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Early social experience: Impact on early and later social-cognitive development

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Early social experience: Impact on early and later social-cognitive development

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Editorial: Early social experience: impact on early and later social-cognitive development

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Editorial on the Research Topic
Early social experience: impact on early and later social-cognitive development

Humans are social beings, and engage in social interactions from early in life. Yet, grasping early social-cognitive development is incredibly complex: besides a child's genetic predisposition, there are a wide variety of environmental experiences, across nested time scales, which are shaping a child's social-cognitive development (e.g., Masten and Cicchetti, 2010; d'Souza et al., 2017; Junge et al., 2020; Tamis-LeMonda, 2023). To further capture the broad range of social experiences, this Research Topic aimed to bring together research that addressed how infants' and young children's social environments shape their early and later social and cognitive development from a variety of perspectives, including both empirical and theoretical papers, spanning typical and atypical populations.

This Research Topic showcases the complexity of social-cognitive development in a variety of ways. For example, it spans a wide range of social experiences: it includes empirical papers ranging from micro-level factors such as parenting styles (He et al.; Iwasaki et al.; Kim; Krijnen et al.; Ramos et al.) and other daily life experiences (Guellai et al.; McCall et al.) to macro-level experiences such as COVID-19 (Almeida et al.; Wermelinger et al.). In addition, it encompasses empirical research on a variety of neurotypical and neurodivergent populations (ASD: He et al.; Adoptees: Ramos et al.; Preterm infants: Krijnen et al.). There is further a great variety in empirical methods employed to capture this development: spanning behavioral observations, eye-tracking (He et al.), and network analyses (Burke et al.). Finally, this Research Topic covers not only empirical research but also provides a case report (McCall et al.), a theoretical paper (Belteki et al.), and a review (Guellai et al.). All in all, this Research Topic fully embraces the complexity of social experiences, as it considers a variety of experiences, outcomes, populations, methods, and approaches, all of which contribute in shaping early development.

As we framed this Research Topic in terms of outcomes on social-cognitive development, authors defined this in various, compelling manners. They examined the influence of early experience upon self-esteem (Kim), emotion labeling (Wermelinger et al.), language development (Bazhydai et al.; Belteki et al.; He et al.), curiosity (Iwasaki et al.), social competence and psychosocial behavior (Krijnen et al.; Ramos et al.; Zhu et al.), and attention and cognitive development more broadly defined (Almeida et al.).

In addition to the scientific impact, these outcomes are also relevant because of the potential interest beyond academia in terms of implications for society. For example, the interest in children's screentime and media exposure (Almeida et al.; Guellai et al.) is a pressing issue for caregivers, policy-makers, and educators alike. Moreover, the consequences of various parenting styles and the development of social networks (Burke et al.; He et al.; Iwasaki et al.; Kim; Krijnen et al.; Ramos et al.) may help inform caregivers and educators. The potential impact of foster care, adoption, and government policies relating to children in care (McCall et al.) is relevant for practitioners and policy-makers. The effects of COVID-19 (Almeida et al.; Wermelinger et al.) are important to consider both for facilitating recovery and future-proofing against potential issues for children and families when global crises may arise.

The impact for both academia and society is even stronger given the striking diversity of researchers who contributed to this Research Topic. The articles come from authors across five continents (Africa, Asia, Europe, North America, and South America) and 14 countries. Including a diversity of both researchers and participants is critical for moving global developmental science forward (Apicella et al., 2020; Moriguchi, 2022; Singh et al., 2023). As such, we hope that this Research Topic models the move toward embracing not only a complexity of methodologies but also the benefits of taking an international view of development and including both researchers and children and families from diverse regions across the globe.

Author contributions

SG: Conceptualization, Writing—original draft, Writing—review and editing. MM: Conceptualization, Writing—original draft, Writing—review and editing. CJ: Conceptualization, Writing—original draft, Writing—review and editing.

