a child's second and third birthday. With these limitations in regard, transferring information between poorly matching contexts such as from screen to reality constitutes a challenge for young children.

The transfer deficit effect does not indicate that it is impossible for young children to generalize learning from screens (e.g., Barr, 2010; Moser et al., 2015; Kirkorian, 2018); only that it is a challenge. Further, research also suggest that the effect can be decreased by various JME strategies such as scaffolding, using verbal or visual cues, social interaction, or repetitions (e.g., Barr, 2010, 2019; Lauricella et al., 2016). Visual cues can enhance the degree of matching between contexts, thereby reducing the importance of perceptual limitations (Barr and Brito, 2014), and verbal cues can support learning either by being embedded into the media content itself, or received from a present person (e.g., Strouse et al., 2018).

As perceptual skills and memory flexibility develop with age, lack of symbolic understanding is thought to become a greater obstacle for successful transfer in older toddlers (Barr, 2013; Courage, 2017). Generalizing learning from a tablet, for example, to real life demands that the child understands that the tablet is not just an object in itself, but also entails symbolic representation of other objects. A task that is especially difficult for young children (Barr, 2013). Related to this, Strouse and Ganea (2017) found that the transfer deficit effect was less evident in children aged 17–30 months who had more variable experiences of media, as opposed to peers whose only experiences of screens came from watching videos. The authors argue that children who use media for multiple purposes have an easier time understanding the relation between on-screen-events and real life (Strouse and Ganea, 2017), which is in accordance with Barr's (2013) reasoning on the importance of symbolic understanding.

In addition to the factors discussed above, lack of social interaction has been suggested as a possible explanation for the transfer deficit effect (Troseth et al., 2006). With increasing age, children start relying more on social cues for learning new information (Golinkoff and Hirsh-Pasek, 2006). Unlike real life situations, media content often lacks socially contingent cues, such as eye contact and gestural communication, which help children understand that the information presented is reliable and relevant.

Joint media engagement is a form of socially interactive scaffolding that has been suggested to be effective as a way to counteract the transfer deficit (Courage, 2017; Barr, 2019). It is argued that if adults (read parents) participate when young children use media, they can help them pay attention and make sense of the content and thereby support learning (Barr et al., 2008; Strouse and Troseth, 2014; American Academy of Pediatrics, 2016; Courage, 2017; Samudra et al., 2020). As an example, Strouse et al. (2018) found that 30-month-old children learned more new words when watching a video together with a parent modeling, as opposed to watching the video alone. In contrast to this, Barr and Wyss (2008) found that co-viewing with a physically present person may not be necessary. In their study, 24-month-olds imitated equally well whether they got scripted verbal cues from a parent that was present or from a prerecorded voice. However, since the parents in Barr and Wyss' study had to follow a script, they examined the mere presence of a parent rather than the naturally occurring parent-child-interaction, which could be of particular importance for learning.

Exactly how and when JME is beneficial is not entirely clarified but taken together, previous research (e.g., Barr, 2019; Ewin et al., 2020) does suggest that socially contingent interactions and verbal cues help young children learn from digital media. We therefore suspect that experiencing JME with a socially responsive adult would compensate for the lack of social contingency in media content, especially for the 2-year old ager group being in focus for this study. In order to investigate this, we initially formulated one key question: (1) To what degree does an instructed verbal strategy of parental JME support children's learning from video compared to a freer non-instructed JME strategy? In order to answer this question an intervention was created. As a second step, we also wanted to gain information on two additional questions: (2) Does JME result in better learning compared to co-viewing together with a parent who is passive and not using JME at all, and (3) does a live presentation support learning better than all or some of the three groups learning from 2D (instructed JME, spontaneous JME, or no JME)? These two questions became possible to address since we were able to use children participating in a separate study on media and learning as an opportunistic comparison group.

More specifically, in relation to our first question, we hypothesized that children viewing a video of a memory test together with a parent who had been instructed to support attention for learning would remember more actions than children having viewed the video with a parent who had received no specific instructions on how to interact with the child. Further, we were able to draw on an opportunistic comparison group that performed half the tasks after 2D presentations and the other half after a live (3D) presentation. Children in the comparison group watched a 2D presentation of some of the memory test items passively, that is without any verbal support from the parent. Regarding research question two, we expected both JME groups to perform better than children in our opportunistic comparison group when compared with the tasks that were presented in 2D. We were more uncertain whether the two JME groups would perform worse, on par or better than children in the comparison group when compared on the tasks that were presented live (3D), thus this part was exploratory, and no explicit hypothesis was formed.

# MATERIALS AND METHODS

## Participants

### JME Intervention Groups

Thirty-five parents (26 mothers, nine fathers) and their 2-year-old child ($M$ = 24.2, range 23.1–25.6 months, $SD$ = 0.71) participated. The dyads were randomized to either a group that received specific instructions ($N$ = 17; eight females) or a group ($N$ = 18; eight females) receiving no specific instructions. There were no differences in age or developmental level as measured with Bayley-S ($M$ = 108; range 94–123; Bayley, 2006), due to gender or intervention assignment. The parents reported that the children were typically developing with no known medical issues. The families were of middle or high SES, 71% of the mothers and 66% had a university degree. All parents were fluent in Swedish.

### Parent's Media Proficiency in the JME Groups

A majority of the participants (58.7% in the instructed group and 61.1% in spontaneous JME group) used a tablet daily or several times a week according to the parents. Their experience with smartphones was at the same level (70.6 and 64.7%, respectively). Parents in both groups reported that they regularly viewed screen content together with their child and a majority that they most of the times discussed the media content with their child (70.2% and 72.2 respectively). Eight parents (four in each JME group) stated that they had never used a tablet together with their child.

### Comparison Group

Data from 95 two-year-old children (44 female) participating in a separate project were used for comparison purposes. Their mean age was 25.5 months (range 24.8–26.4; *SD* = 0.33). There was no difference in age between male and female participants. All children were reported by the parents to display typical development and a majority of the parents held a university degree (83% of the mothers and 66% of the fathers). Swedish was reported as the main language used at home in all families.

### Parent's Media Proficiency in the Comparison Group

Digital media was available in all households and used by both parents and children. All families had a smartphone that was also used by all children. Almost all (95%) households had a TV (used by 87% of the children) or a computer (used by 81% of the children). Tablets were used by 81% of both parents and children.

### Recruitment and Attrition

All participating children were recruited through the Swedish Population Register (SPAR) and an invitation letter was sent to all families with children in the right age range living in the Linköping area. An invitation letter was sent to all families with children in the right age range living in the Linköping area. For the two JME groups participating in the intervention this meant approaching families with a child turning 2-year between January and April 2018 (*N* = 408) while for the study used as an opportunistic comparison group all families with a child turning 9 months between May and September 2017 received a similar invitation (*N* = 1324). Those who expressed an interest (the response rate is usually between 10 and 15%) were contacted by phone and informed about the studies.

For the JME intervention part, the instructed and the non-instructed JME groups, 47 families replied of which 41 expressed a willingness to participate after receiving more detailed information about the study. Of these, three were later excluded due to lack of proficiency in Swedish and three families were lost due to scheduling difficulties. Thus, the final sample to be included consisted of 35 children.

For the comparison group 102 families accepted to be part of a 2-year follow up of which 93 children provided live presentation (3D) data and 86 children 2D no JME data (the parent was told to be silent) on the specific memory test used in this study. The attrition being mainly due to procedural errors, fatigue, scheduling difficulties, or illness.

## Instruments

### The Frankfurt Imitation Test-24 (FIT-24)

It consists of eight object-based tasks adapted for 2-year-old children in order to measure early declarative like memory through the method of deferred imitation (Kolling et al., 2010; Kolling and Knopf, 2015). That is, the test procedure includes three phases: a demonstration phase, a delay of about 30 min (range 20–40 min across all groups in this study) and a recall phase. During the demonstration phase, the children are only allowed to watch as the experimenter demonstrates the actions; it is not until the recall phase that the participants were allowed to manipulate the objects and to produce the target actions.

All demonstrated actions were multi-step sequences, 6 three-step actions, 1 five-step action, and 1 six-step action. An example of a three step-action is the first item, the Gondola. The actions demonstrated were (1) to place a manikin in a plastic gondola, (2) to lean a spoon against the manikin, and (3) to move the gondola back and forth. The second item is an example of tasks requiring more than three steps. The target actions presented for this task, were (1) to pull a blue sheet from of a container, (2) to open the container, (3) to take out a different manikin, (4) to bend the manikin's legs, and (5) to place the manikin in the boat. See **Table 1** for descriptions of all items. The original FIT-24 was developed for live demonstrations and each task should be demonstrated twice according to the manual (Kolling and Knopf, unpublished) and the score (0–29) depends on the number of target actions produced by the child.

### Questionnaire

A brief questionnaire-based interview focusing on the child's developmental history and media proficiency was conducted with the parents in the two JME groups before the experiment. The media questions focused on smartphone use, tablet use, JME, and how often the parents usually talk with their child about media content. The parents in the comparison group answered similar questions through a web based survey administered through Qualtrics.

## Procedure

### JME Intervention Groups

All children in the two JME intervention groups were observed once at the Baby-and Child Lab at Linköping university, Sweden, and each session took 1 h (*M* = 59.74 min; *SD* = 4.86). Two graduate students tested all children (17 and 18 children each, randomized). Before the session began the parents were informed of the procedure and signed an informed consent form. For a complete overview of the procedure, see **Figure 1**.

The parents were informed that they would view a video on a tablet that showed a person demonstrating actions with different objects. The instruction was manualized and parents in both groups were initially given the following information: "You will now watch a short video made up of several short video clips together with your child. In the video you will see a person show several different toys and what you can do with them." After this each group received specific instructions where after the experimenter asked if the parents had any questions: "If you do, it's best if you ask now, so you can focus entirely on the film later." The specific instructions varied depending on their group assignment: Parents belonging to the *instructed joint media engagement group* were told to verbalize what was presented in the video clips. That is, the parent was expected to describe to the child the actions presented in order to support attention and thus strengthen the child's memory of the target actions. The specific instructions read to the parents in the instructed group were: "I want you to

**TABLE 1** | Description of the tasks in the Frankfurt Imitation Test (FIT) and their inclusiveness in the different groups [adapted from Kolling and Knopf, (2015, pp. 366–368)].

| Task | Description | Steps | JME[1] | Comparison[2] | |
|---|---|---|---|---|---|
| | | | 2D | 2D | 3D |
| 1.Gondola | Place a manikin in plastic gondola, lean a spoon against the manikin, and move the gondola back and forth | 3 | Yes | No | Yes |
| 2.Boat and box | Pull a blue sheet from of a container, open container, take out a different manikin, bend its legs, and place the manikin in the boat | 5 | Yes | No | Yes |
| 3.Frog | Lean a board toward stand, frog jumps onto stand, slides down | 3 | Yes | No | Yes |
| 4.Ball with eyes | Find slit in a ball, insert eyes. and let ball jump up and down | 3 | Yes | Yes | No |
| 5. Turtle | Click a cone on ball, place both on turtle, and lift up the turtle | 3 | Yes | No | Yes |
| 6. Bunny | Attach yellow pillow, green square pillow, and a triangular pink pillow on a bunny | 3 | Yes | Yes | No |
| 7. Box | Place ring on a hook, spin the ring, and open drawer (bird appears) | 3 | Yes | Yes | No |
| 8. Magnetic plate | Turn the plate, put red button on top, a yellow button below the red, a black button below the yellow, stick croissant on plate, roll plate | 6 | Yes | Yes | No |

[1]*Two active joint media engagement intervention groups (N = 17 and 18, a between subjects design; see text for details).*
[2]*A within-subjects design: 2D = presentation by video (N = 86); 3D = Live presentation of tasks according to the manual (N = 93).*

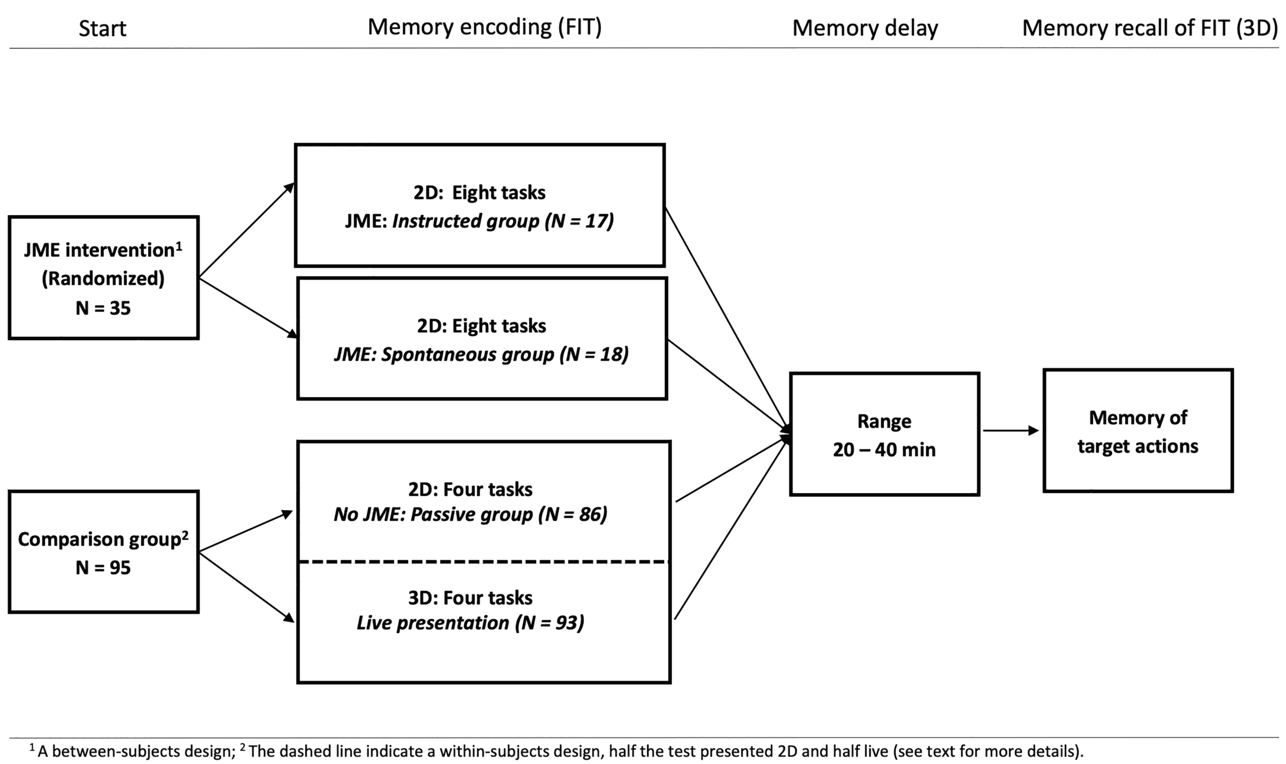


**FIGURE 1** | The figure displays the overall design of the procedure and the groups included: The two JME intervention groups watching the complete Frankfurt Imitation Test (FIT) on a tablet and the children in a separate study used for comparison purposes being presented with half the same test (four items) either passively on a computer screen (2D) or live (3D).

put into words what happens in the various clips so that your child remembers as much as possible. You can tell what's going on, step by step. For example, like this, 'look, now she takes the blanket and puts it over the doll'. It might feel a bit difficult, but just try to talk to your child about what the person in the video is doing." In contrast, the parents in the *spontaneous joint media engagement group* were only told to watch the video together with their child as they would have done if they had been at home. The specific text read to the parents in this group was: "I want the two of you watch the film together, as you would if you had watched it together at home. It may feel a little strange to do in this environment, but just try to do as you would have done at home."

During the video demonstration of the FIT-24, the child sat on the floor together with the parent. Most children sat on their parent's lap.

### Presentation of Target Actions for the JME Intervention Groups

For the purpose of this study, the demonstration phase of all eight FIT-24 tasks were presented in 2D-format on a tablet: Each parent-child dyad watched an 8 min 46 s long video showing a woman demonstrating the eight tasks. In order to ameliorate for a possible transfer deficit, the video contained three demonstrations of each task. This decision was based on research suggesting that an extra repetition sometimes do counter the learning problems associated with the transfer deficit (e.g., Barr, 2010). In addition, we also based our decision on a previous study from our own lab that investigated how infants attend to 2D presentations which revealed a dynamic change in "the distribution of infants' attention to a presenter's face and the action she performs" (Koch et al., 2018, p. 196). Great care was also taken to make sure that video-recordings would be social in a way that the presenter greeted the child and looked straight into the camera before presenting the tasks (i.e., at the child). The presenter's verbal utterances exhibited both interest and excitement in the actions she was about to present. As the presenter demonstrated the action her gaze shifted toward the objects. While performing the action she was quiet, and immediately after she looked back into the camera and expressed a happy and joyful face. Her verbal comments were of a general nature and the presenter did not address the specific actions. Any verbal cues specific to the content of the videos were produced solely by the parents. In order to alleviate any problems in perceptual matching, the objects the presenter used in the video were identical to the ones the child would handle during the recall phase. The interval ($M$ = 27.2 min; $SD$ = 4.22) between watching the video and the recall phase was used to give the child a brief paus and to administer three subscales (cognition, expressive and receptive communication) from Bayley-S (Bayley, 2006).

### Comparison Group

The children in the comparison group participated in a larger longitudinal study on early memory, media and language conducted at the same lab (see **Figure 1**). Their visit was divided into two sections (each 45–60 min long) with a 20–30 min pause in-between. The 2D part was conducted as part of the first section since piloting had shown that this part was more taxing for the children. The 3D presentations of the tasks were administered after the pause when the children had regained both motivation and energy. Beside the FIT-24 test in focus here several additional measures not relevant for the present study were presented during the visit (e.g., measures of language, implicit memory, communication and social skills).

### Presentation of Target Actions for the Comparison Group

The children used for comparison purposes participated in a comprehensive study on learning and media where both 3D and 2D tasks were used and FIT was included as memory test. Since it was both methodological and theoretically impossible to administer all eight tasks included in FIT both as a real life administration (3D) and as 2D on a computer screen the test was split so that four items were used in each condition. The final split, based on extensive pretesting, created two sets of four items with similar levels of difficulty. Each set included three 3-step tasks and one 5-or 6-step task. During the interval ($M$ = 34.5 min; $SD$ = 8.7) between presentation and recall the children participated in other tests such as an implicit memory test for the no JME 2D presentation and a socio-communicative test for the live presentation. A brief pause was also included. Based on piloting and in order to limit attrition due to fatigue, the no JME 2D was presented early during the visit and the 3D live presentation after the pause.

For the passive no JME 2D viewing comparison, the tasks included three three-step tasks (Ball with eye, Bunny and Box) and one 6-step task (Magnetic plate) that were all presented as video clips on a computer screen using the exact same recordings as shown on the tablet for the JME intervention groups. Similar to the 2D procedure used for the instructed and spontaneous JME groups three demonstrations of each task were used in order to minimize the transfer deficit effect. The children sat in their parents' lap in front of a computer screen, approximately 60 cm away from the child's face, silently watching the videos. The parents were instructed to be silent and not to interact with their child or to comment on what was shown although they could verbally support their child's attention by for instance saying "look at that." However, they were also told that brief gazes away were unproblematic and did not matter. A curtain that separated the experimenter from the parent and infant was closed before starting the calibration procedure that always preceded the presentation of the 2D tasks.

For the 3D presentation, three 3-step tasks (Gondola, Frog and Turtle) and one 5-step task (Boat and box) were administered live in a separate room at the lab following the procedure described in the original publication (see Kolling et al., 2010). This entailed that each task was presented only twice.

## Statistical Analysis

The analysis was conducted in two steps. First the two JME intervention groups are analyzed in relation to how successful the intervention was (e.g., the parents verbal behavior), if the memory recall score differed between the groups and if other factors affected the findings (e.g., the child's attention to the tasks). In this first step, the score from FIT is based on all eight items. The second step entailed comparing the FIT recall score observed for the JME intervention groups with the result observed for the children used for comparison purposes. In this analysis only half of the FIT tasks are used in each comparison. The statistical methods for in-between group comparisons are Student's $t$-test when equal sample size and variances are observed and Welch's $t$-test when sample sizes and/or the variances differ (see Delacre et al., 2017). The statistics were computed in SPSS version 26 or Jamovi version 1.2.27.0. An $\alpha$-level of 0.05 is used throughout. Effect sizes are reported as Cohen's $d$ when groups are equally large and as Hedge's g when comparing groups that differ in size.

### Reliability

The FIT-24 deferred imitation test was coded according to the German manual (Kolling and Knopf, unpublished) and reliability was checked by two of the authors (L. H, and E. O.) who independently recoded a random selection of 25% of the videos resulting in an average reliability score of 0.83 (Pearson's $r$). The lowest reliability coefficient was noted for item 1 ($r$ = 0.79) and the highest for item 2 ($r$ = 1.00). For all other items the observed coefficient varied between 0.80 and 0.96. According to Rosso (2003) an r of 0.70 should be considered the lowest acceptable result when using Pearson r. As a rule of thumb, an r >0.80 is viewed as good while a coefficient >0.90 indicates excellent reliability.

## Ethical Statement

The study was approved by the Regional Ethics Review Board in Linköping (no. 2016/490-31).

# RESULTS

## A. The Intervention: Comparing Instructed and Non-Instructed JME

There were no differences in session length between the conditions, male and female participants or between mother-infant and father-infant dyads on any of the measures ($ps$ > 0.501). Thus, neither session length, child or parent gender are analyzed further. In addition, gaze away that is how many times a child looked away from the screen while a task was presented was coded as a proxy for attention. As shown in **Table 2**, the observed frequencies did not differ between the two groups in how many times they looked away from screen, $t(25.8) = 0.47$, $p = 0.64$, $d = -0.08$, equal variances not assumed.

### Verbal Scaffolding

The intervention strongly influenced how the parents interacted verbally with their children (see **Table 2**). The groups differed significantly with respect to the total number of words the parents used during the video demonstration of the tasks, $t(32) = 5.73$, $p < 0.001$, $d = 1.96$, and also with respect to the number of verbs used, $t(23.46) = 6.67$, $p < 0.001$, $d = 2.29$, equal variances not assumed. This difference between the groups reflect the fact that the parents in the instructed JME group used on average approximately three times the number of words [$M$ = 561.65; 95% CI (446.20–667.10)] than the parents in the spontaneous group [$M$ = 177.41; 95% CI (94.40–260.43)] while watching the video together with their child. A similar strong difference between the groups was also noted when comparing the parents' use of verbs. In spite of the observed difference in how much the parent's spoke, no parent was completely silent but three parents used less than 50 words.

**TABLE 2** | Parent verbal interaction, session length, and memory result for the two joint media engagement (JME) intervention groups.

| | Instructed JME *N* = 17 | | Spontaneous JME *N* = 18 | | | |
|---|---|---|---|---|---|---|
| | ***M*** | ***SD*** | ***M*** | ***SD*** | ***P <*** | ***d =*** |
| Words used (freq) | 561.65 | 224.55 | 177.41 | 161.46 | 0.001 | 1.93 |
| Verbs used (freq) | 51.82 | 22.82 | 10.59 | 11.35 | 0.001 | 2.26 |
| Gaze away (freq) | 9.76 | 7.09 | 8.82 | 4.14 | ns | −0.16 |
| Memory delay (min) | 26.24 | 3.91 | 28.11 | 4.40 | ns | −0.44 |
| Memory recall score | 15.94 | 5.55 | 16.33 | 3.77 | ns | −0.08 |

### JME and Learning From 2D

There was no difference between the two JME groups in learning as evident from the obtained memory recall score, $t(33) = -0.246$; $p = 0.81$ (**Table 2**). In other words, there was no memory advantage for the children to the parents having received instruction to verbally support their child which was contradictory to our expectations.

## B. Comparing the JME Intervention Groups With No JME 2D and Standard 3D Presentations

Since the children in both JME groups performed equally well on the deferred imitation memory test (FIT-24) their data were collapsed and thereafter compared with the results from the comparison group.

### 2D With JME vs. Passive 2D Viewing

Since only half of the tasks in the FIT-24 memory test was used for the passive 2D presentation the comparison group saw, the mean score for the two JME groups was based on the same four items (see **Table 3**). This comparison revealed that the children in the JME groups ($N$ = 31) received a significantly higher memory score than the children ($N$ = 86) having viewed exactly the same 2D video presentations passively on a computer screen, Welch's $t(94.55) = 2.65$, $p = 0.009$, equal variances not assumed; Hedges $g$ = 0.42.

**TABLE 3** | Recall memory scores on the Frankfurt Imitation Test (FIT) for the JME intervention groups and the opportunistic comparison group being tested with half the items 3D and half 2D.

| FIT | | 2D JME | | | 2D no JME | | | 3D Comparison | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max | *N* | *M* | *SD* | *N* | *M* | *SD* | *N* | *M* | *SD* | *P*[2] = |
| Items A[1] | 15 | 31 | 9.52 | 1.59 | 86 | 8.41 | 2.83 | - | - | - | 0.012 |
| Items B[1] | 14 | 35 | 7.60 | 2.95 | - | - | - | 93 | 9.57 | 2.55 | 0.001 |

[1]*Items A = tasks number 1, 2, 3, and 5; Items B = tasks number 4, 6, 7, and 8. See Table 1 for description of tasks and text for details.*
[2]*Welch's t-test due to unequal N (between-subjects analysis).*

### 2D With JME vs. Live Presentation (3D)

In a similar fashion as above, the results for the JME 2D groups were compared with the 3D presentation used for the comparison group. The 3D procedure used was closely aligned with the procedure outlined in the manual and in the German standardization of the test (Kolling and Knopf, 2015). The results from the JME groups were based on the same four items that had been used with the comparison group (see **Table 3**). The analysis revealed that the comparison group having seen the target actions live ($N = 93$) displayed a better memory of the target actions than the children in the JME group, Welch's $t(54.2) = -3.49$, $p < 0.001$, equal variances not assumed; Hedges $g = -0.74$.

## DISCUSSION

This study compared how two forms of joint media engagement (JME) might support two-year old children's long-term memory after watching a 2D demonstration of eight different actions on a tablet. All children saw the video together with one of their parents and learning was measured by how many actions from the presented tasks the children recalled after a delay of approximately 30 min. The children were randomized to either an instructed or a spontaneous JME group. Parents in the instructed JME group were explicitly told to verbally support their child's learning while the parents in the spontaneous group were only instructed to support their child as they would ordinarily do if watching at home. The children's learning and memory performance was evaluated first by comparing how the two JME groups performed, second by comparing the JME groups with 2D learning without JME, and third by comparing if 2D JME differed from 3D (live) learning.

In response to our primary research question, to what degree an instructed JME strategy would support children's learning from 2D compared to a freer and non-instructed JME strategy, we found that the two strategies, as measured by children's recall of target actions, did not differ. However, the intervention was successful to the degree that parents in the two groups differed significantly in how much they talked with their child. Parents in having received specific instruction regarding their JME strategy used three times more words and five times the number of verbs than the parents receiving no specific instructions but this difference in verbal scaffolding did not affect the children's recall. Our hypothesis that instructed JME would support child's learning from the video more than the spontaneous group was not confirmed. The parents in the spontaneous group seems to have been verbal enough since the increased verbal activity observed for the parents in the instructed group did not promote better learning.

The two JME groups did not differ on overall memory recall and also not on gaze away, a proxy for attention. This suggests that both JME strategies are equally potent in supporting learning from 2D media and that this effect is not due to the amount of verbal support given. Attention might in fact be the process that drives learning from educational media as suggested by Samudra et al. (2020) and the fact that the JME groups did not differ on our attention measure could thus be the main reason why we did not observe any difference in learning between the JME intervention groups. One might speculate that parents in both groups already were well acquainted with their child's learning strategies, they knew how to tune in to their child's state of mind and they were, therefore, successful in supporting both learning and attention. Future researchers need to study these aspects in more detail as well as the overall emotional climate between the JME partners in order to better understand exactly what an optimal JME interaction should be built upon. According to Padilla-Walker et al. (2020) it is furthermore important to code for both positive and negative behaviors when analyzing JME in detail. They especially underscore the importance of including codes such as positive and negative parental empathic concern.

The second research question focused on if learning with JME supported children's learning better than passively co-viewing together with a parent using no JME strategies. This was confirmed as we found that the employed JME strategies promoted better support for learning than no JME 2D viewing. Children having viewed a 2D presentation of the tasks together with a parent using either of our two JME intervention strategies displayed significantly better recall scores than the children in the comparison group having viewed the video together with a parent who was instructed to be silent. The observed effect size was close to medium. Thus, it seems that the instructed and the spontaneous JME strategies, as used in the current study, are equally potent in counter acting the so-called transfer deficit (Barr, 2019). It is worth remembering that the videos used were identical in all three 2D presentations, instructed JME, spontaneous JME, and the comparison group receiving no JME. The video was produced with the goal to make learning from a screen easier than usually observed for 2D presentations. The tempo, the gaze and the gaze shifts of the presenter in the video as well as the change from talking to presenting the actions were carefully timed and edited such that the actions would be salient to the child. Thus, the observed difference in learning between the three 2D presentations is not due to how the tasks were shown on the screen since all children saw the same videos. A possible interpretation, in our view, is that the observed effect rests on the JME strategies used by the parents.

In order to address our third question, if a live presentation support learning better than learning from 2D, we compared the collapsed performance of the two JME intervention groups with all 93 children in the comparison group having been tested live with the Frankfurt Imitation Test (Kolling and Knopf, unpublished). The result showed that the JME procedures used by the parents in our study, although helpful, failed to completely ameliorate the transfer deficit effect: Children in the comparison group being tested live (3D) performed significantly better than the JME groups, something which is evident by the relatively high effect size observed which was close to being judged as strong (Hedges $g = -0.74$). This effect size between 2D and 3D learning is within the expected range for a study that uses an imitation paradigm when studying learning and the transfer/video deficit. Strouse and Samson (2021), in their meta-analysis of the video deficit effect, found that the average weighted effect size for imitation studies was −0.58 with a 95% CI (−0.76, −0.41). Moreover, the 3D presentation in the present study resulted in a higher mean score than the 2D JME strategies in spite of the fact that the tablet version of the test included three presentations of each task instead of two as prescribed in the manual for live testing and used here. A procedure that we had expected would have boosted learning from 2D.

Overall, we conclude that both 2D JME strategies employed in our study were equally potent to improve the children's recall beyond what passive 2D viewing without JME would entail. This is an important observation. However, of equal interest is our finding that the standard 3D presentation actually resulted in a significantly better recall than the 2D presentations used in the study (the collapsed 2D JME groups as well as the no JME comparison group). It surprised us that the results from the JME strategies employed did not differ as measured by the observed memory scores. One possible reason for this might be that the parents in both groups were well educated representing medium to high SES and had already developed workable JME strategies. A majority of the parents in both groups revealed that they often watched digital media together with their child. It is thus probable that they had developed good enough JME strategies in order to support their child's attention while learning from media. It might be that the children in the two JME groups had had a variable media experience and thus were more open to learn from media than many of their peers since children's experience with symbolic media, being it traditional 2D books or 2D digital media, affects "their likelihood of transferring information to the real world" (Strouse and Ganea, 2017, p. 139). However, we still lack detailed information as to why the strategies were equally potent in supporting learning is spite of the fact that the parent's verbal activities differed strongly between the groups. Factors like joint attention, tempo or emotional attunement are all aspects that might provide us with more specific answers as to exactly what constitutes the active supportive ingredient parent's use. Recently Padilla-Walker et al. (2020) highlighted the importance of parental empathic concern for the development of positive JME experiences.

## Limitations

There are some important limitations to take into consideration when evaluating the results. A major limitation is that both the procedure and the sample size differ between the comparison group and the two JME-groups. In addition, the children in the comparison group were on average 1 month older than the children receiving our JME intervention. The benefit of the included comparison group also becomes partly limited since only half of the memory test was presented live and half as 2D without JME. The reason behind this, as stated earlier, was that the children in the comparison group needed to encounter unknown tasks both for the 3D and 2D presentation. Even though the selection of items for 2D or 3D was decided after pilot observations in order to equalize the difficulty of the tasks selected, any attempt to replicate the findings should use the complete test also for the comparison group. Furthermore, the fact that both an in-between and a within-subjects design were used also limits the lessons possible to draw from the study. The small sample size included in the two JME groups is an added limitation since this could have affected the statistical power available for the analysis. However, the almost identical performance of the two groups makes it unlikely that a larger N would have changed the result. This is further underscored by a mean difference between the two groups in observed memory recall score not larger than 0.39 and an obtained effect size of only −0.08. Such a low effect size suggests that the two JME strategies had an almost identical effect on the children's learning. It is also worth remembering that the effect size observed for the comparison between 2D no JME and the 3D presentation was in line with what other studies have reported.

The study as a whole also suffers from the fact that all participating families were well-educated and represented middle or high SES. Thus, we do not know to what degree the observed findings are generalizable to the society as a whole. Finally, the fact that the study were carried out in a lab and not at home might also affect the generalizability of the findings.

## Conclusion

We conclude that JME can be effective in promoting learning from 2D. Children receiving either one of the two JME strategies employed performed better than children receiving a 2D presentation without JME support. What exactly entails a good JME strategy needs further studies since the two strategies employed here did not affect children's learning differently. In spite of the observation that the parents' verbal activity differed significantly between the two strategies. However, this could be rephrased as indicating that even the minor levels of JME used in our intervention groups have a positive effect on children's media learning. Finally, our findings also suggest that learning from 3D was the most effective way of promoting learning. In other words, our JME strategies reduced the transfer deficit but could not wipe it out.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Ethical Review Board, Linköping University, Sweden. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

The study was conceived by MH, AS, LH, EO, and F-SK. Data were collected by LH, EO, AS, F-SK, and UB, and analyzed by MH. The first draft of the manuscript was written by MH, LH, and EO. MH, AS, LH, EO, F-SK, and UB contributed to the final version. All authors contributed to the article and approved the submitted version.

## FUNDING

This research was supported by grants from the Swedish Research Council (2016-01033) and the Swedish Research Council for Health, Working Life and Welfare (2016-00048) to MH.

## ACKNOWLEDGMENTS

We wish to thank the families that participated in this research.

## REFERENCES

American Academy of Pediatrics (2016). Media and young minds. *Pediatrics* 138, 1–6. doi: 10.1542/peds.2016-2591

Barr, R. (2010). Transfer of learning between 2D and 3D sources during infancy: informing theory and practice. *Dev. Rev.* 30, 128–154. doi: 10.1016/j.dr.2010.03.001

Barr, R. (2013). Memory constraints on infant learning from picture books, television, and touchscreens. *Child Dev. Perspect.* 7, 205–210. doi: 10.1111/cdep.12041

Barr, R. (2019). Growing up in the digital age: early learning and family media ecology. *Curr. Dir. Psychol. Sci.* 28, 341–346. doi: 10.1177/0963721419838245

Barr, R., and Brito, N. (2014). "From specificity to flexibility: early developmental changes in memory generalization" in *The Wiley handbook on the development of children's memory*. eds. P. J. Bauer and R. Fivush (Ltd.: John Wiley & Sons), 453–479.

Barr, R., Dowden, A., and Hayne, H. (1996). Developmental changes in deferred imitation by 6-to 24-month-old infants. *Infant Behav. Dev.* 19, 159–170. doi: 10.1016/S0163-6383(96)90015-6

Barr, R., and Linebarger Nichols, D. (2017). "Preface" in *Media exposure during infancy and early childhood: the effects of content and context on learning and development*. eds. R. Barr and D. Nichols Linebarger (New York, NY: Springer), xi–xv.

Barr, R., and Wyss, N. (2008). Reenactment of televised content by 2-year olds: toddlers use language learned from television to solve a difficult imitation problem. *Infant Behav. Dev.* 31, 696–703. doi: 10.1016/j.infbeh.2008.04.006

Barr, R., Zack, E., Garcia, A., and Muentener, P. (2008). Infants' attention and responsiveness to television increases with prior exposure and parental interaction. *Infancy* 13, 30–56. doi: 10.1080/15250000701779378

Bayley, N. (2006). *Bayley scales of infant and toddler development–III screening test*. San Antonio: NCS Pearson Inc.

Brito, N., Barr, R., McIntyre, P., and Simcock, G. (2012). Long-term transfer of learning from books and video during toddlerhood. *J. Exp. Child Psychol.* 111, 108–119. doi: 10.1016/j.jecp.2011.08.004.

Courage, M. L. (2017). "Screen media and the youngest viewers: implications for attention and learning" in *Cognitive development in digital contexts*. eds. F. C. Blumberg and P. J. Brooks (Academic Press), 3–28.

Delacre, M., Lakens, D., and Leys, C. (2017). Why psychologists should by default use Welch's *t*-test instead of Student's *t*-test. *Int. Rev. Soc. Psychol.* 30, 92–101. doi: 10.5334/irsp.82

DeLoache, J. S. (2004). Becoming symbol-minded. *Trends Cogn. Sci.* 8, 66–70. doi: 10.1016/j.tics.2003.12.004

Ewin, C. A., Reupert, A. E., McLean, L. A., and Ewin, C. J. (2020). The impact of joint media engagement on parent–child interactions: a systematic review. *Human Behav. Emerg. Technol.* 1–25. doi: 10.1002/hbe2.203

Golinkoff, R. M., and Hirsh-Pasek, K. (2006). Baby wordsmith: from associationist to social sophisticate. *Curr. Dir. Psychol. Sci.* 15, 30–33. doi: 10.1111/j.0963-7214.2006.00401.x

Heimann, M., and Meltzoff, A. N. (1996). Deferred imitation in 9-and 14-month-old infants: a longitudinal study of a Swedish sample. *Br. J. Dev. Psychol.* 14, 55–64. doi: 10.1111/j.2044-835X.1996.tb00693.x

Jones, E. J. H., and Herbert, J. S. (2006). Exploring memory in infancy: deferred imitation and the development of declarative memory. *Infant Child Dev.* 15, 195–205. doi: 10.1002/icd.436

Kirkorian, H. L. (2018). When and how do interactive digital media help children connect what they see on and off the screen? *Child Dev. Perspect.* 12, 210–214. doi: 10.1111/cdep.12290

Koch, F. -S., Sundqvist, A., Herbert, J., Tjus, T., and Heimann, M. (2018). Changes in infant visual attention when observing repeated actions. *Infant Behav. Dev.* 50, 189–197. doi: 10.1016/j.infbeh.2018.01.003

Kolling, T., Goertz, C., Stefanie, F., and Knopf, M. (2010). Memory development throughout the second year: overall developmental pattern, individual differences, and developmental trajectories. *Infant Behav. Dev.* 33, 159–167. doi: 10.1016/j.infbeh.2009.12.007

Kolling, T., and Knopf, M. (2015). Measuring declarative memory from infancy to childhood: the Frankfurt imitation tests for infants and children aged 12–36 months. *Eur. J. Dev. Psychol.* 12, 359–376. doi: 10.1080/17405629.2015.1015515

Lauricella, A. R., Barr, R., and Calvert, S. L. (2016). Toddler learning from video: effect of matched pedagogical cues. *Infant Behav. Dev.* 45, 22–30. doi: 10.1016/j.infbeh.2016.08.001

Lukowski, A. F., and Bauer, P. J. (2014). "Long-term memory in infancy and early childhood" in *The Wiley handbook on the development of children's memory*. eds. P. J. Bauer and R. Fivush (Ltd: John Wiley & Sons), 230–254.

Madigan, S., Browne, D., Racine, N., Mori, C., and Tough, S. (2019). Association between screen time and children's performance on a developmental screening test. *JAMA Pediatr.* 173, 244–250. doi: 10.1001/jamapediatrics.2018.5056

McDaniel, B. T., and Radesky, J. S. (2018). Technoference: parent distraction with technology and associations with child behavior problems. *Child Dev.* 89, 100–109. doi: 10.1111/cdev.12822

Meltzoff, A. N. (1988). Infant imitation and memory: nine-month-olds in immediate and deferred tests. *Child Dev.* 59, 217–225. doi: 10.2307/1130404

Moser, A., Zimmermann, L., Dickerson, K., Grenell, A., Barr, R., and Gerhardstein, P. (2015). They can interact, but can they learn? Toddlers' transfer learning from touchscreens and television. *J. Exp. Child Psychol.* 137, 137–155. doi: 10.1016/j.jecp.2015.04.002

Myers, L. J., LeWitt, R. B., Gallo, R. E., and Maselli, N. M. (2017). Baby FaceTime: can toddlers learn from online video chat? *Dev. Sci.* 20:e12430. doi: 10.1111/desc.12430

Padilla-Walker, L. M., Coyne, S. M., Booth, M. A., Domoff, S. E., Summers, K., Schvaneveldt, E., et al. (2020). Parent–child joint media engagement in infancy. *Infancy* 25, 552–570. doi: 10.1111/infa.12355

Rosso, R. (2003). *Statistics for the behavioral sciences*. Hove and New York: Psychology Press.