Conflict of interest

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Maternal Responsive Parenting Trajectories From Birth to Age 3 and Children's Self-Esteem at First Grade

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This paper examines the quality and stability of the responsive parenting practices of mothers with infants and the longitudinal links between these practices and children's self-esteem. Using data presented by the Panel Study on Korean Children, this study identified Korean mothers' responsive parenting trajectories from birth to age three and examined their associations with children's self-esteem at first grade. Korean mothers developed one of three responsive parenting patterns from birth to age three: low (19.0%), moderate (66.0%), or high (15.0%). Children's self-esteem differed according to their mother's responsive parenting trajectory. First-graders with mothers displaying the low responsive parenting trajectory were more likely to have lower self-esteem than children of mothers with the moderate responsive parenting trajectory and children of mothers with the high responsive parenting trajectory. The longitudinal link between mother-reported responsive parenting patterns during infancy and child-reported self-esteem at first grade was verified. This finding highlights the significance of early responsive parenting from mothers as a predictor of the self-esteem of children in later developmental stages.

Keywords: responsive, trajectory, self-esteem, parenting, first grade

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INTRODUCTION

Self-esteem plays a key role in an individual's psychological foundation and deeply influences major life outcomes (Orth et al., 2012). For that reason, identifying predictors of self-esteem has been an essential topic in psychology, education, and mental health research. Many studies have focused on the role of parents in developing children's self-esteem. The general purpose of these studies was to portray the best parenting types or styles for fostering children's positive self-esteem (Tam et al., 2012; Moghaddam et al., 2017). Thus far, the authoritative parenting style (i.e., high warmth and high control) and the permissive parenting style (i.e., high warmth and low control) have been positively linked to high self-esteem in children and adolescents (Milevsky et al., 2007; Pinquart and Gerke, 2019).

Considering that the common feature of both the authoritative and permissive styles is high warmth, the key to fostering positive self-esteem may be in providing affectionate, immediate and appropriate responses contingent on children's needs. The term "responsiveness" has been used to describe responding with understanding and support to fulfill the needs and goals of a partner (Reis and Clark, 2013). The degree of responsiveness in parental behaviors is a key indicator of the quality of parenting (Knauer et al., 2019). High responsiveness in parenting has been known to strengthen parents' relationships with their children and support children's healthy development (Raval et al., 2001; Knauer et al., 2019). Meanwhile, it has been found that the quality, duration, and timing of experiences result in different human development outcomes (Linstead et al., 2017; Milner et al., 2018). More intense experiences over a longer duration at earlier stages of development result in more significant developmental differences. Who is associated with the experiences also matters. The profound impact of maternal parenting on child outcomes has been well validated (Milevsky et al., 2007; Wittig and Rodriguez, 2019). When we adapt these developmental notions to parenting and children's self-esteem, differences in the intensity and stability of responsiveness in maternal parenting during infancy may yield differences in children's self-esteem.

Among the many viewpoints on the causal mechanism between early responsive parenting and children's self-esteem development, the most classic view may be the attachment perspective. In the attachment perspective, the quality of parenting contributes to the development of the internal working model concerned with interpreting the self and others (Bowlby, 1982). If parents have been highly sensitive to and available for the child's needs, the child constructs a model of the self as worthy and lovable. Conversely, if parents have not been sensitive and accessible, the child interprets the self as unworthy and unacceptable (Bretherton et al., 1990). The links between attachment and self-esteem in adolescents and adult populations has been verified (Laible et al., 2004; Curran et al., 2021). For example, Laible et al. (2004) reported that a direct path exists between secure attachment and high self-esteem among college students in the United States. Curran et al. (2021) investigated how attachment styles were related to self-esteem in mother–adult child dyads in the United States. They reported that the secure attachment style was linked to high self-esteem in both generations.