Samudra, P. G., Wong, K. M., and Neuman, S. B. (2020). Is attention the missing link? Coviewing and preschoolers' comprehension of educational media. *J. Appl. Dev. Psychol.* 67:101108. doi: 10.1016/j.appdev.2019.101108

Simcock, G., Garrity, K., and Bar, R. (2011). The effect of narrative cues on infants' imitation from television and picture books. *Child Dev.* 82, 1607–1619. doi: 10.1111/j.1467-8624.2011.01636.x

Strouse, G. A., and Ganea, P. A. (2017). Toddlers' word learning and transfer from electronic and print books. *J. Exp. Child Psychol.* 156, 129–142. doi: 10.1016/j.jecp.2016.12.001

Strouse, G. A., and Samson, J. E. (2021). Learning from video: a meta-analysis of the video deficit in children ges 0 to 6 years. *Child Dev.* doi: 10.1111/cdev.13429

Strouse, G. A., and Troseth, G. L. (2014). Supporting toddlers' transfer of word learning from video. *Cogn. Dev.* 30, 47–64. doi: 10.1016/j.cogdev.2014.01.002

Strouse, G. A., Troseth, G. L., O'Doherty, K. D., and Saylor, M. M. (2018). Co-viewing supports toddlers' word learning from contingent and noncontingent video. *J. Exp. Child Psychol.* 166, 310–326. doi: 10.1016/j.jecp.2017.09.005

Sundqvist, A., Heimann, M., and Koch, F. (2020). Relationship between family technoference and behavior problems in children aged 4-5 years. *Cyberpsychol. Behav. Soc. Netw.* 23, 371–376. doi: 10.1089/cyber.2019.0512

Troseth, G. L., Saylor, M. M., and Archer, A. H. (2006). Young children's use of video as a source of socially relevant information. *Child Dev.* 77, 786–799. doi: 10.1111/j.1467-8624.2006.00903.x

Zack, E., and Barr, R. (2016). The role of interactional quality in learning from touch screens during infancy: context matters. *Front. Psychol.* 7:1264. doi: 10.3389/fpsyg.2016.01264

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 09 October 2020
doi: 10.3389/fpsyg.2020.570712

# Parents' Beliefs About the Benefits and Detriments of Mobile Screen Technologies for Their Young Children's Learning: A Focus on Diverse Latine Mothers and Fathers

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OPEN ACCESS

***Edited by:***
*Rachel Barr,*
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*Rachel M. Flynn,*
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***Specialty section:***
*This article was submitted to*
*Developmental Psychology,*
*a section of the journal*
*Frontiers in Psychology*

***Received:*** *08 June 2020*
***Accepted:*** *14 September 2020*
***Published:*** *09 October 2020*

***Citation:***
*Ochoa W and Reich SM (2020)*
*Parents' Beliefs About the Benefits*
*and Detriments of Mobile Screen*
*Technologies for Their Young*
*Children's Learning: A Focus on*
*Diverse Latine Mothers and Fathers.*
*Front. Psychol. 11:570712.*
*doi: 10.3389/fpsyg.2020.570712*

Young children's use of mobile screens is increasing despite the American Academy of Pediatrics' recommendations to limit screen use. Research on TV has found that maternal beliefs about the effects of screens on children's learning and parental socioeconomic status influence children's media consumption. However, few studies have explored parents' beliefs about mobile screens and whether there are differences in beliefs by socioeconomic status, particularly within the largest ethnic minoritized group — Latines. Because Latines are a socioeconomically and linguistically heterogenous group, but are often represented by low-income mothers in research, it is important to understand whether there are socioeconomic and linguistic differences on how and why Latine mothers *AND* fathers permit their children to use mobile screens. This study used in-depth, semi-structured interviews to understand how and why Latine mothers (low-income = 10, middle-to-high income = 10) and fathers (low-income = 10, middle-to-high income = 10) permitted their children (0–4 years) to use mobile screens. Specifically, we discussed their beliefs about how mobile screens support and hinder their children's learning and how their children used them. Results from qualitative content analysis showed that mothers and fathers, across income, education levels, and language use, believed that they, as parents, were the key decision-makers in determining the extent to which mobile screens supported and hindered their young children's learning. They described mediation strategies of selecting appropriate content, setting time limits, and monitoring use, to ensure that their children primarily benefited from device use. However, two distinctions were noted. Parents with a high school diploma or beyond stressed the importance of co-using devices with their children. This was not mentioned by less formally educated parents. Additionally, low-income parents with diverse educational levels, mentioned the importance of continuously monitoring device use to avoid their children encountering inappropriate content. Findings can inform work seeking to promote optimal media habits among Latine families.

**Keywords: mobile, screens, children, parents, beliefs, Latino, technology, attitudes**

## INTRODUCTION

Mobile screen technologies, such as smartphones and tablets, have permeated the everyday lives of most US families with young children across socioeconomic and ethnic groups, including Latine[1] families (Kabali et al., 2015; Common Sense Media, 2017; Pew Research Center, 2017). In fact, as of 2017, 98% of families with children under the age of 8 years own at least one smartphone and 78% own at least one tablet device (Common Sense Media, 2017). Although higher-income families are still slightly more likely than lower-income families to have access to high speed internet (96% vs. 74%), low-income and higher-income families are just as likely to own a smartphone and have children who own a personal tablet device (Common Sense Media, 2017). Importantly, recent reports show that children as young as 6 months old are increasingly being exposed to more time viewing or using mobile screen devices, especially children from low-income homes (Kabali et al., 2015; Common Sense Media, 2017).

The upward trend in children's exposure to mobile screen devices is of particular interest because extensive research on TV and emerging studies on mobile screens have found positive and negative associations between children's exposure to screens and key child outcomes, depending on how the devices are used (Mendelsohn et al., 2010; Roseberry et al., 2013; Zack and Barr, 2016; Madigan et al., 2019). For example, a study conducted among a majority of low-income, Latina mothers (94%) showed that verbal interactions between mothers and their 14-month-old toddler while using screen media moderated the negative impact of media exposure on children's language outcomes (Mendelsohn et al., 2010). That is, media use was negatively associated with children's language outcomes only in the absence of mother-child interactions while viewing or using screens (Mendelsohn et al., 2010). More recently, a study conducted by Zack and Barr (2016) among predominantly White, middle-class mothers and their toddlers showed that children were able to transfer what they learned from a 2D touchscreen device to a 3D object when their mothers scaffolded them during the task (e.g., modeling device use, talk).

Due to the prevalence of mobile screen devices and the implications these could have on young children's outcomes, it is important that we not only investigate how young children are using them, but that we also understand factors that might contribute to patterns of device use in diverse families. From the extensive research, primarily conducted in the context of TV, it is well known that maternal beliefs about the role of screens on children's learning and parents' socioeconomic status (SES) are two of the factors that most consistently predict children's screen consumption (Certain and Kahn, 2002; Njoroge et al., 2013; Rideout, 2014). To date, however, very few studies have focused on exploring parents' views about mobile screen technologies, and the few that do exist have primarily consisted of survey studies.

It is important to explore parents' views about mobile screens because mobile devices are nearly ubiquitous in the lives of children. Further, their portability and multifunctional capabilities not only permit families to use them in the same way they would use a TV (e.g., watch a show), but provide a host of other uses, such as instant access to the Internet, interactive apps/games, and video chat – all possible in any place and at any time. Additionally, the touchscreen interface enables very young children to successfully use these devices, even without assistance from an adult. Such constant connectivity and affordances could shape parents' beliefs about mobile screens and their role in their child's learning differently from their beliefs about TV, and also contribute to differences in the ways families are taking advantage of these features and allowing their children to use them. However, because most studies investigating parents' beliefs about mobile screens have consisted of surveys, our understanding of their beliefs about the role of mobile screens on their children's learning have been limited to the questions posed by researchers, who are also likely from the majority culture. Hence, we likely do not yet have a complete understanding about how and why minoritized parents might believe mobile screen technologies are beneficial or detrimental to their young children's learning. Moreover, despite the prevalence of mobile screens among socioeconomically and ethnically diverse families, White, middle-class parents make up the vast majority of samples in the extant research. In most of these studies, ethnic minority parents, particularly Latines, have comprised only a small portion of the entire sample, been disproportionately represented by low-income households, or their socioeconomic status has not been stated (Rideout, 2014; Wartella et al., 2014; Radesky et al., 2016; Common Sense Media, 2017; Sergi et al., 2017; McCloskey et al., 2018). As a result, it has been difficult to discern whether the SES or ethnic differences found in parent beliefs are associated with SES or cultural differences for ethnic minority parents (Cabrera and The SRCD Ethnic and Racial Issues Committee, 2013). Thus, we have virtually no understanding about the role of SES on parents' beliefs about their young children's use of mobile screen technologies among ethnically minoritized parents.

A particular ethnic group who has been largely excluded from research on screen media are Latine parents, even though they are the largest minoritized ethnic group in the United States, and are among the ethnic groups most likely to rely on smartphones for access to the Internet (Pew Research Center, 2017). Further, within Latine parents, fathers and Spanish-speaking parents have been especially underrepresented in screen media research. Not including fathers in media research among Latines is limiting because two out of three Latine children live in a two-parent household (Pew Research Center, 2015), and research has shown that fathers make unique and important contributions to their children's development (Cabrera et al., 2007). Furthermore, it is important to include linguistically diverse Latine parents because research in various areas of parenting has shown that English- and Spanish-speaking parents sometimes differ in their ideas about parenting practices and child development, likely due

[1]The term Latine is used to refer to individuals whose cultural background originated in Latin America. In United States academic circles, Latinx is used as a gender-inclusive term to refer to people from Latin American backgrounds. Many Spanish-speakers, including the first author of the current study – a native Spanish-speaker, find the term unpronounceable (see Zentella, 2017). Thus, we have opted to use the gender-inclusive term, Latine, commonly used throughout Spanish-speaking Latin American countries.

to nativity (Keels, 2009). Therefore, to address some of the gaps in the literature, this study focuses on obtaining a deeper understanding of socioeconomically and linguistically diverse Latine mothers and fathers' beliefs about the role of mobile screen devices on their very young children's learning. Parents of children ages 0–4 years old are the focus of this study because this is the age when screens (e.g., TV) have been found to have a large impact on children's developmental outcomes (Rice et al., 1990; Mendelsohn et al., 2010). Additionally, this is also an age when parents can play a major role in regulating the content and amount of time children spend viewing or using screens, which can shape the child's media consumption trajectory.

## PARENT BELIEFS ABOUT THE ROLE OF MOBILE SCREEN TECHNOLOGIES ON CHILDREN'S LEARNING

Although research exploring parents' beliefs about the role of mobile screen technologies on their children's learning is still in its early stages, emerging research suggest that most parents believe mobile screen technologies could both support and detract from their children's learning (Wartella et al., 2014; Radesky et al., 2016; Common Sense Media, 2017; Sergi et al., 2017; McCloskey et al., 2018). For example, a national survey conducted by Wartella et al. (2014) among a socioeconomically diverse sample of predominantly White (56%), Latine (23%), and Black (9%) parents of children 8 years old and younger found that 37% of the parents believed mobile screen technologies had a positive effect on their children's math skills and creativity. However, 46% of these parents also believed that mobile devices negatively affected their children's attention span (Wartella et al., 2014). Similar results were found in a qualitative study among five highly educated, racially diverse parents of children ages 4–7 years old. Specifically, most of these parents thought that mobile screen technologies had helped their children improve their math and language skills (Sergi et al., 2017). Nevertheless, most parents also expressed concerns about their children's excessive use of mobile devices, the random pop-up advertisements, unlimited access to entertainment apps, and the possibility that their children would become socially isolated due to excessive device use (Sergi et al., 2017). Many of these same concerns were also voiced by US parents in a recent national survey study (Common Sense Media, 2017).

Although only a handful of studies have made SES and ethnic comparisons of parents' beliefs about the role of mobile screen technologies on their children's learning, interesting differences have been found within these studies. For instance, through the use of semi-structured interviews among socioeconomically diverse White (58%), Black (29%), and Latine (5%) mothers (74%) and fathers (26%) of children between the ages of 0 and 8 years old, Radesky et al. (2016) found that more low-income parents than middle-to-high income parents reported feeling good about exposing their children to mobile screen devices, because they believed they would give their child an advantage later on in life. Similarly, a national survey of a socioeconomically diverse sample of Latine (43%), White (39%), and Black (18%) parents of children ages 2–10 years found that low-income parents tended to attribute more educational benefits to mobile devices than middle-to-high income parents (Rideout, 2014). Within this study, the author also found that Latine and African American parents were more likely than White parents to consider mobile screen devices to be an important source of learning for their children (Rideout, 2014).

In contrast to the aforementioned findings, however, a more recent national survey among a socioeconomically diverse sample of White (56%), Latine (22%), and Black (10%) mothers (60%) and fathers (40%) of children 8 years and younger found that Latine parents tended to express more concerns about the effects of mobile screen technologies on their children than White and Black parents (Common Sense Media, 2017). Moreover, Latine parents were more likely than parents from other ethnic groups to agree with the statement that the less time children spent with media the better (Common Sense Media, 2017). These latter findings align with those found in a recent survey study among a low-income sample of primarily Latine (78%) mothers (86%) and fathers (6%) of children in Head Start Centers (age 4 years) (McCloskey et al., 2018). Findings from this study showed that Latine parents were less likely than parents from other ethnic groups to say that their children used mobile screen technologies to learn. Across these few studies, it is unclear whether Latine parents hold more positive, negative, or neutral views than other ethnic groups about the role of mobile screen technologies on their children's learning. Moreover, we have almost no understanding on how SES and language might influence the beliefs of Latine parents, and especially Latino fathers, of young children because most studies have consisted of surveys with low-income Latine mothers. Therefore, the aim of this qualitative study is to use semi-structured interviews to understand how a sample ($n$ = 40) of socioeconomically and linguistically diverse Latine mothers and fathers of children 4 years old or younger believe mobile screen technologies support and/or hinder their children's learning.

## MATERIALS AND METHODS

### Study Design

A semi-structured interview design was used to obtain a deeper understanding of how and why diverse Latine parents of young children permit their children to use mobile screens, along with their beliefs about how these devices contribute or detract from children's learning. Qualitative approaches are appropriate to use when the goal is to identify and understand different perspectives about a given phenomenon (Giacomini and Cook, 2000).

### Recruitment and Participants

#### Recruitment

Latine mothers and fathers of children under the age of five, living in Southern California were invited to participate in one-on-one interviews between June 2018 and April 2019. Recruitment was done in one of three ways. The first method involved asking participants who were interested but ineligible to participate in another research study if they would be interested in participating in this study instead. The second method included posting flyers at businesses, churches, and grocery stores. Finally, the third method was through snowball sampling. All parents were asked to participate in a 45–60-min audio-recorded, in-person interview in English or Spanish in a place of their choice, including their home or a local coffee shop. To be eligible to participate in the study, parents needed to report 1) owning at least one mobile screen device and having access to the Internet on it, 2) self-identify as Latine, and 3) have at least one child who was 4 years old or younger. No restrictions were placed on the parents' age, number of children, marital status, nationality, or primary language spoken.

Given that we were interested in understanding the role of SES and parent gender on Latine parents' use and beliefs about mobile devices, we wanted to ensure equal representation of socioeconomically diverse Latine mothers and fathers. Therefore, using the approach of previous researchers, we used income as a proxy for SES and recruited parents from low-income and middle-to-high income households (Davis-Kean, 2005; Bodnar-Deren et al., 2017). Parents' income was determined by calculating their poverty index using the following demographic information: (1) total household annual income, (2) total number of people living in their household at least 4 days of the week, and (3) the number of these individuals who were minors and adults. In total, we purposefully recruited 20 low-income parents (10 mothers and 10 fathers) and 20 middle-to-high income parents (10 mothers and 10 fathers). Although we initially aimed to recruit equal numbers of low-income and middle-to-high income Spanish-speaking mothers and fathers, we were not successful because all monolingual Spanish-speaking parents who expressed interest in participating in our study had low incomes and all middle-to-high income parents were fluent in English (and all but one father reported speaking Spanish too). Therefore, Spanish-only-speaking parents are not represented in the middle-to-high income groups.

### Participants

In total, 40 Latine parents ($n$ = 20 mothers, $n$ = 20 fathers) of children between the ages of 0–4 years of age participated. All mothers and fathers were distributed equally across the low-income ($n$ = 20) and middle-to-high income ($n$ = 20) groups. There were a total of four couples, two in each income group. The next sections describe the demographic characteristics of parents from each of the four groups.

### Low-Income Mothers

Low-income mothers ($n$ = 10) ranged in age from 22 to 36 years ($M$ = 28.77, $SD$ = 5.33). On average, they had two children ($M$ = 2.1, $SD$ = 1.37) and all had at least one child under the age of 5 years ($M$ = 1.9 yrs., $SD$ = 1.5). Of the target children that were 4 years old or younger, 21% were female and 79% were male. Sixty percent of the mothers had a high school education or less, 20% had some college, and 20% obtained a Bachelor's degree. More than half of the mothers (60%) were born outside of the United States, with most being from Mexico (50%) or Ecuador (10%). These mothers had been in the United States for an average of 15 years ($M$ = 15.08, $SD$ = 9.19). Finally, the majority of mothers (70%) were English-Spanish bilingual and only 30% were monolingual Spanish-speakers. Noticeably, two monolingual Spanish-speaking mothers had an elementary school education and one had a Bachelor's degree.

### Low-Income Fathers

Low-income fathers ($n$ = 10) ranged in age from 26 to 45 years ($M$ = 31.50, $SD$ = 6.28). On average they had two children ($M$ = 1.9, $SD$ = 0.87) and all had at least one child under the age of 5 years ($M$ = 2.0 yrs., $SD$ = 1.2). Of the target children (i.e., 0–4 years), 36% were female and 64% male. Forty percent of the fathers had a high school education or less, 50% had completed some college or a 2-year degree, and 10% obtained a Bachelor's degree. Additionally, 40% of the fathers were born in Mexico and had been in the United States for an average of 24 years ($M$ = 24.14, $SD$ = 14.45). Finally, the majority of fathers (70%) were English-Spanish bilingual and only 30% were monolingual Spanish-speakers. Noticeably, the two monolingual Spanish-speaking fathers had a middle-school education or less.

### Middle-to-High Income Mothers

Middle-to-high income mothers ($n$ = 10) ranged in age from 23 to 35 years ($M$ = 30.60, $SD$ = 4.74). On average they had one child ($M$ = 1.20, $SD$ = 0.42) and all had a child under the age of 5 years ($M$ = 2.0 yrs., $SD$ = 1.3). Of the target children (i.e., 0–4 years), 33% were female and 67% male. Twenty percent of the mothers had completed some college, 20% had a Bachelor's degree, and 60% had a Master's degree or beyond. Additionally, all but one of the mothers were born in the United States. Finally, all mothers were English-Spanish bilinguals.

### Middle-to-High Income Fathers

Middle-to-high income fathers ($n$ = 10) ranged in age from 23 to 41 years ($M$ = 33.50, $SD$ = 5.72). On average they had two children ($M$ = 1.90, $SD$ = 0.99) and all had at least one child under the age of 5 years ($M$ = 2.3 yrs., $SD$ = 1.4). Of the target children (i.e., 0–4 years), 38% were female and 62% male. Sixty percent of the fathers had completed some college or a 2-year degree and 40% had a Master's degree or beyond. Additionally, only one of the fathers was born in Mexico and had been in the United States for 20 years. Finally, 90% of the fathers were English-Spanish bilinguals and only one was an English-monolingual speaker.

## Procedure

Once interested parents were confirmed to be eligible to participate in the study, a date and time was set to interview the parent. At the start of the interview, the first author, an English-Spanish bilingual Latina, provided the parent with an informed consent form. The form included a description and goals of the study, the parent's right to stop the interview at any time or to opt to not answer any question that made them uncomfortable, and asked for permission to audio-record the interview. All parents were assured that their confidentiality would be protected. After the parent signed the informed consent form, the researcher turned on an audio-recording device and began the interview. When the interview was over, parents were compensated with a $10 Target gift card and a bilingual children's book. A university Institutional Review Board (IRB) approved all procedures and materials.

## Measures

### Parents' Income Category

Parents were asked to report on their: (1) total household annual income, (2) total number of people living in their household at least 4 days of the week, and (3) the number of these individuals who were minors and adults. Using this information, parental income level was determined by calculating their poverty index, which compared a family's annual household income to an income threshold level that varied by family size and composition (i.e., number of children and adults).

The threshold levels are updated every year for inflation with the Consumer Price Index (United States Census Bureau, Poverty Thresholds, 2016). A family is considered to be living in poverty if their household annual income is less than the threshold level (United States Census Bureau, Poverty Thresholds, 2016). In their study, Brooks-Gunn et al. (1999) identified five income-to-needs ratio: (1) deep poverty (income-to-needs ratio less than 0.50), (2) poverty (income-to-needs ratio greater than or equal to 0.50, but less than 1.0), (3) near poverty (income-to-needs ratio between 1.0 and 1.5), low income (income-to-needs ratio between 1.5 and 2.0) and middle income (income-to-needs ratio greater than or equal to 2.0). However, we only identified two categories for this study: Low income (income-to-needs ratio: less than 2.0) and middle-to-high income (income-to-needs ratio: equal to or greater than 2.0).

### Background Questionnaire

Parents were asked to answer a 15-item background questionnaire created for this study. Questions included whether they were a mother or father, their and their children's gender, ages, ethnicity, family income, number of people living in their household, their education level, marital status, nationality, years living in the United States, and language(s) spoken.

### Semi-Structured Interview

A Spanish and English semi-structured, in-depth interview with open-ended questions was created for this study. The semi-structured interview asked parents about their beliefs and attitudes about the ways mobile screen devices support and/or hinder their children's learning (e.g., *Do you think smartphones and/or tablets have benefited your children's learning? How? Do you think smartphones and or tablets can be bad for your child's learning, how?*). Parents were also asked about the types of device limits they set for their children (e.g., *Do you have specific time limits for your children to use mobile devices? What kind of limits? Why?*) and to also describe how the target child used mobile screen devices (e.g., *What does your child typically do when s/he uses the smartphone and/or tablet?*). It is important to highlight that in answering the questions, parents were asked to think about their child(ren) that were 4 years of age or younger. To ensure that the questions were clear and interpreted as intended in both languages, extensive Spanish and English cognitive interviews were done with other low and middle-to-high income parents in this geographic region prior to data collection.

## Qualitative Coding and Analysis

The audio-recordings were transcribed in their original language. The transcripts were then coded in their original language using the MAXQDA qualitative software. All parents were given a pseudonym to protect their identity. Qualitative content analysis (Schreier, 2014) was then employed with a blended approach to answer our main research questions. Open coding enabled the emergence of new themes (Strauss and Corbin, 1998) while deductive coding guided the coding of data in light of existing findings (Saldaña, 2003). For instance, we expected to see key aspects of parental monitoring (deductive codes were framed in the literature) but did not have expectations about parents' views of benefits and detriments globally (inductive codes were derived from patterns that emerged from the data). By sorting parents' own words conceptually (Strauss and Corbin, 1990), we identified patterns of practices and beliefs about the ways mobile screens benefit and hinder their children's learning.