The contemporary claim is that early responsive parenting builds a sound brain foundation for supporting children's healthy social, emotional, and cognitive development (Belsky and De Haan, 2011). Bernier et al. (2016) investigated the links between the observed quality of mother–infant interactions and brain development in a normative sample of 352 mother–infant dyads. They reported that higher-quality mother–infant interactions predicted a higher frontal resting electroencephalography (EEG) power in infants, indicating more neural activity. Chen et al. (2021) investigated the neural bases of self-esteem in school-aged children. They found that children's self-esteem was positively related to spontaneous activity in the right dorsolateral prefrontal cortex (dlPFC). They suggested that dlPFC might be a core brain region involved in promoting self-related cognitive processing in high self-esteem children. Considering the claim that early intensive and positive experiences during infancy can alter the brain's functions and structures (Als et al., 2004), it is likely that high-quality responsive parenting from mothers during infancy enhances children's brain structure related to self-esteem. Moreover, the impact embedded in the neurological foundation will extend into later developmental periods and will be observed as forming positive self-esteem.

Meanwhile, to clearly understand the role of maternal responsive parenting on children's self-esteem development, identifying distinct sub-groups of mothers sharing a similar stability and intensity pattern of responsiveness can be effective (Ram and Grimm, 2009). Some studies, taking a person-centered perspective, have identified latent profiles of parenting behaviors among mothers with young children (Cook et al., 2012; Paschall and Mastergeorge, 2018; Farkas et al., 2020). For example, Cook et al. (2012) identified three latent groups with distinct parenting practices among Early Head Start mothers across three points in time when children were 14, 24, and 36 months: developmentally supportive, unsupportive, and negative. They reported that mothers' latent group memberships were stable across these three points. Farkas et al. (2020) identified three different clusters among 90 Chilean mothers sharing similar parenting competencies at two different points in time, when children were at 12 and 30 months: highly competent, average competent, and poorly competent. Unlike the claims of Cook et al. (2012), the Chilean mothers increased their parenting competences. Only 16.7% of the mothers classified into the poorly competent group when children were at 12 months remained in the same group when children were at 30 months. The other mothers moved into the average or highly competent groups. The results of these studies imply that the quality of parenting behaviors cannot be explained with a single trend or profile and that there are some groups of mothers who deviate from normative trends in the quality and stability of their parenting behaviors.

However, few studies have endeavored to capture both within-group changes and between-group differences in responsive parenting among a normative sample of mothers. Previous studies in general have tried to identify a single trajectory representing the parenting practices of at-risk or clinical populations (Bornstein et al., 2008; Kim et al., 2010; Ettinger et al., 2018) or have searched for course modifiers (Azak and Raeder, 2013). Like other behaviors or psychological traits such as depressive symptoms (Kim, 2017) or alcohol use (De Genna et al., 2017), mothers' parenting practices can vary in stability and intensity. Mothers with infants may be classified into multiple groups, each sharing similar stability and intensity of responsiveness. Group differences in the stability and intensity of mothers' parenting practices indicates that the children of mothers in each group experience distinct parenting practices. Considering that the stability and intensity of experiences is associated with developmental outcomes (Liu et al., 2021), distinct trajectories of maternal responsive parenting can be a source of differences in children's self-esteem in later years.

To sum up, the present study will investigate the associations between mothers' early responsive parenting trajectories and their children's self-esteem at first grade using a normative nationwide Korean sample. Self-esteem emerges in an individual's early years and changes across one's lifespan according to important life events or transitions (Chung et al., 2017; Orth et al., 2018). Entering the first grade is a crucial life transition. The transition from early childhood centers to elementary school also indicates the transition from early childhood to middle childhood. First-graders must adjust to new school environments and find their standing as social and academic beings among their peers. Self-esteem measured at first grade may reflect how children have grown up, while predicting how they will adjust in a school setting (Entwisle et al., 2005).

The Current Study

Few studies have examined the quality and stability of the responsive parenting practices of mothers with infants and the longitudinal links between these practices and children's self-esteem. Using data presented by the Panel Study on Korean Children, this study identified Korean mothers' responsive parenting trajectories from birth to age three and examined the associations with children's self-esteem at first grade. The study proposed two specific hypotheses. First, Korean mothers with infants will be classified into several distinct groups sharing a similar intensity and stability in their responsive parenting. This assumption is based on other related literature classifying normative samples of people into several distinct groups displaying similar intensity and stability in behavioral patterns. Like other human behaviors or traits, responsiveness in maternal parenting is anticipated to change over time. This study intends to capture the within-group changes and the between-group differences in maternal responsive parenting as multiple trajectories. Second, it is expected that first-graders who experienced more stable and intense responsive parenting from their mothers from birth to age three will score higher on the self-esteem measure than their peers. This hypothesis is rooted in the concept that more intense experiences over a longer duration at earlier stages of development result in more significant developmental differences; it is also based on the insight that high-quality parenting contributes to developing children's neuro-psychological foundations in a positive manner.

MATERIALS AND METHODS

Participants

The analyses for this study are based on data from the Panel Study on Korea Children (PSKC). The PSKC is an ongoing nationwide data collection project conducted by the Korea Institute of Child Care and Education. The PSKC provides comprehensive information on child development, parenting, family function, and policy effectiveness in Korean households. A total of 2,150 households with infants born between April and July 2008 were sampled using a stratified multi-stage method. The sample retention rate when children reached age 7 was 74.3%. The characteristics of participants are presented in **Table 1**.

Maternal Responsive Parenting

Maternal responsive parenting was measured with six items excerpted from the Korean version of the Parenting Style Questionnaire (Bornstein, 1989; Bornstein et al., 1996; Korea Institute of Childcare and Education, 2022). Using the six items (e.g., I understand what my child wants or how he/she feels; I promptly and appropriately respond to my child's expressed distress or discomfort), mothers rated their responsiveness from 1 (hardly at all) to 5 (all the time) at age 0, 1, 2, and 3. High scores indicated that mothers display prompt, affectionate, and appropriate responses when they interact with their children. The internal consistencies (Cronbach's alpha) of the six items across four years were 0.820, 0.833, 0.847, and 0.830, respectively.

Self-Esteem of Children

Five items from the Rosenberg self-esteem questionnaire (Rosenberg, 1965; Korea Institute of Childcare and Education, 2022) translated into Korean were employed for this study. The original Rosenberg self-esteem questionnaire consisted of ten items. The PSKC research team selected five items from the ten to measure first-graders' self-esteem in reference to the prior work of the Millennium Cohort Study in the UK. To measure the self-esteem of first-graders, trained interviewers visited children's homes and guided them to respond to each question from 1 (strongly disagree) to 4 (strongly agree). The internal consistency (Cronbach's alpha) of the five-item self-esteem questionnaire for this study was 0.77. Higher scores indicated that the first-graders had more positive self-esteem.

Analyses

The current study followed the standard three-step method proposed by Van De Schoot et al. (2017). First, mothers' responsive parenting trajectories from birth to age three were identified with latent class growth analysis by assuming the variances and covariances of the growth factors within each class were zero. By adopting the unconditional latent class growth analysis, the current study explored the number of latent classes without considering covariates. It enables future studies to replicate the research and compare results. Missing values were treated using maximum likelihood estimation under missing completely at random, the default function in Mplus 8.0. Second, the most likely class membership of maternal responsive parenting was saved as the independent variable into the main data. Third, for exploring differences in children's self-esteem by maternal responsive parenting trajectories, analysis of covariance was conducted separately from the latent trajectory modeling. The most likely class membership of maternal responsive parenting was used as the fixed factor and children's self-esteem as the dependent variable. Bonferroni multiple comparison tests were used for *post hoc* comparison.