Our initial coding did not consider gender or whether parents had low or middle-to-high incomes. Instead, patterns were identified across interviews as soon as they were transcribed. The main categories were generated through a concept-driven strategy that used a combination of prior research, logic, everyday knowledge, and the main research questions (i.e., benefits and detriments to children's learning) by the lead researcher. This resulted in the generation of three main categories (i.e., parents' beliefs about the ways mobile screen devices benefit children's learning, parents' beliefs about the ways mobile screen devices hinder children's learning, and the ways parents regulated their children's use of mobile screens). Sub-categories were then generated within each of these larger main categories using the data-driven strategy of subsumption summarizing to capture the *specific ways* in which parents believed mobile screens were beneficial (e.g., learning concepts) and detrimental (e.g., lack of social interactions) to children's learning, along with the specific ways in which parents regulated their children's use of these technologies. After the lead researcher developed the main categories and subcategories, a group of independent researchers were asked to read relevant excerpts of one of four random interviews that the lead researcher had coded to create their own main categories and sub-categories. Then, they met to compare their categories and subcategories. Categories and sub-categories were compared and discussed, and the most frequently created main categories and subcategories were then used to develop the final coding frame. Upon finalizing the coding frame, all interviews were coded using the coding frame. Then, a subset of excerpts of the transcripts were shared with five doctoral students who were asked to code into the coding frame or recommend different codes, if needed.

To ensure data trustworthiness, not only did the lead researcher hold peer debriefing meetings with other researchers but also often asked interviewees if her interpretation of what they had said during the interview was correct. Finally, after all transcripts had been coded using the final coding scheme, the researchers used the features of MAXQDA software to obtain frequencies and make SES, gender, and linguistic comparisons to answer the research question. A 2:1 ratio was used to determine whether there were differences in themes and sub-themes on income and parent gender. However, because there were only six monolingual Spanish-speakers and one monolingual English-speaker compared to 33 English-Spanish bilingual parents, we only considered there to be differences between monolingual Spanish-speakers and English-Spanish bilinguals when none of the six Spanish-speakers mentioned a particular theme or sub-theme but 30% or more of the 33 English-Spanish bilinguals did. Similarly, if none of the English-Spanish bilinguals mentioned a theme but the six monolingual Spanish-speakers did, we also considered there to be a difference between linguistic groups. Because there was only one monolingual English-speaker, no differences or similarities with monolingual Spanish-speakers or English-Spanish bilinguals were discussed.

## RESULTS

Descriptive analyses indicated that the majority of parents across income and gender had access to the Internet and also owned about the same number of mobile screen technologies. Specifically, households across income ($M$ = 2.95 low, $M$ = 2.53 middle-to-high income, $p$ns) and gender ($M$ = 2.68 mothers, $M$ = 2.79 fathers, $p$ns) groups had access to two smartphones per household on average. Similarly, no differences were found in the average number of tablets owned per household across income ($M$ = 0.95 low, $M$ = 1.10 middle-to-high income, $p$ns) or gender ($M$ = 0.95 mothers, $M$ = 1.10 fathers, $p$ns) groups. Unexpectedly, a slightly higher percentage of target children (ages 0–4) from low-income households (37%) owned a personal tablet device than children from middle-to-high income households (16%). Additionally, most households across income (70% low, 80% middle-to-high income) and gender (70% mothers, 80% fathers) groups had access to both home Wi-Fi and data through their smartphones (Income: 85% low, 95% middle-to-high; Parent gender: 95% mothers, 85% fathers).

Analyses of the transcripts revealed that four themes emerged that centered around parents' beliefs about the ways mobile screen devices benefited their children's learning. Two themes captured parents' discussions about what they believed their children could learn from mobile screen devices (e.g., academic concepts, language), and the two other themes captured the specific activities they believed their child should do on the device to support their learning (e.g., view videos, use apps/games). Three themes also emerged that revolved around parents' beliefs about the ways mobile screen devices could hinder their children's learning (i.e., lack of social interactions, dependence, and accessing inappropriate content). However, in addition to the specific benefits and hindrances parents associated with mobile screen technologies, one major theme emerged that centered on how parents regulated children's use, which we refer to as *mediation practices*. This included such sub-themes as ensuring the content and/or game used was appropriate for the child, restricting the amount of time that the child was permitted to use the device, constantly monitoring the child while using the device to ensure they did not deviate into inappropriate content, and co-using the device with the child to scaffold their learning. Importantly, across income, gender, and linguistic groups, most parents believed that mobile screen technologies could both support and hinder children's learning depending on the types of mediation practices parents implemented. Hence, parental mediation practices, as a theme, focused on parents' opinions about the specific types of mediation practices (each sub-theme practice) they believed contributed to mobile devices being beneficial or detrimental toward children's learning. Comparisons across income groups (i.e., low and middle-to-high income), education level, parent gender, and language groups are described in more detail for each theme and subtheme below. Additionally, comparisons across groups are summarized in **Table 1**.

### Benefits of Mobile Screen Technologies on Children's Learning

Virtually all parents ($n$ = 39) believed that mobile screen technologies could offer some benefit to their children's learning. Although we left the term "children's learning" vague during our questioning, parents generally described learning from a device as learning some type of academic concept (e.g., colors, numbers, shapes, animals, letters) promoting Spanish or English language learning, and, from watching videos or using apps/playing games. Though the majority of parents thought children learned from viewing videos on the device, a little less than half of the sample also thought young children could learn from using apps/playing games. The next few sections describe these themes in more detail.

#### Learning Concepts

In total, 67% of parents across income ($n$ = 13 low, $n$ = 14 middle-to-high income), gender ($n$ = 16 mothers, $n$ = 11 fathers), linguistic groups ($n$ = 5 monolingual Spanish-speaking, $n$ = 21 English-Spanish bilinguals, $n$ = 1 monolingual English-speaking), and education levels (elementary school to Ph.D.) thought their children could learn academic concepts through the use of mobile screen devices, with most parents mentioning numbers, letters, shapes, patterns, body parts, animals, food labels, and music. For example, Eric, a middle-to-high income, English-Spanish bilingual father who completed some college, described how his child had learned how to count through using the smartphone, "*she knows how to count to ten through like... what is that guy called? Bleepy? And then she tries to count to twenty. It's a little, you know, but it's funny... it's cute.*" A little over half (55%) of the academic concepts that parents discussed their child had learned were attributed to videos. For instance, Carlos, a middle-to-high income English-Spanish bilingual father with a master's degree discussed that his children had learned how to count from watching videos, "*there's these videos. To me they're weird but like a lot of what he watches is educational. So they'll have all the marvel characters. All these super heroes, and then the super heroes are like...they teach him how to count.*" Additionally, 45% of the concepts that children had learned were also attributed to the use of educational apps/games. For example, Aniceto, a low-income Spanish-speaking father with an elementary education discussed how his children had learned letters from apps/games, "*usualmente, hay unos juegos que mencionan el nombre de la letra y basado a eso es como ellos pueden aprender.*" [English

**TABLE 1 |** Comparison of themes and subthemes across groups.

| Themes and Sub-themes | Total % theme mentioned (*n* = 40) | Differences in themes by groups | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Parent gender | | Income | | Language | | | Education | Differences |
| **Benefits** | **97%** | **Mothers (*n* = 20)** | **Fathers (*n* = 20)** | **Low-Income (*n* = 20)** | **Middle-High Income (*n* = 20)** | **Monolingual Spanish-Speaking (*n* = 6)** | **Bilingual (*n* = 33)** | **Monolingual English-speaking (*n* = 1)** | | |
| Child learns academic concepts | 67% | 16 | 11 | 13 | 14 | 5 | 21 | 1 | Elementary-Ph.D. | *No difference between groups* |
| | | *No difference* | | *No difference* | | | *No difference* | | *No difference* | |
| Child develops language skills | 87% | 15 | 20 | 17 | 18 | 6 | 28 | 1 | Elementary-Ph.D. | *No difference between groups* |
| | | No difference | | No difference | | | No difference | | No difference | |
| Child learns from videos | 77% | 15 | 16 | 16 | 15 | 5 | 25 | 1 | Elementary-Ph.D. | *No difference between groups* |
| | | *No difference* | | *No difference* | | | *No difference* | | *No difference* | |
| Child learns from apps | 40% | 6 | 10 | 9 | 7 | 3 | 12 | 1 | Elementary-Ph.D. | *No difference between groups* |
| | | *No difference* | | *No difference* | | | *No difference* | | *No difference* | |
| **Detriments** | 92% | | | | | | | | | |
| Social interactions | 35% | 7 | 7 | 4 | 10 | 0 | 14 | 0 | High School-Ph.D. | *Differences across 3 groups* |
| | | *No difference* | | *Difference* | | | *Difference* | | *Difference* | |
| Dependence or addiction | 45% | 9 | 9 | 7 | 11 | 0 | 18 | 0 | High School-Ph.D. | *Difference for 1 group* |
| | | *No difference* | | *No difference* | | | *Difference* | | *No Difference* | |
| Accessing inappropriate content | 30% | 6 | 6 | 6 | 6 | 2 | 9 | 1 | Middle School-MA | *No difference between groups* |
| | | *No difference* | | *No difference* | | | *No difference* | | *No difference* | |
| **Mediation strategies** | 85% | 18 | 16 | 17 | 17 | 6 | 27 | 1 | Elementary-Ph.D. | *No difference between groups* |
| | | *No difference* | | *No difference* | | | *No difference* | | *No difference* | |
| *Quality content* | 67% | 14 | 13 | 12 | 15 | 5 | 21 | 1 | Elementary-Ph.D. | *No difference between groups* |
| | | *No difference* | | *No difference* | | | *No difference* | | *No difference* | |
| *Time limits* | 40% | 9 | 7 | 8 | 8 | 5 | 10 | 1 | Elementary-Ph.D. | *No difference between groups* |
| | | *No difference* | | *No difference* | | | *No difference* | | *No difference* | |
| *Parental monitoring* | 22% | 3 | 6 | 6 | 3 | 1 | 7 | 1 | Elementary-BA | *Difference across 2 group* |
| | | *Difference* | | *Difference* | | | *No difference* | | *No difference* | |
| *Co-use* | 20% | 5 | 4 | 4 | 5 | 2 | 6 | 1 | High School-Ph.D. | *Difference for 1 group* |
| | | *No difference* | | *No difference* | | | *No difference* | | *Difference* | |
| **Mediation combination** | 52% | 12 | 9 | 9 | 12 | 4 | 16 | 1 | Elementary-Ph.D. | *No difference between groups* |
| | | *No difference* | | *No difference* | | | *No difference* | | *No difference* | |

translation: "*usually, there are some games that say the name of the letter and based on that is how they can learn.*"].

### Learning Language Skills

In addition to learning academic concepts, 87% of parents across income (*n* = 17 low, *n* = 18 middle-to-high income), gender (*n* = 15 mothers, *n* = 20 fathers), linguistic groups (*n* = 6 Spanish-speaking, *n* = 28 English-Spanish bilinguals, *n* = 1 monolingual English-speaking), and education levels (elementary school to Ph.D.) also thought children could learn language skills, such as develop their English or Spanish skills, from using mobile screen devices. As Karina, a low-income English-Spanish bilingual mother with a high school degree explained, "*yeah it has [benefited child]. She learned how to speak English from there. Cuz I wasn't speaking English to her at all, so she's learning, and now she speaks English and Spanish to me. She says the colors in English and Spanish to me.*" The majority (67%) of language skills that parents discussed their children had learned were attributed to videos. For example, Daniel, a low-income English-Spanish bilingual father with a 2-year certificate, discussed that his child had learned different languages from watching Youtube videos, "*I mean, there's a lot of Youtubers. A lot of people that, you know, are from different ethnicities that speak other languages, you know? And he [child] tends to copy them sometimes.*" Additionally, 33% of the language skills that parents mentioned their child had learned were attributed to apps/games. For instance, Anthony, a low-income English-Spanish bilingual father who had completed some college described his child's use of an app to learn Spanish and English words, "*so they can translate... cuz I remember, I remember I had an app for a while they [children] would play with, and it would like say in English and Spanish like certain things, like apple, manzana, and stuff like that.*"

### Viewing Videos to Learn

Most parents (77%) said their children could learn concepts and/or language skills by viewing videos on the device, and no differences existed by income (*n* = 16 low, *n* = 15 middle-to-high income), gender (*n* = 15 mothers, *n* = 16 fathers), linguistic groups (*n* = 5 monolingual Spanish-speaking, *n* = 25 English-Spanish bilinguals, *n* = 1 monolingual English-speaking), or education level (elementary school to Ph.D.). Additionally, many parents of children ages 3 months to 4 years thought their children's learning could benefit from viewing videos on the device. For example, Cindy, a middle-to-high income English-Spanish bilingual mother with a Master's degree, said, "*they could learn a new language. Um. one of the things I want her to do is, I want her to learn English and Spanish. So like I talk to her in Spanish and I try to put like, when I have the phone, nursery rhymes in Spanish... So I go on Youtube and that's mainly how I've used it. I would say I use it every day.*" **Table 2** contains a list of the specific types of videos parents across income and parent gender groups said their children viewed.

### Using Apps to Learn

Almost half of parents (40%) thought their children could learn academic concepts and/or language skills from using apps. These parents were distributed across income (*n* = 9 low, *n* = 7 middle-to-high), parent gender (*n* = 6 mothers, *n* = 10 fathers), linguistic groups (*n* = 3 monolingual Spanish-speaking, *n* = 12 English-Spanish bilingual, 1 = monolingual English-speaking) and education levels (elementary school to Ph.D.). For example, Ricardo, a middle-to-high income English-Spanish bilingual father with a Ph.D., expressed his opinion on whether mobile screen technologies could benefit his children's learning, "*I think definitely with um...there's a lot of good apps that um... teach kids um...how to recognize letters, you know? And how to sound out words with the letters. Um...I think there's a lot of good educational apps for kids.*" Furthermore, while neither of the two couples who had infants thought their children could learn from apps at their very young age, many parents of children ages 1.5–4 years thought their children could learn from using apps. **Table 3** contains a list of the specific types of apps parents across income and parent gender groups said their children used or viewed.

**TABLE 2** | Specific video platforms, programs, and topics parents said their children viewed.

| Content of videos | Low-income mothers | Low-income fathers | Middle-high income mothers | Middle-high income fathers | Totals |
|---|---|---|---|---|---|
| Cartoons | 4 | 3 | 2 | 2 | 11 |
| Teen Titans | | 1 | | | 1 |
| The Magic School Bus | | | | 1 | 1 |
| Sesame Street/Elmo | 1 | | 1 | 2 | 4 |
| Colors | | | 1 | | 1 |
| Numbers | | | 1 | 1 | 2 |
| Shapes | | | 1 | 1 | 2 |
| Spanish songs/lullabies | 3 | 1 | 3 | 1 | 8 |
| ABCs | | | 2 | 1 | 3 |
| Animals | 1 | 1 | | 1 | 3 |
| Potty-training | | | 1 | | 1 |
| Fitness | 1 | | | | 1 |
| Children's toy reviews | | 1 | | 3 | 4 |
| Making slime | 1 | | | | 1 |
| Playing with playdough | 1 | | 1 | 1 | 3 |
| Other children playing | | | 2 | | 2 |
| Family videos | 3 | 2 | 3 | 3 | 11 |
| Lullabies | 3 | | 4 | 5 | 12 |
| Netflix | 1 | 1 | | | 2 |
| Total | 29 | 10 | 21 | 20 | |

## Detriments of Mobile Screen Technologies on Children's Learning

In addition to thinking that mobile screen technologies could benefit children's learning, almost all parents (92%) also thought these devices could be detrimental to children's learning. However, parents' descriptions of "learning" when discussing detriments associated with mobile screen technologies encompassed such things as lack of social interactions for the child, children's dependence on or addiction to the device, and encountering inappropriate content. Although the concerns of children's dependence on or addiction to the device and encountering inappropriate content were mentioned across all

**TABLE 3 |** Specific types of apps parents said their children used.

| App type/Name for the child | Low-income mothers | Low-income fathers | Middle-high income mothers | Middle-high income fathers | Totals |
|---|---|---|---|---|---|
| Patterns, puzzles, and maps | 1 | 1 | 2 | | 4 |
| Coloring and art | 1 | 1 | 4 | | 6 |
| Colors | | 2 | 1 | | 3 |
| Animals | | 2 | | 1 | 3 |
| Letters and reading | 1 | 1 | 5 | 2 | 9 |
| Spanish | | 1 | 1 | | 2 |
| Music | | 1 | 1 | 2 | 4 |
| Numbers and math | 1 | 1 | 2 | 1 | 5 |
| Shapes | | 2 | 1 | 1 | 4 |
| Entertainment game | 2 | 1 | 1 | 3 | 6 |
| Unsure | | 1 | | | 1 |
| Total | 6 | 14 | 18 | 10 | |

gender, income, and educational groups, being worried about children's social interactions was a concern that was more prevalent among middle-to-high income parents than low-income parents. The next few sections discuss the themes related to hindrances in greater detail.

### Lack of Social Interactions

In total, 35% of parents expressed concerns about how mobile screen technologies could be detrimental to their children's social interactions. For example, Yaritza, a middle-to-high-income English-Spanish bilingual mother with a Master's degree, said, "*I still feel like, yes the technology and everything is great in her age but I feel like it does. it can interfere with it in terms of social interactions or them wanting to go out and be social and wanting them to go out and play.*" Noticeably however, slightly more middle-to-high income parents (*n* = 5 mothers, *n* = 5 fathers) than low-income parents (*n* = 2 mothers, *n* = 2 fathers) expressed concerns about the negative effects mobile screen technologies could have on their children's social interactions. Furthermore, none of the monolingual Spanish-speaking parents expressed this concern, but two of the six Spanish-speaking parents (education level: high school – bachelor's degree) had an infant and might not have experienced this issue yet. However, there might still be differences by language that should be further explored in future studies. In looking at the education level of the four monolingual Spanish-speaking parents who had children older than 1-year-old, the highest level of formal education attained was some high school. Thus, overall, it appears that education of a high school degree or higher was associated with worrying about mobile screen technologies interfering with children's social interactions.

### Dependence on or Addiction to the Device

A large percentage of parents (45%) also worried about the possibility of their children becoming dependent on, or addicted to, the mobile device. For instance, Yvonne, a low-income English-Spanish bilingual mother who completed some college, described, "*when he wants to go to sleep, he will just grab my phone and demand that I put something for him. That's the downside. I don't want him to like get addicted to it. And I don't know he just sees it as, as something that he has to be on all the time now.*" This concern was spread across income (*n* = 7 low, *n* = 11 middle-to-high income) and gender (*n* = 9 mothers, *n* = 9 fathers) groups, but not linguistic groups. That is, none of the six monolingual Spanish-speaking parents (education level: elementary – bachelor's degree) expressed the concern that their child could become dependent or addicted to the mobile device. This suggests that this concern might be more prevalent among parents of children older than one who have a high school degree or more than among parents with lower levels of formal education. It could also reflect differences in access to information about technology dependence based on language.

### Accessing Inappropriate Content

In addition to sharing concerns about children's lack of social interactions and dependence on the device, 30% of parents also expressed concern that their child would come across inappropriate content while using the device. This concern was dispersed across income (*n* = 6 low, *n* = 6 middle-to-high income), gender (*n* = 6 mothers, *n* = 6 fathers), linguistic groups (*n* = 2 monolingual Spanish-speaking, *n* = 9 English-Spanish bilinguals, 1 = monolingual English-speaking), and education levels (middle school – Master's degree). For example, Gerardo, a low-income English-Spanish bilingual father who completed a 2-year certificate, captured the anxiety of many parents when he said, "*like advertisements or there's this one program. I don't know if it's still there anymore. I know there was a lot of complaints from parents, cuz I saw it on the news as well, that it was on some show where it's like Spider Man and Anna from Frozen and um... they did some things that are not like meant for children.*" Most of the parents who expressed concerns about their children coming across inappropriate content also reported monitoring their children's use of the device. However, these parents felt that they had little control over the random ads that suddenly appeared when their child was viewing a video or video links their children would click on when they turned their attention away. It should be noted that half of the parents that brought up this issue (*n* = 6) had a high school degree or beyond and used content restrictions (e.g., parental controls) on the device.

## Importance of Parental Mediation Practices

Although most parents believed that mobile screen devices both benefited and hindered their children's learning, the vast majority of parents (85%) across income (*n* = 17 low, *n* = 17 middle-to-high income), gender (*n* = 18 mothers, *n* = 16 fathers), linguistic groups (*n* = 6 monolingual Spanish-speaking, *n* = 27 English-Spanish bilingual, 1 = monolingual English-speaking), and education levels (elementary school to Ph.D.) also discussed their important role, as parents, in determining the extent to which mobile screen technologies could support and limit their child's learning. As Luis, a middle-to-high income English-Spanish bilingual father with a Master's degree explained, "*it's gotta be hand in hand with um, what the parent is doing.*" Parents' descriptions of mediation strategies included the importance of appropriate content or apps, setting time limits, monitoring children's activities with the device, and assisting or helping the child understand the content encountered when using the device (i.e., co-use). However, although all of the aforementioned mediation strategies were cited, some were mentioned more frequently than others.