Covariates

Several variables likely to be linked to mothers' parenting behaviors or children's self-esteem were entered into analysis of covariance. Child sex (boys, girls), child birth weight (kg), and birth complications (i.e., intensive care unit treatment or hospitalization: yes, no) were extracted from the first-wave data (child age 0). Maternal and paternal education (2-year college education and more: yes, no), maternal employment (yes, no), family monthly income (Korean won), mothers' depressive symptoms, and children's behavior problems were extracted from the sixth-wave data (child age 7).

Mothers' depressive symptoms were measured with the Korean version of the Kessler Screening Scale for Psychological

TABLE 1 | Descriptive characteristics of participants.

Characteristics	Maternal responsive parenting trajectory group: Low M (SD)	Low %	Moderate M (SD)	Moderate %	High M (SD)	High %	Total M (SD)	Total %	Test statistics
Child sex (boy)[a]		53.8		50.2		49.0		50.7	$X^2_{(2, N=2,101)}=2.058$
Birth weight (kg)[a]	3.265 (0.422)		3.255 (0.401)		3.274 (0.435)		3.260 (0.410)		$F_{(2, 2021)}=0.307$
Birth complication (yes)[a]		11.5		14.0		15.9		13.8	$X^2_{(2, N=2018)}=2.943$
Maternal education (2 year college and more)[b]		58.2		75.0		69.9		70.9	$X^2_{(2, N=1,584)}=33.411$***
Paternal education (2 year college and more)[b]		65.2		75.4		75.2		73.3	$X^2_{(2, N=1,559)}=13.155$**
Maternal employment (yes)[b]		48.7		43.4		43.9		44.6	$X^2_{(2, N=1,562)}=2.781$
Family monthly income (Korean won)[b]	431.643 (210.633)		466.393 (197.545)		489.953 (200.852)		462.566 (201.348)		$F_{(2, 1,570)}=5.976$***
Maternal depressive symptoms[b]	12.455 (4.762)		10.909 (4.223)		9.724 (4.032)		11.057 (4.384)		$F_{(2, 1,547)}=27.226$***
Behavioral problems[b]	19.416 (14.812)		14.170 (12.560)		12.052 (18.486)		14.935 (14.152)		$F_{(2, 1,567)}=22.323$***
Child reported self-esteem[b]	16.595 (2.715)		17.328 (2.348)		17.592 (2.621)		17.215 (2.484)		$F_{(2, 1,552)}=13.551$***

[a]*Child age at 0.*
[b]*Child age at 7.*
***p < 0.01; ***p < 0.001.*

Distress (K-K6; Kessler et al., 2003; Korea Institute of Childcare and Education, 2022), which is a six-item self-reporting instrument. Mothers rated their emotional states over the past 30 days with 5-point Likert scales. The internal consistency (Cronbach's alpha) was 0.919. Children's behavioral problems were measured with the Korean version of the Child Behavior Checklist for Ages 6–18 (CBCL 6–18; Achenbach and Rescorla, 2001; Oh et al., 2010). The Korean version of CBCL 6–18 consisted of 120 items, and mothers rated their children's behavior from 0 (not true) to 2 (very true or often true). The total behavior problem scores from the Korean version of CBCL 6–18 were utilized for the present study.

RESULTS

Trajectories of Maternal Responsive Parenting From Birth to Age Three

As a process for identifying the best group model for maternal responsive parenting trajectories, one- to five-group models were consecutively tested both in linear and quadratic shapes with latent class growth analysis. Statistical indices including entropy (close to 1), Bayesian information criteria (BIC; the smaller the better), the smallest class size (at least 5% of the total cases), bootstrap likelihood ratio tests (BLRT), and Lo–Mendell–Rubin likelihood ratio tests (LMR-LRT) were considered for determining the best group model (Jung and Wickrama, 2008). The overall rationality for the classification and independence between trajectories in each model was graphically judged using plots of sample and estimated means.

Statistical indices and graphics of the latent class growth analyses indicated that the three-class quadratic model best describes Korean mothers' responsive parenting from birth to age three (**Table 2**). The four-class models showed the highest entropy and the lowest BIC; however, they found classes with less than 5% of the total cases. The three-class models displayed acceptable BLRT and LMR-LRT results and found no classes with less than 5% of the total cases. The entropy and BIC of the three-class quadratic model were better than those of the three-class linear model. The plots of sample means graphically indicate independence between trajectories (**Figure 1**).

In the three-class quadratic model (**Table 3**), the majority of mothers (66.0%) displayed a moderate level of responsiveness in their parenting. The sample mean of their responsive parenting scores at child age 0 was 24.584, and 23.218 at age three. The differences in responsive parenting scores within the trajectory are significant. The responsive parenting scores decrease from birth to age three with meaningful linear and quadradic changes (Slope = −1.168, $p < 0.001$, Quadradic = 0.242, $p < 0.001$). This group of mothers is considered to have *moderate responsive parenting* trajectory. About 19% of mothers displayed a low level of responsive parenting. The sample mean of their responsive parenting scores at child age 0 was 21.203, and 19.626 at age three. There were significant differences in the responsive parenting scores within the trajectory. Their responsive parenting scores decreased from birth to age three with meaningful linear and quadradic changes (Slope = −1.512,

TABLE 2 | Statistical indices for 1–4 trajectories of maternal responsive parenting from child age 0 to 3.

Number of trajectories		BIC	Entropy	The smallest class (% of total cases)	BLRT *p* value	LMR-LRT *p* value
1	Linear	36530.221				
	Quadratic	36530.221				
2	Linear	35217.756	0.683	30.319	0.0000	0.0000
	Quadratic	35171.398	0.684	30.462	0.0000	0.0000
3	Linear	34695.771	0.734	14.755	0.0000	0.0000
	Quadratic	34638.384	0.739	14.755	0.0000	0.0000
4	Linear	34591.506	0.770	1.142	0.0000	0.0000
	Quadratic	34531.276	0.775	1.190	0000	0000