### Quality Considerations of Content of Video or App

Across income ($n$ = 12 low, $n$ = 15 middle-to-high income), gender ($n$ = 14 mothers, $n$ = 13 fathers), linguistic groups ($n$ = 5 monolingual Spanish-speaking, $n$ = 21 English-Spanish bilingual, 1 = monolingual English-speaking), and education levels (elementary school to Ph.D.), most parents (67%) talked about the importance of ensuring children were viewing "appropriate" or "educational" content in videos and or apps. When prompted, most parents described "educational" content as videos or apps that taught children specific academic concepts, such as numbers, colors, shapes, or language, such as letter sounds or Spanish/English vocabulary. Olga, a low-income English-Spanish bilingual mother with a high school degree, stressed the importance of ensuring the content was age-appropriate when she stated, "*um. . .que no tengan mucha violencia para su edad. Y que sean entretenidos, que sean adecuados a la edad de el niño.*" [English translation: "*um. . .that they [videos/apps] don't have a lot of violence for his age. And that are entertaining and appropriate for the child*"].

### Setting Time Limits

The second most frequently mentioned mediation strategy by parents across income ($n$ = 8 low, $n$ = 8 middle-to-high income), gender ($n$ = 9 mothers, $n$ = 7 fathers), linguistic groups ($n$ = 5 monolingual Spanish-speaking, $n$ = 10 English-Spanish bilingual, 1 = monolingual English-speaking), and education levels (elementary school to Ph.D.) was setting time limits for children when they used mobile screen technologies (40%). Parents saw setting time limits as a way to maximize the learning benefits of the device while minimizing its detriments. For example, Chayo, a low-income monolingual Spanish-speaking mother with an elementary school education, gave the following response when asked if she thought mobile devices could benefit her children's learning "*creo que. . . les ayudaría un poco pero no tanto. Creo que cierta. . .media hora. . . um. . . pero no demasiado tiempo. Si les serviría un poco.*" [English translation: "*I think that. . .it would help them a little bit but not a lot. I think that certain. . .half an hour. . .um. . . but not too much time. It would help them a little bit*"]. Similarly, most parents also mentioned limiting the amount of time or the frequency of device use by their child. For example, Jennifer, a middle-to-high income English-Spanish bilingual mother who had completed some college stated, "*we're not specific with minutes but we try to not go more than like 30 or 35 min.*"

### Parental Monitoring

The third type of mediation strategy that was mentioned by 22% of parents across groups was monitoring their children's use of mobile devices. Parental monitoring was often described as the importance of constantly checking or knowing what children were doing on the mobile device without necessarily co-using the device with children. For this category, slightly more low-income parents (education level: elementary school-bachelor's degree) ($n$ = 6) than middle-to-high income parents ($n$ = 3) talked about the importance of parental monitoring. Additionally, more fathers ($n$ = 6) than mothers ($n$ = 3) also mentioned this strategy. Nevertheless, parental monitoring was mentioned by Spanish- and English-speaking parents ($n$ = 1 monolingual Spanish-speaking, $n$ = 7 English-Spanish bilingual, 1 = monolingual English-speaking). Olga, a low-income English-Spanish bilingual mother with a high school degree, illustrated the importance of monitoring what her 2-year-old child did with the device in response to the question about mobile screen technologies being bad for children's learning, "*no si tu estas al pendiente de, de lo que el esta mirando*." [English translation: "*not if you are aware of, of what he is watching*"].

### Co-use

Finally, the fifth type of mediation strategy that was only mentioned by a fifth of the parents (20%) stressed the importance of co-using the mobile device with the child in order to assist them or to help them understand the content they were viewing or using. Although fewer parents mentioned this mediation strategy as being important for children's learning, the parents who did mention it were distributed equally across income ($n$ = 4 low, $n$ = 5 middle-to-high income), gender ($n$ = 5 mothers, $n$ = 4 fathers), and linguistic groups ($n$ = 2 monolingual Spanish-speaking, $n$ = 6 English-Spanish bilingual, 1 = monolingual English-speaking). In contrast with patterns from previous mediation strategies, however, only parents with a high school degree or more discussed the importance of co-use for their child's learning. For example, Luis, a middle-to-high income English-Spanish bilingual father with a Master's degree talked about an experience when his son asked him a question about the show he was viewing on his tablet, "*so my son is learning about the brain, so because I know that he's watching the Magic School Bus, I'll say, yes son. You go in through the nose and did you see that they went and they got, and they learned about the brain's connections, and that the brain has all these connections, right? And that the brain has all these capacities, right? So he is learning, right? But that learning is not happening if I'm not closing those gaps, right?*"

### Combination of Mediation Strategies

In addition to most parents talking about the importance of using some form of mediation strategy to ensure children benefited from mobile screen technologies, slightly more than half of the parents (52%) also mentioned the importance of using multiple types of mediation strategies. Notably, these parents were spread across income ($n$ = 9 low, $n$ = 12 middle-to-high income), gender ($n$ = 12 mothers, $n$ = 9 fathers), and linguistic groups ($n$ = 4 monolingual Spanish-speaking, $n$ = 16 English-Spanish bilingual, 1 = monolingual English-speaking), as well as education levels (elementary school-Ph.D.). Nevertheless, it should be noted that more middle-to-high income mothers ($n$ = 8) discussed the importance of using a combination of mediation strategies than middle-to-high income fathers ($n$ = 4) and low-income parents ($n$ = 4 mothers, $n$ = 5 fathers). In the following excerpt, Jennifer, a middle-to-high income English-Spanish bilingual mother who had completed some college, talked about the importance of using several types of mediation strategies (i.e., appropriate content, time limits) with her daughter, "*it just depends how the parents um, how long they let their child use it and what they're doing with it.*" Similarly, Leslie, a bilingual middle-to-high income mother with a master's degree mentioned using the mediation strategies of monitoring content and setting time limits for her child, "*of course, I check his videos before so it's very, you know, talks about friendship. And I set limits to that… I went to the APA and took what they recommended for children on screen time. He has 30 min for educational videos and 30 min for activities.*" Likewise, Luis, a middle-to-high income bilingual father with a Master's degree, also mentioned the strategies of monitoring, content, and time limits when he stated, "*we're very aware of the game apps. Like my daughter for example, downloaded an app, like two so she's played on apps. But again, it's not an everyday thing. She might do it once every other week for about 20 min.*" It is important to remember that Luis also mentioned co-using the device with his children in the previous section. Thus, Luis engaged in the mediation strategies of monitoring, ensuring content was appropriate, setting time limits, and co-using the device with his children.

In sum, most parents (85%) across income, gender, linguistic groups, and education levels viewed parental mediation strategies as the key factor in determining whether mobile screen technologies benefited or hindered their children's learning.

## DISCUSSION

This study investigated diverse Latine parents' beliefs and attitudes about the ways mobile screen technologies supported and/or hindered their young children's learning and development (ages 0–4). For the most part, our findings showed that parents across income levels, gender, linguistic groups, and education levels thought that they, as parents, played a key role in determining the extent to which mobile screen technologies positively or negatively influenced their children's learning, and only minor differences were noted across groups.

In general, parents thought that by using mediation strategies, such as ensuring their children viewed appropriate content, setting time limits for their children's use of devices, and continuously monitoring their children while they used a device, they could ensure that their children primarily benefited from using mobile screen devices. Although research exploring parental mediation strategies in the context of mobile screen technologies is still limited, the forms of mediation practices parents in our study described using are consistent with those found in the limited but growing body of research on mobile screen technologies and young children (e.g., Beyens and Beullens, 2017; Tang et al., 2018; Domoff et al., 2019), and those found in the extensive research on TV, which have been primarily been conducted among middle-class, White parents (Nathanson, 1999, 2001; Warren, 2003; Collier et al., 2016; Piotrowski, 2017). Furthermore, the diverse Latine parents in this study described being cognizant of the important role they play in mediating their children's use of mobile screen devices. This is particularly meaningful since extensive research in the context of TV has found that the types of mediation strategies parents engage in are related to children's success in learning from screens (Nathanson, 1999; Livingstone et al., 2015). Specifically, viewing age-appropriate and educational content has been associated with children's letter recognition, numeric skills, vocabulary, behavior, and cognitive scores (Linebarger and Walker, 2005; Tomopoulos et al., 2010).

However, despite finding that most mediation strategies were spread across groups, we did note two differences. First, almost a quarter of the parents with a high school degree or more stressed the importance of actively co-using devices with their children to ensure their child knew how to use the device and also understood the content. Second, more educationally diverse, low-income parents than middle-to-high income parents and more fathers than mothers mentioned the importance of continuously monitoring their children's use of devices so that they did not encounter inappropriate content. Other research has found that parents with lower incomes have less knowledge about technology and privacy-protecting features than higher income parents (Nikken and Opree, 2018), and that lower income parents utilize more free, commercial-laden apps as part of the "app economy" (Burroughs, 2017). This could help explain these patterns, if differences exist in access to information and high-quality and commercial-free apps between families with more and fewer financial resources, then children from lower-income homes might be at a greater risk of encountering third-party advertisements and having fewer parental control settings, which would explain why lower-income parents in our sample stressed the importance of more hands-on monitoring during use. Finding that more fathers than mothers mentioned the importance of continuously monitoring their children while using the mobile screen device is a new finding that has not been explored in previous research. In our sample, fathers were slightly older than mothers. Thus, it could be that older parents considered continuously monitoring their children more important than younger parents.

Our finding of income differences in mediation is consistent with the mediation of TV literature, which finds that middle-to-high income parents are more likely to endorse active co-use of the TV than low income parents (Warren, 2003), and that low income parents are more likely to endorse more restrictive forms of mediation than middle-to-high income parents (Warren, 2003). These differences are meaningful because past research on TV has shown that viewing appropriate content and active co-use of devices are two of the most effective mediation strategies in ensuring that children learn from screens. Specifically, co-viewing TV and co-using mobile screen devices have been found to be among the most effective mediation strategies in promoting child learning, especially among young children (Zack and Barr, 2016; Herodotou, 2017; Sheehan et al., 2019). This is because parents can use this time to help their child better navigate the device and/or understand the concepts they are viewing or reading about through the use of relevant and appropriate scaffolds, such as explaining or elaborating in a way the child can understand (Zack and Barr, 2016). In fact, research among toddlers has shown that children can transfer learning from screen devices to real life when their parents engage in high quality interactions while they co-use the device (Zack and Barr, 2016).

More than income differences, formal education seems to matter to utilizing the mediation strategy of co-use. We found that parents with a high school education or higher more often described engaging in active co-use of devices to ensure their children learned, compared to parents with less educational attainment. Thus, efforts might need to be made to reach parents with lower levels of formal education (i.e., less than high school diploma) and provide them with information about the benefits of actively co-using mobile devices with their children along with specific tips on how to actively co-use devices (Zack and Barr, 2016). In providing this information, researchers should also stress the importance of actively engaging with the child while they use the device as opposed to just passively sitting next to the child, but not engaging in discussions or conversations (i.e., active versus passive co-use).

In addition to expressing the importance of implementing mediation strategies, all parents in our study believed that mobile devices could benefit their children by helping them learn concepts or develop their language skills. The lack of differences in this belief between low-income and middle-to-high income parents is in contrast with most of the existing literature, which finds that low-income parents are more likely than middle-to-high income parents to attribute learning benefits to mobile screen technologies (Rideout, 2014; Radesky et al., 2016). Furthermore, when asked about the ways mobile screen technologies negatively affected their children's learning, a large portion of parents across income, education levels, gender, and language groups talked about the risk of being exposed to inappropriate content. Noticeably, none of the parents in our sample talked about purchasing apps or subscriptions to reduce the pop-up ads their children were exposed to while viewing Youtube videos or using apps. Furthermore, only six parents, with a high school degree or more, mentioned having content restrictions on the device to control the content their children were exposed to (e.g., Youtube for children). This suggests that more efforts should be made toward making apps and videos targeted toward young children ad-free and providing guidance for parents on how to utilize parental controls.

Parents also talked about the negative effect mobile devices could have on their children's social interactions and about the danger of becoming dependent on the device. These concerns are similar to the views expressed by ethnically diverse parents in survey studies and the few interview studies on mobile screen technologies (Wartella et al., 2014; Radesky et al., 2016; Common Sense Media, 2017; Sergi et al., 2017; McCloskey et al., 2018). Future efforts should provide parents with information and tips on how to reduce the risk of device dependence and ways to recognize signs of device addiction. Importantly, researchers should be cognizant of parents' financial situation when recommending alternative activities to device use. Ideally, the alternatives should be free and easily accessible to parents across the income spectrum, and also feasible for parents who are tired from working long shifts.

Parents, for the most part, viewed mobile devices as having the potential to be beneficial to their children's learning, but their control through the use of mediation practices, determined the benefit as well as risk. This is promising for future media interventions that could build on parents' existing views about mediation practices and help bolster optimal practices. In other words, parents are already aware that they play a vital role in determining whether mobile screen technologies have a positive or negative effect on their children's learning. As such, interventions should capitalize on this awareness and focus on increasing parents' knowledge about effective mediation strategies, particularly active co-use of mobile devices and time limits, especially for younger children.

## Limitation

There are a few limitations worth mentioning. First, although we obtained an equal number of monolingual Spanish-speaking mothers ($n$ = 3) and fathers ($n$ = 3), they were all from lower income families with very low formal educational attainment. Additionally, the vast majority of the sample spoke English ($n$ = 34), although 33 were bilingual. Hence, we were not able to capture how experiences may differ between monolingual Spanish-speaking and monolingual English-speaking parents, especially across different economic and educational backgrounds. Because language and SES were confounded for the small sample of Spanish-speaking parents, it was difficult to discern whether some of the findings were attributable to their language, which is often used as a proxy for acculturation, or their education level. Moreover, only one monolingual Spanish-speaking mother had a bachelor's degree. Future studies should place more effort toward obtaining a more socioeconomically diverse sample of Spanish-only speaking parents.

Secondly, a large portion of the low-income fathers (40%) and mothers (60%) in our sample were born in Mexico and Ecuador compared to the majority of middle-to-high income mothers (90%) and fathers (90%) who were born in the United States. Given that research in other topics about parenting beliefs has found that foreign-born Latina mothers sometimes conceptualize parenting topics differently from US-born Latina mothers (Zepeda and Espinosa, 1988), it is possible that we did not fully capture the experiences of low-income, US-born Latina mothers. Nevertheless, most of our findings appeared to be driven by education level and gender, rather than country of origin.

Our sample was unexpectedly and primarily composed of parents who were married or living with their partner. Hence our findings might not generalize to single parents. Additionally, the majority of the parents in our sample happened to be parents to sons. Thus, it is possible that patterns might be different for parents of daughters. Future studies should include parents with equitable numbers of sons and daughters. Finally, it is also important to mention that we only examined parent beliefs about the role of mobile devices on their children's learning and not actual practices. Therefore, it is possible that beliefs might not always translate to actual practices for some parents. This underscores the need for future work to examine whether parent beliefs about their role as parents in mediating their children's experiences with mobile devices are related to their actual mediating practices.

## CONCLUSION

This study addressed an important gap in the literature by investigating how socioeconomically and linguistically diverse Latine mothers and fathers believed mobile screen technologies benefit and/or hinder their children's learning. Our findings suggest that low and middle-to-high income mothers and fathers with diverse levels of education and linguistic abilities are well aware of the important role they play in mediating their children's use of mobile devices to benefit their learning and protect against potential harms. These findings also underscore the importance of not just including diverse ethnic groups but also considering the heterogeneity within ethnic groups. Observed differences based on gender, income, language and education are important and indicate that guidance around mobile screen device use could be tailored for different types of parents. These findings can help inform future work that seeks to promote optimal media habits among diverse Latine families. Importantly, because there are more similarities than differences across groups, it enables many intervention efforts and information resources to look similar, with other materials being tailored such as targeted materials for parents with little formal education (e.g., less than high school diploma).

Regardless of income or ethnicity, mobile devices are part of almost all young children's lives (Common Sense Media, 2017). However, parental beliefs about the way these devices can support their children's learning and the ways in which parents can bolster the benefits and minimize detriments have not been well studied across different racial and ethnic groups. This study demonstrates the many similarities and few differences in beliefs and practices among socioeconomically diverse mothers and fathers within the same ethnic group. To better understand how these ever-present devices relate to young children's learning, research should include more educationally, economically, racially, and ethnically diverse families.

## DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of California, Irvine IRB Committee. The participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

WO the first author thought about the research idea, collected the data, analyzed the data, and wrote the manuscript. SR the second author supported the first author in conceptualizing and polishing the research idea along with the methodology, helped with developing and verifying the codes, wrote portions of the manuscript, and helped edit the final draft. Both authors contributed to the article and approved the submitted version.

## ACKNOWLEDGMENTS

The first author wishes to thank her Mexican parents, family and community whose love, example and support continue to guide and inspire her. La primera autora desea agradecer a sus padres, familia, y comunidad Mexicana cuyo amor, ejemplo y apoyo continúan guiándola e inspirándola. Special thanks to the participating parents and Esmeralda Martin, Maritza Morales-Gracia, Juan Gaytan, Dr. Diaz and the Development in Social Context (DISC) Lab for help with this project! This study was part of the first author's doctoral dissertation. Therefore, substantial content overlaps with the dissertation available online (Ochoa, 2019).

## REFERENCES

Beyens, I., and Beullens, K. (2017). Parent-child conflict about children's tablet use: the role of parental mediation. *New Media Soc.* 19, 2075–2093. doi: 10.1177/1461444816655099

Bodnar-Deren, S., Benn, E. K. T., and Howell, E. (2017). Stigma and postpartum depression treatment acceptability among black and white women in the first six months postpartum. *Matern. Clin. Health J.* 21, 1457–1468. doi: 10.1007/s10995-017-2263-6

Brooks-Gunn, J., Duncan, G. J., and Rebello, P. R. (1999). "Are socioeconomic gradients for children similar to those for adults: achievement and health of children in the United States," in *Developmental Health and the Wealth of Nations: Social, Biological, and Educational Dynamics*, eds D. P. Keating, and C. Hertzman, (New York, NY: The Guilford Press), 94–124.

Burroughs, B. (2017). YouTube kids: the app economy and mobile parenting. *Soc. Media Soc.* 3, 1–8. doi: 10.1177/2056305117707189

Cabrera, N., Fitzgerald, H. E., Bradley, R. H., and Roggman, L. (2007). Modeling the dynamics of paternal influences on children over the life course. *Appl. Dev. Sci.* 11, 185–189. doi: 10.1080/10888690701762027

Cabrera, N. J., and The SRCD Ethnic and Racial Issues Committee, (2013). Social policy report: positive development of minority children. *Shar. Child Youth Dev. Knowledge* 27, 1–30. doi: 10.1002/j.2379-3988.2013.tb00075.x

Certain, L. K., and Kahn, R. S. (2002). Prevalence, correlates, and trajectory of television viewing among infants and toddlers. *Pediatrics* 109, 634–642. doi: 10.1542/peds.109.4.634

Collier, K. M., Coyne, S. M., Hawkins, A. J., Padilla-Walker, L. M., Erickson, S. E., Memmot-Elison, M. K., et al. (2016). Does parental mediation of media influence child outcomes? Meta-analysis on media time, aggression, substance use, and sexual behavior. *Dev. Psychol.* 52, 798–812. doi: 10.1037/dev0000108

Common Sense Media, (2017). *The Common Sense Census: Media use by Kids age Zero to Eight*. San Francisco, CA: Common Sense Media.

Davis-Kean, P. E. (2005). The influence of parent education and family income on child achievement: the indirect role of parental expectations and the home environment. *J. Fam. Psychol.* 19, 294–304. doi: 10.1037/0893-3200.19.2.29

Domoff, S. E., Borgen, A. L., Foley, R. P., and Maffett, A. (2019). Excessive use of mobile devices and children's physical health. *Hum. Behav. Emerg. Technol.* 1, 169–175. doi: 10.1002/hbe2.145

Giacomini, M. K., and Cook, D. J. (2000). Users' guides to the medical literature: XXIII. Qualitative research in health care. Are the results of the study valid? *JAMA* 2000, 357–362. doi: 10.1001/jama.284.4.478

Herodotou, C. (2017). Young children and tablets: a systematic review of effects learning and development. *J. Comput. Assist. Learn.* 34, 1–9. doi: 10.1111/jcal.12220

Kabali, H. K., Irigoyen, M. M., Nunez-Davis, R., Budacki, J. G., Mohanty, S. H., Leister, K. P., et al. (2015). Exposure and use of mobile media devices by young children. *Pediatrics* 136, 1044–1050. doi: 10.1542/peds.2015-2151

Keels, M. (2009). Ethnic group differences in early head start parents' parenting beliefs and practices and links to children's early cognitive development. *Early Childh. Res. Q.* 24, 381–397. doi: 10.1016/j.ecresq.2009.08.002

Linebarger, D. L., and Walker, D. (2005). Infants and toddlers' television viewing and language outcomes. *Am. Behav. Sci.* 48, 624–645. doi: 10.1177/0002764204271505

Livingstone, S., Mascheroni, G., Dreier, M., Chaudron, S., and Lagae, K. (2015). *How Parents of Young Children Manage Digital Devices at Home: The Role of Income, Education and Parental Style*. Hamburg: EU Kids Online LSE.

Madigan, S., Browne, S., Racine, N., Mori, C., and Tough, S. (2019). Association between screen time and children's performance on a developmental screening test. *JAMA Pediatr.* 173, 244–250. doi: 10.1001/jamapediatrics.2018.5056

McCloskey, M., Johnson, S. L., Benz, C., Thompson, D. A., Chamberlin, B., Clark, L., et al. (2018). Parent perceptions of mobile device use among preschool-aged children in Rural Head Start centers. *J. Nutr. Educ. Behav.* 50, 83–89. doi: 10.1016/j.jneb.2017.03.006

Mendelsohn, A. L., Brockmeyer, C. A., Dreyer, B. P., Fierman, A. H., Berkule-Silberman, S., and Tomopoulos, S. (2010). Do verbal interactions with infants during electronic media exposure mitigate adverse impacts on their language development as toddlers? *Infant Child Dev.* 19, 577–593. doi: 10.1002/icd.711

Nathanson, A. I. (1999). Identifying and explaining the relationship between parental mediation and children's aggression. *Commun. Res.* 26, 124–143. doi: 10.1177/009365099026002002

Nathanson, A. I. (2001). Parents versus peers: exploring the significance of peer mediation of antisocial television. *Commun. Res.* 28, 251–274. doi: 10.1177/009365001028003001

Nikken, P., and Opree, S. J. (2018). Guiding young children's digital media use: SES-differences in mediation concerns and competence. *J. Child Fam. Stud.* 27, 1844–1857. doi: 10.1007/s10826-018-1018-3

Njoroge, W. F., Elenbaas, L. M., Garrison, M. M., Myaing, M., and Christakis, D. A. (2013). Parental cultural attitudes and beliefs regarding young children and television. *JAMA Pediatr.* 167, 739–745. doi: 10.1001/jamapediatrics.2013.75

Ochoa, W. (2019). *Mobile Screen Technologies and Parents of Young Children: Investigating Diverse Parents' Attitudes, Beliefs, and their Interactions with Children*. Doctoral Dissertation, University of California, Irvine, Irvine. Available online at: https://escholarship.org/uc/item/3605m10z#main

Pew Research Center, (2015). *The American Family Today*. Washington, DC: Pew Research Center.

Pew Research Center, (2017). *Mobile Fact Sheet*. Washington, DC: Pew Research Center.

Piotrowski, J. (2017). "The parental media mediation context of young children's media use," in *Media Exposure During Infancy and Early Childhood: The Effect of Content and Context on Learning and Development*, eds R. Barr, and D. Linebarger, (Cham: Springer International Publishing), 205–219. doi: 10.1007/978-3-319-45102-2_13

Radesky, J. S., Eisenberg, S., Kistin, C. J., Gross, J., Block, G., Zuckerman, B., et al. (2016). Overstimulated consumers or next-generation learners? Parent tensions about child mobile technology use. *Ann. Fam. Med.* 14, 503–508. doi: 10.1370/afm.1976

Rice, M. L., Huston, A. C., Truglio, R., and Wright, J. C. (1990). Words from "Sesame Stree": learning vocabulary while viewing. *Dev. Psychol.* 26, 421–428. doi: 10.1037/0012-1649.26.3.421

Rideout, V. J. (2014). *Learning at Home: Families' Educational Media use in America*. A Report of the Families and Media Project. New York, NY: The Joan Ganz Cooney Center at Sesame Workshop.

Roseberry, S., Hirsh-Pasek, K., and Golinkoff, R. M. (2013). Skype me! Socially contingent interactions help toddlers learn language. *Child Dev.* 85, 956–970. doi: 10.1111/cdev.12166

Saldaña, J. (2003). Dramatizing data: a primer. *Qual. Inq.* 9, 218–236. doi: 10.1177/1077800402250932

Schreier, M. (2014). "Qualitative content analysis," in *The SAGE Handbook of Qualitative Data Analysis*, ed. E. Flick, (Thousand Oaks, CA: SAGE), 170–184. doi: 10.4135/9781446282243.n12

Sergi, K., Gatewood, R. Jr., Elder, A., and Xu, J. (2017). Parental perspectives on children's use of portable digital devices. *Behav. Inform. Technol.* 11, 1–14. doi: 10.1080/0144929X.2017.1360941

Sheehan, K. J., Pila, S. P., Lauricella, A. R., and Wartella, E. A. (2019). Parent-child interaction and children's learning from a coding application. *Comput. Educ.* 140, 1–11. doi: 10.1016/j.compedu.2019.103601

Strauss, A., and Corbin, J. (1990). *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Thousand Oaks, CA: Sage Publications, Inc.

Strauss, A., and Corbin, J. (1998). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. Thousand Oaks, CA: SAGE Publications, Inc.

Tang, L., Darlington, G., Ma, D. W. L., Haines, J., and Guelph Family Health Study, (2018). Mothers' and fathers' media parenting practices associated with young children's screen-time: a cross-sectional study. *BMC Obsesity* 5:37. doi: 10.1186/s40608-018-0214-4

Tomopoulos, S., Dreyer, B. P., Berkule, S., Fierman, A. H., Brockmeyer, C., and Mendelsohn, A. L. (2010). Infant media exposure and toddler development. *JAMA Pediatr.* 164, 1105–1111. doi: 10.1001/archpediatrics.2010.235

United States Census Bureau, (2016). *Poverty Thresholds: 2016*. Suitland, MD: United States Census Bureau.

Warren, R. (2003). Parental mediation of preschool children's television viewing. *J. Broadcast. Electron. Med.* 47, 394–417. doi: 10.1207/s15506878jobem4703_5

Wartella, E., Rideout, V., Lauricella, A. R., and Connell, S. L. (2014). *Parenting in the Age of Digital Technology: A National Survey. Center on Media and Human Development, School of Communication, Northwestern University*. Evanston, IL: Northwestern University.

Zack, E., and Barr, R. (2016). The role of interactional quality in learning from touch screens during infancy: context matters. *Front. Psychol.* 7:1264. doi: 10.3389/fpsyg.2016.01264

Zentella, A. C. (2017). "Limpia, fija y da esplendor": challenging the symbolic violence of the royal Spanish academy. *Chiricú Journal: Latina/o Literatures, Arts, and Cultures*, 1, 21–42. doi: 10.2979/chiricu.1.2.04

Zepeda, M., and Espinosa, M. (1988). Parental knowledge of children's behavioral capabilities: a study of low-income parents. *Hisp. J. Behav. Sci.* 10, 149–159. doi: 10.1177/07399863880102005

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Education

ORIGINAL RESEARCH
published: 14 January 2021
doi: 10.3389/feduc.2020.569615

# Comparing the Effects of a Different Social Partner (Social Robot vs. Human) on Children's Social Referencing in Interaction

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Social robots have emerged as a new digital technology that is increasingly being implemented in the educational landscape. While social robots could be deployed to assist young children with their learning in a variety of different ways, the typical approach in educational practices is to supplement the learning process rather than to replace the human caregiver, e.g., the teacher, parent, educator or therapist. When functioning in the role of an educational assistant, social robots will likely constitute a part of a triadic interaction with the child and the human caregiver. Surprisingly, there is little research that systematically investigates the role of the caregiver by examining the ways in which children involve or check in with them during their interaction with another partner—a phenomenon that is known as social referencing. In the present study, we investigated social referencing in the context of a dyadic child–robot interaction. Over the course of four sessions within our longitudinal language-learning study, we observed how 20 pre-school children aged 4–5 years checked in with their accompanying caregivers who were not actively involved in the language-learning procedure. The children participating in the study were randomly assigned to either an interaction with a social robot or a human partner. Our results revealed that all children across both conditions utilized social referencing behaviors to address their caregiver. However, we found that the children who interacted with the social robot did so significantly more frequently in each of the four sessions than those who interacted with the human partner. Further analyses showed that no significant change in their behavior over the course of the sessions could be observed. Findings are discussed with regard to the caregiver's role during children's interactions with social robots and the implications for future interaction design.

**Keywords: child-robot interaction, early childhood education, social referencing, children, social robots, humanoid robots**

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***Edited by:***
*Adriana Bus,*
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***Specialty section:***
*This article was submitted to Educational Psychology, a section of the journal Frontiers in Education*

***Received:*** *04 June 2020*
***Accepted:*** *14 December 2020*
***Published:*** *14 January 2021*

***Citation:***
*Tolksdorf NF, Crawshaw CE and Rohlfing KJ (2021) Comparing the Effects of a Different Social Partner (Social Robot vs. Human) on Children's Social Referencing in Interaction. Front. Educ. 5:569615. doi: 10.3389/feduc.2020.569615*

## INTRODUCTION

In recent years, there has been a growth in studies examining young children's interactions with social robots as partners in learning environments (Belpaeme et al., 2018). Benefiting from the presence of an embodied social agent and the ability to use various social signals, social robots could offer wide-ranging opportunities to support and expand early childhood education by providing new ways to engage children in social interaction. The areas of application range from language learning (Vogt et al., 2019) to the promotion of children's growth mindsets (Park et al., 2017) or supporting children's development of computational thinking skills (Ioannou and Makridou, 2018). Social robots can also be used in therapy-centered activities by delivering interventions to children on the autistic spectrum to support their social and emotional communication abilities (Boccanfuso et al., 2017; Cao et al., 2019). Whereas, social robots may assist young children in their learning across these various fields, the common purpose of approaches incorporating this technology in educational practices is typically to supplement the educational process rather than to replace the human caregiver, e.g., the teacher, parent, educator or therapist. More precisely, for both ethical and present technological reasons, a social robot is seen as a tool which can play a potential supportive role within an interaction in an educational setting but not as the sole interaction partner of the child (Coeckelbergh et al., 2016; Kennedy et al., 2016; Tolksdorf et al., 2020b).

Given this preferred configuration of a triadic interaction between the child, caregiver, and a social robot, there is surprisingly little research paying explicit attention to the role of the caregiver or systematically examining the ways in which children involve or check in with them during their interaction with a robot. From current studies, it seems clear that children accept social robots as informants (Breazeal et al., 2016; Oranç and Küntay, 2020) that need, however, to be introduced by a caregiver to establish a good learning environment (Vogt et al., 2017). More specifically, relating to the phenomenon of social referencing, Rohlfing et al. (2020a) argue that young children react with uncertainty when facing a robot for the first time; in such a situation, children typically refer visually to their caregivers to regulate their emotions and to gauge the situation (Hornik et al., 1987). Although Rohlfing et al. (2020a) noticed that some children at the age of 5 years verbally referred to their caregiver during an educational child–robot interaction, little is known about how often children non-verbally request support from their caregivers during such interactions. To investigate this phenomenon, non-verbal behavior has to be considered. Recently, Tolksdorf and Mertens (2020) showed that in child–robot interactions, children make use of non-verbal signals to a large extent, especially when engaging in a complex communicative task, such as retelling an event or retrieving a newly acquired word from memory. It is thus reasonable to focus the investigation of the role of the caregiver in child–robot interaction on the systematic similarities and differences between children's multimodal interaction behavior with robots vs. human partners. Furthermore, some effects upon children's behavior appear to occur in the first exposure and disappear when children familiarize with the situation (Feinman et al., 1992). In this respect, the literature lacks a perspective that considers children's social referencing during a long-term interaction occurring across multiple points in time. Our study addresses this research gap: We explored how pre-school children involved their caregiver over the course of a long-term language learning study, comparing children's behavior when interacting with a social robot or a human interaction partner within two conditions that were designed to be directly comparable.

Our motivation for the direct comparison stems from research providing wide evidence that an adult can be a helpful resource for a child experiencing an unfamiliar situation, providing them with guidance on how to interpret and navigate it (Feinman et al., 1992). However, within the area of child–robot interaction, very few attempts have been made to consider the caregiver's role during triadic interactions between the child, the robot, and the caregiver. From a more implicit angle, Vogt et al. reported that at the beginning of language lessons with a social robot, certain pre-school children needed assistance and had to be encouraged by the caregiver to interact with the robot in order to respond to it (Vogt et al., 2019). This observation strongly suggests that a caregiver plays a crucial role when a novel partner is first introduced. This is corroborated by a study which showed that even very young children at the age of 1 year often extended their dyadic interaction with a Keepon robot into triadic interactions with their human caregivers when they were trying to share pleasure and surprise within the interaction (Kozima and Nakagawa, 2006). Whereas, children obviously benefit from caregivers' involvement at the beginning of a novel situation through aligning with their emotional interpretation, they also seem to receive specific cues for how to communicatively manage the interaction. A study by Serholt (2018) thoroughly analyzed dialogical breakdowns during an educational child–robot interaction at a primary school in Sweden. They demonstrated that although the children were able to solve some dialogical problems on their own, in most of the cases they were dependent on the human caregiver, especially when technological problems occurred (Serholt, 2018). In a more recent work, Rohlfing et al. (2020a) systematically investigated the caregivers' role during a single learning situation within a child–robot interaction and focused on the verbal ways in which the caregiver provided support to their child. The results revealed that a caregiver did not have to adopt an active role during the interaction but provided valuable instructions on how to repair the interaction when dialogical breakdowns occurred (Rohlfing et al., 2020a). We need to emphasize, however, that in this particular study, the analysis of children's social referencing behavior was limited to verbal turns toward the caregiver, such as requesting help explicitly.

Together, these few studies indicate that triadic interactions often emerge within child–robot interactions when a caregiver is present and that children particularly rely on the caregiver at certain stages. However, because prior work has not directly compared child–robot interactions to ones with a human partner, research can only speculate on what is typical of social referencing behavior during interaction with a robotic partner. Current insights are limited to single, one-off interactions or are based on observations made in the context of dialogical or technological problems occurring with the robotic system. Our study extends previous work by systematically investigating children's visual social referencing over a long-term interaction within parallel learning situations across two different conditions: interaction with either a social robot or a human partner. We assumed that children in both groups would involve their caregivers because they were all faced with a novel and unfamiliar situation. Our main research goals were to explore the extent to which a child would involve their caregiver over the course of a long-term interaction as well as to examine the similarities and differences in children's social referencing between a child–robot interaction and a human-human interaction within an educational setting. The following hypotheses were addressed in our study:

**(H1)** We expect that an interaction with a social robot will lead to more social referencing in children compared to an interaction with a human partner. This hypothesis is grounded in research demonstrating that children rely on their caregivers during novel situations, including encounters with social robots (Kozima and Nakagawa, 2006; Serholt, 2018; Rohlfing et al., 2020a). A robot, which differs in its behavior from a human, might be perceived as less familiar by the children, meaning children's greater familiarity with human partners in contrast to social robots will lead to fewer attempts to involve the caregiver during a human-human interaction.

**(H2)** It is also expected that instances of children's social referencing will decrease over the course of a long-term interaction. This is anticipated because prior research has shown that children's social referencing varies in relation to their familiarity with a situation (Walden and Baxter, 1989). Moreover, with increasing repetition within an interaction, the interactional demands become more predictable for the child (Bruner, 1983; Rohlfing et al., 2016). This might result in children becoming less dependent on guidance from their caregivers.

## MATERIALS AND METHODS

This study is part of a broader ongoing study in which we investigate how children learn a specific linguistic structure within a recurrent interaction. In this study, our main goal was to investigate children's social referencing, and how this behavior may differ when children interact with either a novel social robot or an unfamiliar human interaction partner.

### Participants

Originally, 21 pre-school children participated in our explorative long-term study. Data from one child had to be excluded because they did not attend all sessions. For this reason, 20 children (6 females), ranging in age from 4;0 to 5;8 [years;months] (mean age = 5;0, *SD* = 0.6) were included in the final analysis, and their behavior was assessed across four sessions. The children were recruited in local kindergartens, libraries, via newspapers, and through our database of families willing to participate in research studies. The children and their parents were recruited from the wider areas of the Paderborn region (North Rhine-Westphalia, Germany). Parents were present during all interactions but were not actively involved in the interaction. In compliance with university ethics procedures for research with children, parents provided written consent prior to their children's participation. Children also provided verbal assent prior to taking part in the interaction and the interaction could be discontinued at any time at no disadvantage to the child. Each child received stickers and a toy to thank them for their participation.

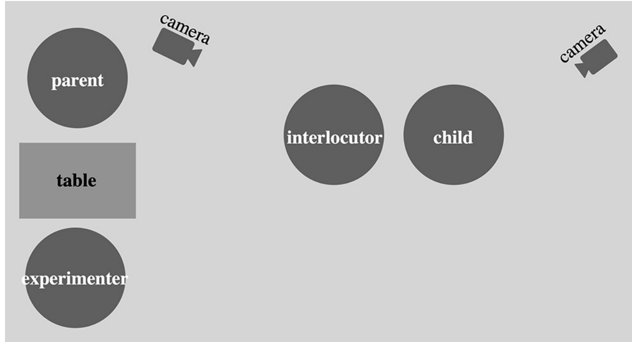


**FIGURE 1 |** Setup of the study (either the robot or the human served as the interlocutor).

### General Procedure

The children and their parents were invited to come to the laboratory at Paderborn University for four sessions within a 2-week period. Each session lasted ∼20–35 min and all sessions were video recorded. The course of the sessions and the learning situation was explained to the parents by the experimenter; it was also communicated to the children in a child-oriented way. In our study we used a between-subjects experimental design with two conditions. The children were randomly assigned to a parallel learning situation with either (1) the social robot or (2) the human interlocutor. The final distribution consisted of 11 children (four females) interacting with the social robot and nine children (two females) interacting with the human interlocutor. During the experiment, every child taking part was accompanied by one parent; as illustrated in **Figure 1**, the child sat next to the interlocutor (either the robot or the human) at a 90-degree angle. The parent sat to the left of the child while the experimenter sat behind the child and operated the robot in the condition with the robot or sat in that position and avoided interaction with the parent or child in the condition with the human interlocutor. Parents were additionally instructed to avoid talking to their children during the experimental part of the children's interaction with the robot or the human interlocutor.

To design the learning situation, we were guided by existing theoretical concepts of learning, emphasizing that communication is jointly organized by the interaction partners in a multimodal way and toward a goal (Rohlfing et al., 2016). The resulting design of the learning setting therefore involved activities with which pre-school children are familiar. More specifically, a story was told by the robot or the human that had been created to frame the word learning situation. The story contained the plot of the interlocutor's trip to our university and the things they had seen on their journey. This narrative served as a context in which the novel words were provided as input over the course of the interaction. This setting was selected because previous work has shown the context of a story to be particularly facilitative for children's word learning (e.g.,

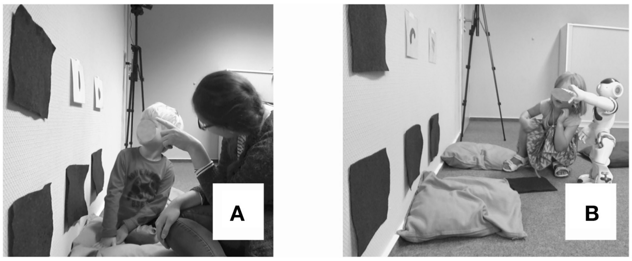


**FIGURE 2 |** Teaching of the novel word either by **(A)** the human or **(B)** the robot interlocutor.


**FIGURE 3 |** Test situation with either the human **(A)** or the robot interlocutor **(B)**.

Horst, 2013; Nachtigäller et al., 2013). The referents of the target words were presented as pictures hanging on the wall. They were covered by a small cloth and the child had to uncover each one to see the target referent at the request of the interlocutor (see **Figure 2**).

After the exposure to the training situation, children from both groups were tested for retention of the target words. To do so, we used a routinized activity for children and embedded the test procedure within a shared picture book reading situation (Grimminger and Rohlfing, 2017). In this test the child was asked to turn the pages while the interlocutor talked about the pictures with the child and elicited the trained words (see **Figure 3**).

In the following sections, we present the details of the experimental procedures for each condition (firstly the robot condition and then the human condition). We further detail our endeavors to make the learning settings as similar as possible.

## Procedure With the Robot Interlocutor

In the first of the four sessions, there was a short warm-up phase in order to decrease the novelty effect of the robot (Kanero et al., 2018). The script for the learning situation with the robot was then launched, during which the robot introduced itself and shared the story containing the new words with the child. To make the robot's interaction behavior responsive to the child's communicative actions (Tolksdorf and Mertens, 2020) and in accordance with recent research postulating an important role of multimodal joint activities (Rohlfing et al., 2016, 2019), the robot performed a series of actions. First, the robot accompanied the novel words with pointing gestures in front of its upper body to coordinate the child's attention and to establish a shared reference. It also coordinated its gaze between the child and the referents of the target words. After naming the first four target words, the robot then walked with the child to the two remaining target referents in order to make the situation more natural and to take advantage of the physical presence of the robot (van den Berghe et al., 2019). Once the robot had finished the story, it thanked the child and said goodbye. In the second session, the learning situation was repeated and the robot told the same story but adapted its greeting and farewell. In the third session, a similar learning situation took place. Afterwards, the retention task was administered, in which the child and the robot were engaged in the shared picture-book-reading situation. In the fourth session, the child was tested again on retention of the target words.

## Procedure With the Human Interlocutor

As in the robot condition, the experimental procedure in the human condition consisted of four sessions between the child and a human interlocutor. The human interlocutor was the same person in all of the sessions across the condition and a non-native speaker of German (one of the authors). This design decision was made to address the novelty of the robot as an unfamiliar interaction partner and to render the word-learning story told to the child as plausible. Like in the robot condition, a caregiver was present as well as another experimenter further to the one acting as the interlocutor (see **Figure 2**). In the human condition, the interlocutor also introduced herself in the first session with a short backstory, whereupon the learning situation began. Following the introduction, the same story and stimuli from the robot condition were used during the learning situation and only minor edits were made to make the story more representative of human experience (e.g., "born in…" rather than "built in…"). The human interlocutor used an equal amount of deictic pointing gestures at matching points in the story to the robot condition, carrying these out within the same upper-body area and holding the gestures for an equivalent duration of time. Parallel to the robot condition, the interlocutor further coordinated her gaze between the child and the referents of the target words. For purposes of achieving a fair comparison, we also wanted to keep the verbal and linguistic input in the human condition as close to the robot condition as possible and the human interlocutor tried to copy these to a degree that would appear most natural. These elements included not only the language used but also factors such as emphasis and speed. As within the robot condition, the child was asked to uncover the pictures in a randomized order. After naming the first four target words, the human interlocutor also suggested moving over again so that they were in range of the remaining two items. Once the human interlocutor had finished telling the story, she thanked the child and said goodbye. In the second and third session, another learning situation took place and the story was told again, but with an appropriately adapted greeting and farewell by the human interlocutor, just as it did in the condition with the robot. Following the learning situation in the third session, the retention task took place and involved the same shared picture book reading interaction as in the robot condition, during which the child was asked to turn the pages

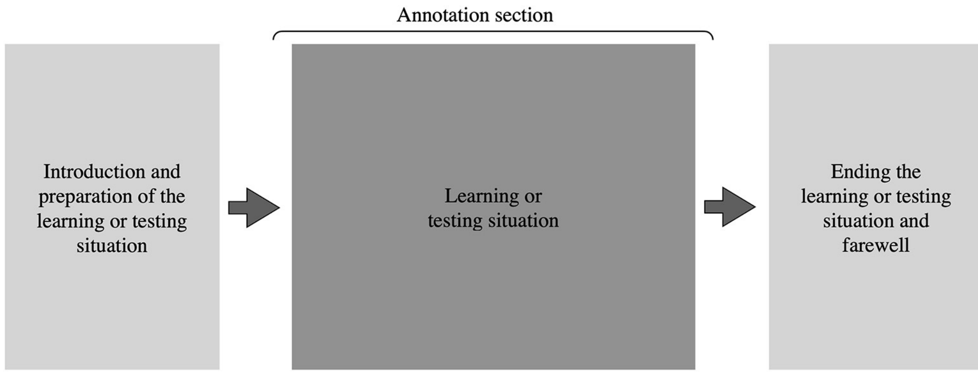


**FIGURE 4 |** Sequence of the interaction during the sessions and annotated section.

and the human interlocutor asked them about the trained words. In the final (fourth) session, the retention task was conducted again after which the human interlocutor thanked the child and said goodbye.

## Stimuli

The robot used in our study was the Nao robot from Softbank Robotics, which is a small, toy-like, humanoid robot used widely in child–robot interaction studies (Belpaeme et al., 2018). The Nao is 58 cm high with 25 degrees of freedom of motion with its body. Teleoperation was employed to enable the robot to act contingently (Kennedy et al., 2017). We implemented the behaviors in the NAO robot by using the *Choregraphe* Software and used the integrated text-to-speech production of the robot, with German language enabled and speech reduced to 85% speed to achieve a more natural pronunciation. The target words imparted by the robot were spoken at a speed of 75% speed in order to emphasize them verbally. The target items consisted of six morphologically complex German words (noun-adjective compounds such as "quince yellow [quittengelb]") that represented different colors as features of different objects. Each item was presented as a picture on paper measuring 14.8 × 21 cm.

## Coding of the Children's Behavior

In our analysis, we were interested in children's social referencing to their caregivers during the learning and testing situations with either the social robot or the human interlocutor across the different sessions. In typical social referencing paradigms, children are confronted with unfamiliar situations, e.g., unknown interaction partners or novel toys, and then the children's non-verbal behavior in terms of their looking is measured along with the (visual or vocal) cues of their caregiver (Baldwin and Moses, 1996). In the present study, we did not analyze the kinds of cues that the caregiver provides to his or her child but rather focused on the instances in which the child independently sought to visually check in with their caregiver. Our focus on children's non-verbal behavior was also motivated by the fact that the values of the children's verbal initiation to their caregivers tended toward zero across almost all learning and testing situations. For this reason and with reference to Vaish and Striano, we coded children's looking behaviors in the direction of their caregivers (Vaish and Striano, 2004). We measured this non-verbal social behavior across the period of time in the interaction during which the robot or the human interlocutor shared the story and taught the new words (see **Figure 4**).

We chose to analyze this sequence in each session because at this stage, all children had already achieved a certain familiarity with the novel interaction partner. This also represented the main part of the interaction while a welcome or farewell situation would represent a different social situation with its own contextually appropriate social behaviors (Vaughn and La Greca, 1992). Examining the selected sequence is particularly relevant because it provides an opportunity to understand how children involve a caregiver during a learning situation with a social robot in comparison to a human interaction partner. We additionally coded children's looking during the testing of retention of the target words (the situation in which the interlocutor asked the child about the trained words). As the duration of the interactions varies slightly between children, the children's looking to their parents were expressed in proportion per minute. To evaluate coding reliability, two coders independently coded 15% of the data. We used Cohen's kappa to measure intercoder agreement for children's looking ($\kappa = 0.954$).

# RESULTS

Our data shows that children in both groups demonstrated social referencing behaviors during all their interactions with the novel interlocutor (robot or human) and attempted to involve or check in with their caregiver. At first, in order to investigate the effect of the different conditions and sessions, we performed an ANOVA type statistic (ATS), with children's social referencing as the dependent variable, condition as the between-subjects independent variable, and time as the within-subjects independent variable. Due to non-normally distributed data and small sample size, the ATS was used which represents a non-parametric equivalent of a mixed ANOVA (Akritas et al., 1997) and exactly meets the α-level while being conservative. It is robust in studying small sample sizes and longitudinal data considering its progression over time (Noguchi et al., 2012)

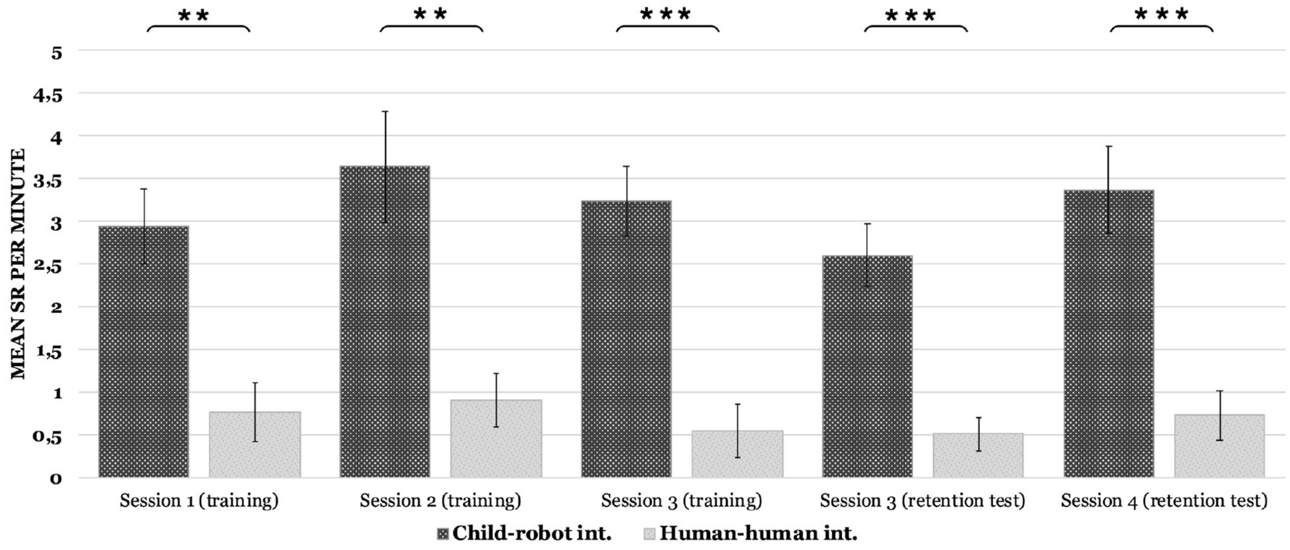


**FIGURE 5 |** Children's social referencing (SR) per minute (**$p < 0.01$, ***$p < 0.001$).

and has been applied in developmental approaches (Viertel, 2019). Contrary to our hypothesis, there was no main effect of time, $F_{(3,\infty)} = 0.638$, $p = 0.166$, and no significant interaction between experimental condition and time, $F_{(3,\infty)} = 0.427$, $p = 0.133$, indicating that no significant changes in children's social referencing behavior were found in either group over the entire course of the sessions, including all learning and test situations. However, there was a highly significant main effect of condition $F_{(1, 16.99)} = 49.08$, $p < 0.001$, demonstrating that children in the human condition displayed social referencing significantly less often than their peers interacting with the robotic partner.

In a second step, pairwise *post-hoc* analysis using Bonferroni correction was conducted to determine the differences between the groups in each training and testing situation. As depicted in **Figure 5**, we found significant differences between the groups in children's social referencing (SR) in the first session ($p < 0.01$) $Z = -2.929$, with a large effect size of $r = 0.65$; accordingly, children in the robot condition showed significantly more social referencing per minute ($M = 2.93$; $SD = 1.45$) than the children interacting with the human ($M = 0.75$; $SD = 1.03$).

In session 2, a significant difference with a large effect size could be observed again ($p < 0.01$, $Z = -3.154$, $r = 0.71$). Children interacting with the robot demonstrated more occurrences of social referencing ($M = 3.63$; $SD = 2.14$) than those children interacting with the human interlocutor ($M = 0.9$; $SD = 0.93$).

During the third session, in the last training situation, the groups again differed significantly ($p < 0.001$, $Z = -3.58$, $r = 0.80$). Among the children interacting with the robot, the frequency of attempts to involve their caregiver was higher ($M = 3.23$; $SD = 1.34$) than among the children interacting with the human interlocutor ($M = 0.54$; $SD = 0.93$). In the following retention task (also in session 3), the level of social referencing among the children in the robot condition was again greater ($M = 2.6$; $SD = 1.2$) compared to the human interlocutor condition ($M = 0.50$; $SD = 0.58$), and the groups again differed significantly ($p < 0.001$, $Z = -3.459$, $r = 0.77$).

In the last session, during which the retention task was repeated, a significant difference could again be seen between the two groups ($p < 0.001$, $Z = -3.304$, $r = 0.74$). The children who interacted with the robot utilized more social referencing toward their parents ($M = 3.36$; $SD = 1.67$), while the group of children interacting with the human interlocutor were clearly less likely to involve their parents ($M = 0.72$; $SD = 0.82$).

Finally, we took a closer look at the nature of children's social referencing during the interactions with the robotic or the human partner and qualitatively analyzed at which particular stages the children involved their caregivers and sought guidance from them. **Table 1** presents an overview of the different interactional contexts in which children's social referencing was situated during the long-term interaction. We identified four interactional main contexts and three additional contexts specifically occurring during the retention tests in which the children involved their caregivers.

Certain occurrences of social referencing appeared exclusively in the interaction with the robot, such as an involvement of the caregiver after a delay in the dialogue occurred and the robot required too much time to provide an adequate utterance. Additionally, children who interacted with the robot checked in with their parents before manipulating some elements of the setting, for example, when uncovering the pictures at the request of the robot. An explanation for this type of social referencing could be that although children socially conform with what a social robot suggests (Vollmer et al., 2018), social conformity is even higher in interaction with a human interaction partner and children are less dependent on additional reassurance from their caregiver to follow an instruction. Another context in

**TABLE 1 |** Interactional contexts of children's social referencing (SR).

| Contexts of SR | Robot condition | Human condition | Examples |
|---|---|---|---|
| Delays or interruptions in the dialogue | ✓ | - | The child expects an utterance from the robot |
| Reassurance before a manipulation of the setting | ✓ | - | Child is requested by the robot to uncover the pictures |
| New interactional event | ✓ | ✓ | A new book page is opened, the interlocutor introduces a new referent, the interlocutor performs a gesture |
| Naming of the unknown target words | ✓ | ✓ | The interlocutor names a target word |
| **Test specific contexts of SR** | | | |
| Reassurance before the production of a target word | ✓ | ✓ | Before producing the requested word, the child refers to the parent |
| No retrieval of the target word | ✓ | ✓ | The child fails to retrieve the target word and refers to the parent |
| Successful retrieval of a target word | ✓ | ✓ | The child is able to retrieve the target word and refers to the parent |

which the children turned to their caregiver was when the target words were named while the story was being told. This type of social referencing occurred in both conditions, but was more pronounced in interaction with the robot. Since the target words were unknown to the children, it is reasonable that the children addressed their parents to obtain more information in order to dissolve the ambiguous situation. More specifically, this observation ties in with accounts suggesting that children seem to need reassurance from familiar interaction partners (such as their parents) to trust information provided by less familiar partners (Ehli et al., 2020). The last context in which social referencing occurred concerned the occurrence of a new event during the interaction. This included situations in the dialogue such as when a picture was uncovered, a new page was turned in the book during the retention test, the interlocutor began to walk to the position for the final two target referents, or when the interlocutor displayed a specific communicative means such as a gesture. In such situations, the children in the robot condition particularly extended the dyadic situation into a triadic interaction with their caregiver as they were clearly more unfamiliar with the robot's interaction behavior. For example, they often shared their positive surprise when the robot performed a pointing gesture, which on the other hand was possibly more ambiguous for the child compared to a human gesture. Thus, children's social referencing in these situations can be explained in two ways: on the one hand by their preference for sharing affective experiences with their caregivers, since they have only limited skills for downregulating their arousal on their own (Ainsworth et al., 2015). On the other hand, some of the situations could also have been unclear to a child, which led them to turn to their caregiver to disambiguate the ongoing situation (a strategy for information seeking).

During the retention tests, we observed additional contexts in which social referencing occurred: The children additionally referred to their caregivers before they produced a target word to the interlocutor, when they failed to retrieve a target word, and in cases in which they successfully retrieved a target word. The first two contextual types can be attributed to children's attempt to gather information or reassurance within the ambiguous situation as well as receiving emotional support from their familiar social partner when confronted with the situation of not being able to produce the requested word. Children's social referencing occurring in the context of a successful production of a target word mostly reflected the child's intention to share its positive affect with their caregiver and its joy in successfully contributing to the communicative task.

To summarize, our analysis of children's social referencing during the interactions revealed that each child involved their caregiver and used them as a resource during their interaction with a novel interlocutor. In this vein, we identified several contextual factors in which children consistently involved their caregivers, indicating that the familiar social partner fulfilled diverse functions during the entirety of the long-term interaction. However, in accordance with our first hypothesis, the children who interacted with the robot were significantly more likely to approach their caregiver across all sessions (during both the language learning situations as well as the test situations) than the children who interacted with the human interlocutor. Regarding our second hypothesis that children's social referencing would decrease over the course of the long-term interaction, our results appear to demonstrate the reverse, indicating that social referencing occurred consistently during the interactions, especially during the interaction with the robot.

## DISCUSSION

Our study involved a long-term interaction in an educational setting through which we explored how children interacting with an unfamiliar partner—either a social robot or a human — involved their caregiver by displaying behavior known as social referencing. The motivation for our approach was informed by recent research suggesting that a caregiver might serve as a helpful resource in an interaction between a child and a social robot (Serholt, 2018; Rohlfing et al., 2020a). In terms of novel aspects, the present study has focused on children's non-verbal means of social referencing and analyzed children's looking behavior within an educational setting of language learning over multiple sessions. Overall, our results show that not only do children socially refer to their caregiver in a novel learning situation with a social robot and that they do so significantly more often than during an interaction with an unfamiliar human interlocutor, but that this behavior also persists long-term: Across four sessions, we found continuous social referencing to the caregiver that was significantly more pronounced in the group of children interacting with a social robot than in the group interacting with an unfamiliar human partner. Contrary to our prior assumption, we could not observe a significant decrease in children's social referencing in both groups despite the repetition of the interaction and increasing familiarity with the situation. Whereas, there appeared to be a slight decreasing tendency from the second to the third learning situation in each group, this trend may have been slowed down by the subsequent novel situation of the retention task, which again increased children's reliance on the caregiver despite increasing familiarity with the interaction partner. This could be supported by the observation that some types of social referencing occur specifically in the test situations. Since children's social referencing is sensitive to contextual variation (Feinman et al., 1992), we had expected the difference between the groups to change during a test situation (an interaction where the imparted knowledge was now being assessed). Surprisingly, the group effect persisted and we could not observe a significant change between the situations in terms of children's involvement of their caregivers. Thus, children interacting with a social robot turned to their caregivers more often than children interacting with an unfamiliar human partner. A reason for the lack of increase in the test situation could be that children became familiar with the interlocutor as well as the interactional demands at that point in time, since three interactions had already taken place before the first retention test was administered.

The large difference in children's social referencing behavior between an interaction with the human vs. robotic partner is striking. One explanation for our findings is that a human partner naturally responds to various social cues (Kahle and Argyle, 2014) from the child in ways that social robots are not yet capable of, given their present technological limitations. More specifically, current social robots are not yet able to adapt to their social partner by rapidly processing and responding to this on-line non-verbal communicative information (Belpaeme et al., 2018). In contrast, in more familiar human-human interaction, a child might expect to share and exchange perceptual information and emotional attitudes with an interaction partner such as the caregiver (Butterworth and Jarrett, 1991; Tomasello, 1999). These exchanges not only enable the child to temporally synchronize with the interaction partner but also to monitor the state of the interaction partner and to establish a mutual understanding of the unfolding situation (Kozima et al., 2004). In fact, despite practice to reduce it, the human partner was observed to naturally use many subtle backchanneling signals in response to the children. This might mean that the robot does not meet certain expectations about the ongoing social interaction or that it is not possible to establish a mutual monitoring in the same way with a robotic partner. In other words, because the robot does not pick up on the child's non-verbal cues, the "flow of conversation" (Wrede et al., 2010) is disrupted resulting in children looking for reassurance or other solutions to repair. It appears that the process of mutual monitoring during an unfolding interaction represents "a key mechanism of a social interaction enabling partners to align and jointly act" (Rohlfing et al., 2020b: 4). According to Clark and Krych (2004), a successful dialogue requires the speaker to monitor both their own actions and the understanding of the addressee during the interaction and, if necessary, adapt their actions to the addressee, who in turn continuously provides the speaker with information about their current level of understanding. For example, research has demonstrated that if the interactants are unable to monitor each other, they make eight times more errors than if they benefit from mutual monitoring (Clark and Krych, 2004). This is even more pertinent to settings where the goal is to convey knowledge to a learner. Moreover, this joint bilateral process is multimodal, involving verbal and non-verbal means of communication (Vollmer et al., 2010). Although the learning and testing procedures in the present study were kept consistent between the conditions and we endeavored to design the settings as similarly as possible regarding the verbal and non-verbal input, it is conceivable that the children interacting with the human partner could take advantage of some social adaptation or confirmation (e.g., mutual gaze or nodding) that the children interacting with the robot could not. Consequently, those children interacting with the robot were more frequently dependent on their caregiver as an additional resource for interpreting the ongoing situation and overcoming the disruption in the flow of conversation.

Along these lines, we further observed that the timing of the social robot's interactional behavior (the fluency of its turn-taking) might also have contributed to the greater proportion of social referencing among the children interacting with it. In multimodal reciprocal interaction between humans, children are used to rapidly exchanging utterances via multiple channels such as speech, gaze or gesture (Rohlfing et al., 2019). This fluent exchange is organized in a way in which the interactants' contributions can minimally overlap (Levinson, 2016). Although we employed teleoperation in order to enable the robot to act contingently with an appropriate timing and manner, the higher latency of the robot's responses compared to those of the human interaction partner was unavoidable. Due to this increased latency, it is possible that the children were confused, which might have resulted in them seeking guidance from their caregiver. In the study by Rohlfing et al. (2020a), it was shown that caregivers' suggestions during communicative breakdowns were about what to expect from a differently acting partner and how to cope with it: Children were advised to speak louder, to repeat themselves or to wait. Clearly, children thus expect and rely upon concrete coping strategies solicited from their caregivers for how to repair the flow of a conversation. In contrast, children interacting with the human interlocutor might have benefited from a more fluid interaction with a minimum of interruptions or delays, which could have decreased children's need for or reliance on guidance from their caregiver in such situations. In fact, in the present study, social referencing during delays in the dialogue was only observed within the robot condition. The duration of the interaction with the robot further supports this interpretation as in many cases, it lasted longer in comparison to the human-human interaction, although the human interlocutor deliberately slowed down the speed of her utterances.

A considerable strength of our study relates to the close parallels between the designs of the two conditions, allowing us to make finely grained comparisons of their outcomes. This also played out in the positioning of both the robot and human interaction partners as peer-learners or informal tutors for the child. The backstory during the familiarization phase in the robot condition was designed to reinforce this interpretation and this was mirrored in the human condition. As the human interaction partner was not a native speaker of German, it was credible that they had learnt these new words and concepts and that the child (as a young native speaker of German) could be a peer learner. We actually observed one of the participants making reference to this backstory during a later experimental session when they asked: *"Did you just learn "blue" when you came to Germany?"* In this case, the human interaction partner replied: *"Yes, in my language we have a different word for it,"* in order to answer the child in as authentically a way as possible.

With respect to the methodology applied in this study, we acknowledge the fact that other possibilities exist for the assessment of children's social referencing. Whereas, we decided to operationalize social referencing in line with typical paradigms and measured the cases in which the child visually checked in with their caregiver, one could also think of verbal behavior as a form of explicitly turning to the caregiver. In our study, however, hardly any child used this form of social referencing suggesting that our sample may have been too young to use this form. Another decision that we made concerned the amount of social referencing that we considered on average for each child. An alternative would be to look at how social referencing as a behavior develops (increases or decreases) individually over the course of one session. However, such an analysis of the development within a session would have depended heavily on the individual and his or her temperamental characteristics such as shyness (de Rosnay et al., 2006). Thus, we argue, when focusing on changes within a session, an assessment is only valuable if it is considered in relation to individual personality traits (Tolksdorf et al., 2020a), which were not examined in the work presented here.

We would also like to point to the possibility that the study design and procedure could have impacted our results. Adapting the design of the interaction from the robot experimental setting to be suitably comparable when taking place with a human interaction partner required us to make certain decisions. These pertained to verbal, non-verbal, and pragmatic aspects which relate to children's expectations about social roles and behaviors. In fact, this process of designing a comparable setting highlighted to us the difficulty inherent in controlling for potential behavioral differences between interactions and in realizing an appropriate introduction of the interaction partner so as to avoid biasing the data. The pilot sessions were therefore a crucial part of the design process. We reviewed these videotaped sessions as a group, noting and making revisions for the human interaction partner's verbal input and delivery, including non-verbal signals. As a consequence, the human interaction partner attempted to limit their visual checking as well as the coordination of their gaze between the child and the target word referents in order to be comparable with the robot. As already mentioned above, they further endeavored to inhibit their nodding and other confirmatory signals such as corrective feedback and praise. During the interaction, the human interaction partner also observed that many of the children sought eye contact with her beyond the points in the learning situation specifically scripted for it, to which it was challenging not to respond instinctively. Although implicit, non-verbal, subconscious behaviors like nodding and eye contact were therefore very difficult to consistently control for, the human interaction partner was more successful at constraining explicit verbal feedback.

## LIMITATIONS

As already suggested above, there are some limitations to our study regarding the generalizability of our results. First, our obtained results were likely influenced by the specific setting employed. The specific social robot used and the human interlocutor and their social behavior during the learning situation may have affected the child's behavior. A different social robot such as a pet-like or semi-humanoid social robot (Neumann, 2020) as well as another human interlocutor may have led to other results. Second, it is also important to emphasize that this study is limited by a relatively small sample size. We have to point out, however, that by conducting a long-term study over multiple sessions, the repeated measurement of the variable of interest over time strengthens the replicability and robustness of our findings (Smith and Little, 2018), while also allowing us to provide a particularly nuanced view of the development of children's behavior. Even though the sample size employed is in accordance with prior studies using a similar paradigm (Mcgregor et al., 2009) and we found clear differences between the groups in each session, each with a large effect size, further studies are necessary to validate our findings.

Yet another possible limitation concerns the representativeness of our results because the two groups were not balanced in gender. In this respect, past research suggests that children's social referencing to their parents is generalizable across gender (Feinman et al., 1992; Aktar et al., 2013). This finding indicates that similar behavior can be expected across gender groups, which is supported by the fact that gender-specific effects are traditionally low in the literature of social referencing (de Rosnay et al., 2006). Third, despite our best attempts to minimize differences between conditions, it is possible that some non-verbal and subconscious processes of familiarization and socialization could have already played out before the learning-situation part of the interaction began. For example, the child could already have been subconsciously aware that their caregiver had accepted the human interaction partner as a non-threat simply due to their presence and social cues during the conversation about the ethics procedures with the experimenter. However, this level of contact is arguably comparable to the familiarization and warm-up stages carried out in the robot condition, considering that the human interaction partner was also unknown to the child and further represented some novelty factor to them as a person from a different country. Finally, there were a number of other issues that we had to consider involving the course of the interactions. One question concerned whether to tightly control the length of the possible interaction between the child and human interaction partner, preventing any further interaction beyond that of the learning situation. This would have been more comparable to the robot condition (switching it on and off) but less natural and could have been disruptive for the child. As a result, when the children and their caregiver were saying goodbye and leaving, there was slightly more interaction with the human interaction partner than they would have had with the robot. This was almost unavoidable because of the need to appropriately meet their social expectations. We contemplated inventing a story for the human interaction partner that would require them to leave suddenly to "go to a meeting" or "catch a train," allowing them to cut short the interaction with the child. However, we eventually decided that this was ethically an unnecessary level of deception and that it could cause the child to develop negative ideas about the reliability of the interaction partner, regarding time-keeping for example, potentially influencing the interaction.

## CONCLUSIONS AND PERSPECTIVES

In conclusion, the findings presented here have important implications for both carrying out research with social robots and implementing them within educational practice. Our results indicate that a caregiver serves as an important resource in children's interactions with digital learning tools such as social robots (at the current technological stage) and show that social referencing emerges as an important phenomenon in child–robot interaction. In this vein, our study not only revealed that children frequently initiate non-verbal exchanges between themselves and their caregivers at certain stages during an interaction with a robot, but also do so consistently over the long-term. In contrast, children who interacted in the same learning and testing situations with an unfamiliar human interlocutor addressed their caregiver to a considerably reduced amount.

At this point, we would like to be clear in our objective: When designing technology, the solution should not be to reduce social referencing within a child–robot interaction; instead, it is important to focus on where the child needs additional support in those interactions with the goal of developing more child-oriented technologies. Thus, referring to our observations above, we can postulate some crucial aspects when designing child-oriented social robots: On the one hand, educational social robots require means of monitoring the child's engagement and understanding in the interaction while simultaneously enabling the child to monitor the state of the robot. For this reason, a social robot should utilize multiple social signals to allow the child to better interpret the ongoing interaction and to allow socioemotional perception toward the robot. This ties in with recent research highlighting that emotional expressions by a robot are expected to occur at specific stages within an interaction and can be beneficial (Fischer et al., 2019). However, many of the current social robots, including the Nao robot used here, are highly restricted in terms of their capabilities for affective expression (Song and Yamada, 2017). On the other hand, to further minimize interruptions and irritations in a child–robot dialogue, future implementations of social robots in educational contexts need a better multimodal turn-taking model in terms of the timing of the reciprocal interaction with a child (Baxter et al., 2013; Tolksdorf and Mertens, 2020). This would include, for example, a better child-specific speech recognition (Kennedy et al., 2017) to allow for a more contingent interaction and to reduce the latency of the responses of the robotic system. Clearly, the integration of these technologies will require further technical advances across a range of processes within artificial intelligence and robotics (Belpaeme et al., 2018). To conclude, addressing children's behavior and recognizing their emotional states within these interactions can inform future digital technologies and better enable their integration into the educational landscape. In future work, it would also be of interest to explore the role of a child's individual temperament in their social behavior and learning within the interaction with a social robot. This would further shed light on how suitable learning environments for children can be created in the digital world in the future.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Review Board of Bielefeld University (EUB 2014-043). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

## AUTHOR CONTRIBUTIONS

NT, CC, and KR conceived, designed, and piloted the study and drafted the manuscript. NT recruited participants and analyzed the data. NT and CC conducted the data collection. All authors commented on, edited, and revised the manuscript prior to submission.

## FUNDING

This research was supported by the Digital Society research program funded by the Ministry of Culture and Science of the German State of North Rhine-Westphalia.

## ACKNOWLEDGMENTS

We gratefully thank all the parents and children who participated in this study.

## REFERENCES


Ainsworth, M. D., Blehar, M. C., Waters, E., and Wall, S. N. (2015). *Patterns of Attachment. A Psychological Study of the Strange Situation Classic*. New York, NY: Psychology Press.

Akritas, M. G., Arnold, S. F., and Brunner, E. (1997). Nonparametric hypotheses and rank statistics for unbalanced factorial designs. *J. Am. Stat. Assoc.* 92, 258–265. doi: 10.1080/01621459.1997.10473623

Aktar, E., MajdandŽić, M., de Vente, W., and Bögels, S. M. (2013). The interplay between expressed parental anxiety and infant behavioural inhibition predicts infant avoidance in a social referencing paradigm: expressed parental anxiety and infant behavioural inhibition. *J. Child Psychol. Psychiatry* 54, 144–156. doi: 10.1111/j.1469-7610.2012.02601.x

Baldwin, D., and Moses, L. J. (1996). The ontogeny of social information gathering. *Child Dev.* 67, 1915–1935. doi: 10.2307/1131601

Baxter, P., Kennedy, J., Belpaeme, T., Wood, R., Baroni, I., and Nalin, M. (2013). "Emergence of turn-taking in unstructured child–robot social interactions," in *2013 8th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (Tokyo: IEEE), 77–78. doi: 10.1109/HRI.2013.6483509

Belpaeme, T., Kennedy, J., Ramachandran, A., Scassellati, B., and Tanaka, F. (2018). Social robots for education: a review. *Sci. Rob.* 3:eaat5954. doi: 10.1126/scirobotics.aat5954

Boccanfuso, L., Scarborough, S., Abramson, R. K., Hall, A. V., Wright, H. H., and O'Kane, J. M. (2017). A low-cost socially assistive robot and robot-assisted intervention for children with autism spectrum disorder: field trials and lessons learned. *Auton. Robot.* 41, 637–655. doi: 10.1007/s10514-016-9554-4

Breazeal, C., Harris, P. L., DeSteno, D., Kory Westlund, J. M., Dickens, L., and Jeong, S. (2016). Young children treat robots as informants. *Top. Cogn. Sci.* 8, 481–491. doi: 10.1111/tops.12192

Bruner, J. S. (1983). *Child's Talk: Learning to Use Language*. 1st ed. New York, NY: W.W. Norton.

Butterworth, G., and Jarrett, N. (1991). What minds have in common is space: Spatial mechanisms serving joint visual attention in infancy. *Br. J. Dev. Psychol.* 9, 55–72. doi: 10.1111/j.2044-835X.1991.tb00862.x

Cao, H.-L., Esteban, P. G., Bartlett, M., Baxter, P., Belpaeme, T., Billing, E., et al. (2019). Robot-enhanced therapy: development and validation of supervised autonomous robotic system for autism spectrum disorders therapy. *IEEE Robot. Automat. Mag.* 26, 49–58. doi: 10.1109/MRA.2019.2904121

Clark, H. H., and Krych, M. A. (2004). Speaking while monitoring addressees for understanding. *J. Mem. Lang.* 50, 62–81. doi: 10.1016/j.jml.2003.08.004

Coeckelbergh, M., Pop, C., Simut, R., Peca, A., Pintea, S., David, D., et al. (2016). A survey of expectations about the role of robots in robot-assisted therapy for children with ASD: Ethical acceptability, trust, sociability, appearance, and attachment. *Sci. Eng. Ethics* 22, 47–65. doi: 10.1007/s11948-015-9649-x

de Rosnay, M., Cooper, P. J., Tsigaras, N., and Murray, L. (2006). Transmission of social anxiety from mother to infant: an experimental study using a social referencing paradigm. *Behav. Res. Ther.* 44, 1165–1175. doi: 10.1016/j.brat.2005.09.003

Ehli, S., Wolf, J., Newen, A., Schneider, S., and Voigt, B. (2020). Determining the function of social referencing: the role of familiarity and situational threat. *Front. Psychol.* 11:538228. doi: 10.3389/fpsyg.2020.538228

Feinman, S., Roberts, D., Hsieh, K.-F., Sawyer, D., and Swanson, D. (1992). "A critical review of social referencing in infancy," in *Social Referencing and the Social Construction of Reality in Infancy*, ed S. Feinman (Boston, MA: Springer US), 15–54. doi: 10.1007/978-1-4899-2462-9_2

Fischer, K., Jung, M., Jensen, L. C., and aus der Wieschen, M. V. (2019). "Emotion expression in HRI – when and why," in *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (Daegu: IEEE), 29–38. doi: 10.1109/HRI.2019.8673078

Grimminger, A., and Rohlfing, K. J. (2017). "Can you teach me?: children teaching new words to a robot in a book reading scenario," in *Proceedings WOCCI 2017: 6th International Workshop on Child Computer Interaction* (Glasgow: ISCA), 28–33. doi: 10.21437/WOCCI.2017-5

Hornik, R., Risenhoover, N., and Gunnar, M. (1987). The effects of maternal positive, neutral, and negative affective communications on infant responses to new toys. *Child Dev.* 58:937. doi: 10.2307/1130534

Horst, J. S. (2013). Context and repetition in word learning. *Front. Psychol.* 4:149. doi: 10.3389/fpsyg.2013.00149

Ioannou, A., and Makridou, E. (2018). Exploring the potentials of educational robotics in the development of computational thinking: a summary of current research and practical proposal for future work. *Educ. Inf. Technol.* 23, 2531–2544. doi: 10.1007/s10639-018-9729-z

Kahle, L. R., and Argyle, M. (2014). *Attitudes and Social Adaptation: A Person-Situation Interaction Approach*. Kent: Elsevier Science.

Kanero, J., Geçkin, V., Oranç, C., Mamus, E., Küntay, A. C., and Göksun, T. (2018). Social robots for early language learning: current evidence and future directions. *Child Dev. Perspect.* 12, 146–151. doi: 10.1111/cdep.12277

Kennedy, J., Baxter, P., Senft, E., and Belpaeme, T. (2016). "Heart vs hard drive: children learn more from a human tutor than a social robot," in *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (Christchurch: IEEE), 451–452. doi: 10.1109/HRI.2016.7451801

Kennedy, J., Lemaignan, S., Montassier, C., Lavalade, P., Irfan, B., Papadopoulos, F., et al. (2017). "Child speech recognition in human-robot interaction: evaluations and recommendations," in *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction* (Vienna: ACM), 82–90. doi: 10.1145/2909824.3020229

Kozima, H., and Nakagawa, C. (2006). "Social robots for children: practice in communication-care," in *9th IEEE International Workshop on Advanced Motion Control, 2006* (Istanbul: IEEE), 768–773. doi: 10.1109/AMC.2006.1631756

Kozima, H., Nakagawa, C., and Yano, H. (2004). Can a robot empathize with people? *Artif. Life Rob.* 8, 83–88. doi: 10.1007/s10015-004-0293-9

Levinson, S. C. (2016). Turn-taking in human communication–origins and implications for language processing. *Trends Cogn. Sci.* 20, 6–14. doi: 10.1016/j.tics.2015.10.010

Mcgregor, K. K., Rohlfing, K. J., Bean, A., and Marschner, E. (2009). Gesture as a support for word learning: the case of under. *J. Child Lang.* 36, 807–828. doi: 10.1017/S0305000908009173

Nachtigäller, K., Rohlfing, K. J., and Mcgregor, K. K. (2013). A story about a word: does narrative presentation promote learning of a spatial preposition in German two-year-olds? *J. Child Lang.* 40, 900–917. doi: 10.1017/S0305000912000311

Neumann, M. M. (2020). Social robots and young children's early language and literacy learning. *Early Childhood Educ. J.* 48, 157–170. doi: 10.1007/s10643-019-00997-7

Noguchi, K., Gel, Y. R., Brunner, E., and Konietschke, F. (2012). nparLD: an R software package for the nonparametric analysis of longitudinal data in factorial experiments. *J. Stat. Softw* 50, 1–23. doi: 10.18637/jss.v050.i12

Oranç, C., and Küntay, A. C. (2020). Children's perception of social robots as a source of information across different domains of knowledge. *Cogn. Dev.* 54:100875. doi: 10.1016/j.cogdev.2020.100875

Park, H. W., Rosenberg-Kima, R., Rosenberg, M., Gordon, G., and Breazeal, C. (2017). "Growing growth mindset with a social robot peer," in *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction* (Vienna: ACM), 137–145. doi: 10.1145/2909824.3020213

Rohlfing, K. J., G., Leonardi, I., Nomikou, J., Raczaszek-Leonardi, and Hüllermeier, E. (2019). Multimodal turn-taking: motivations, methodological challenges, and novel approaches. *IEEE Trans. Cogn. Dev. Syst.* 12, 260–271. doi: 10.1109/TCDS.2019.2892991

Rohlfing, K. J., Grimminger, A., and Wrede, B. (2020a). "The caregiver's role in keeping a child–robot interaction going," in *International Perspectives on Digital Media and Early Literacy: The Impact of Digital Devices on Learning, Language Acquisition and Social Interaction*, eds K. J. Rohlfing and C. Müller-Brauers (London: Routledge), 73–89. doi: 10.4324/9780429321399

Rohlfing, K. J., Cimiano, P., Scharlau, I., Matzner, T., Buhl, H. M., Buschmeier, H., et al. (2020b). Explanation as a social practice: Toward a conceptual framework for the social design of AI systems. *IEEE Trans. Cogn. Dev. Syst.* 1–12. doi: 10.1109/TCDS.2020.3044366

Rohlfing, K. J., Wrede, B., Vollmer, A.-L., and Oudeyer, P.-Y. (2016). An alternative to mapping a word onto a concept in language acquisition: pragmatic frames. *Front. Psychol.* 7:470. doi: 10.3389/fpsyg.2016.00470

Serholt, S. (2018). Breakdowns in children's interactions with a robotic tutor: a longitudinal study. *Comput. Hum. Behav.* 81, 250–264. doi: 10.1016/j.chb.2017.12.030

Smith, P. L., and Little, D. R. (2018). Small is beautiful: in defense of the small-N design. *Psychon. Bull. Rev.* 25, 2083–2101. doi: 10.3758/s13423-018-1451-8

Song, S., and Yamada, S. (2017). "Expressing emotions through color, sound, and vibration with an appearance-constrained social robot," in *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction* (Vienna: ACM), 2–11. doi: 10.1145/2909824.3020239

Tolksdorf, N. F., and Mertens, U. (2020). "Beyond words: children's multimodal responses during word learning with a robot," in *International Perspectives on Digital Media and Early Literacy: The Impact of Digital Devices on Learning, Language Acquisition and Social Interaction*, eds K. J. Rohlfing and C. Müller-Brauers (London: Routledge), 90–102.

Tolksdorf, N. F., Siebert, S., Zorn, I., Horwath, I., and Rohlfing, K. J. (2020a). Ethical considerations of applying robots in kindergarten settings: towards an approach from a macroperspective. *Int. J. Soc. Rob.* doi: 10.1007/s12369-020-00622-3. [Epub ahead of print].

Tolksdorf, N. F., Viertel, F., and Rohlfing, K. J. (2020b). "Do shy children behave differently than non-shy children in a long-term child–robot interaction?: an analysis of positive and negative expressions of shyness in kindergarten children," in *Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction* (Cambridge: ACM), 488–490. doi: 10.1145/3371382.3378367

Tomasello, M. (1999). *The Cultural Origins of Human Cognition*. Cambridge, MA: Harvard University Press.

Vaish, A., and Striano, T. (2004). Is visual reference necessary? Contributions of facial versus vocal cues in 12-month-olds' social referencing behavior. *Dev. Sci.* 7, 261–269. doi: 10.1111/j.1467-7687.2004.00344.x

van den Berghe, R., Verhagen, J., Oudgenoeg-Paz, O., van der Ven, S., and Leseman, P. (2019). Social robots for language learning: a review. *Rev. Educ. Res.* 89, 259–295. doi: 10.3102/0034654318821286

Vaughn, S., and La Greca, A. (1992). "Beyond greetings and making friends: social skills from a broader perspective," in *Contemporary Intervention Research in Learning Disabilities*, ed B. Y. L. Wong (New York, NY: Springer New York), 96–114. doi: 10.1007/978-1-4612-2786-1_6

Viertel, F. E. (2019). *Training of Visual Perspective-taking (level 1) by Means of Role Reversal Imitation in 18-20-month-olds With Particular Regard to the Temperamental Trait Shyness.* Paderborn: Paderborn University Library.

Vogt, P., de Haas, M., de Jong, C., Baxter, P., and Krahmer, E. (2017). Child–robot interactions for second language tutoring to preschool children. *Front. Hum. Neurosci.* 11, 1–6. doi: 10.3389/fnhum.2017.00073

Vogt, P., van den Berghe, R., de Haas, M., Hoffman, L., Kanero, J., Mamus, E., et al. (2019). "Second language tutoring using social robots: a large-scale study," in *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (Daegu: IEEE), 497–505. doi: 10.1109/HRI.2019.8673077

Vollmer, A.-L., Pitsch, K., Lohan, K. S., Fritsch, J., Rohlfing, K. J., and Wrede, B. (2010). "Developing feedback: how children of different age contribute to a tutoring interaction with adults," in *2010 IEEE 9th International Conference on Development and Learning* (Ann Arbor, MI: IEEE), 76–81. doi: 10.1109/DEVLRN.2010.5578863

Vollmer, A.-L., Read, R., Trippas, D., and Belpaeme, T. (2018). Children conform, adults resist: A robot group induced peer pressure on normative social conformity. *Sci. Rob.* 3:eaat7111. doi: 10.1126/scirobotics.aat7111

Walden, T. A., and Baxter, A. (1989). The effect of context and age on social referencing. *Child Dev.* 60, 1511–1518. doi: 10.2307/1130939

Wrede, B., Kopp, S., Rohlfing, K., Lohse, M., and Muhl, C. (2010). Appropriate feedback in asymmetric interactions. *J. Pragmat.* 42, 2369–2384. doi: 10.1016/j.pragma.2010.01.003

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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