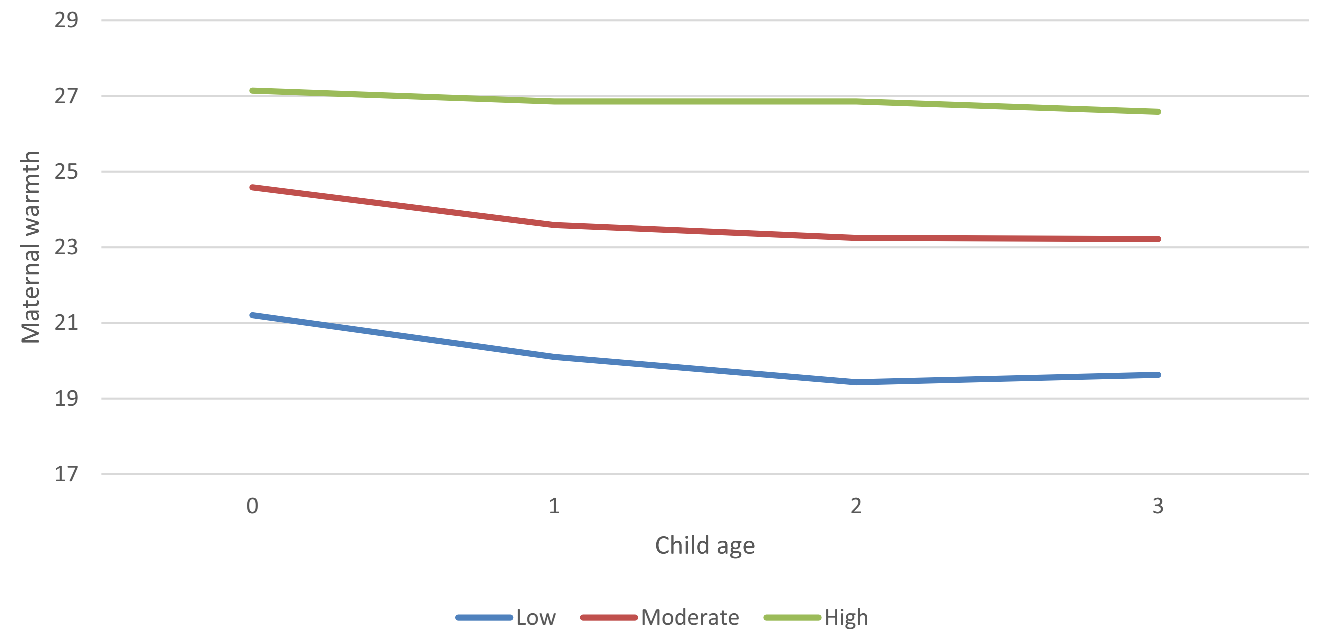

FIGURE 1 | Trajectories of maternal responsive parenting from birth to age 3: sample means.

$p < 0.001$, Quadradic = 0.323, $p < 0.001$). This group of mothers is considered to have *low responsive parenting* trajectory.

Approximately 15% of mothers displayed a constant and high level of responsive parenting. The sample mean of their responsive parenting scores at child age 0 was 27.142, and 26.584 at age three. Unlike in the other trajectories, no significant differences in responsive parenting scores existed within the trajectory (Slope = −0.179, Quadradic = 0.004). This group of mothers is considered to have high *responsive parenting trajectory.*

Self-Esteem of First-Graders by Maternal Responsive Parenting Trajectories From Birth to Age Three

Simple correlation results between maternal responsive parenting scores and child self-esteem at first grade are presented in **Table 4**. The correlations between maternal responsive parenting scores across four years are significant. Also, first graders' self-esteem was positively correlated with maternal responsiveness scores. As **Table 5** presents, the main effects of the maternal responsive parenting trajectories are statistically valid in first graders' self-esteem, after controlling confounders. The *post hoc* comparison results (**Table 6**) revealed that first graders whose mothers have the low responsive parenting trajectory display significantly lower self-esteem than children whose mothers have the moderate responsive parenting trajectory or the high responsive parenting trajectory. However, there is no statistically meaningful difference in self-esteem between children whose mothers have the moderate responsive parenting trajectory and children whose mothers have the high responsive parenting trajectory.

A series of analyses of covariance were additionally conducted to compare the effect size of the maternal responsive parenting trajectories with those of the maternal responsive parenting scores each year. As presented in **Table 7**, the effect size of the maternal responsive parenting trajectories was larger than those of maternal responsive parenting scores at childbirth, age 1, age 2, and age 3.

TABLE 3 | Sample means of maternal responsive parenting from child age 0 to 3 by trajectories ($n = 2,101$).

Child age	Low $N = 405$, 19.3%	Moderate $N = 1,386$, 66.0%	High $N = 310$, 14.8%
0	21.203	24.584	27.142
1	20.101	23.588	26.858
2	19.432	23.248	26.854
3	19.626	23.218	26.584
Intercept (*SE*)	21.230 (0.257)***	24.563 (0.112)***	27.110 (0.147)***
Slope (*SE*)	−1.512 (0.257)***	−1.168 (0.105)***	0.179 (0.271)
Quadradic (*SE*)	0.323 (0.073)***	0.242 (0.033)***	0.004 (0.080)

****p* < 0.001.*

TABLE 4 | Correlations between maternal responsive parenting scores from birth to age 3 and child self-esteem at first grade ($n = 1,560$).

S. No.	Variables	1	2	3	4	5
1.	Maternal responsive parenting score at child age 0	1	0.515***	0.446***	0.434***	0.091**
2.	Maternal responsive parenting score at child age 1		1	0.544***	0.505***	0.062*
3.	Maternal responsive parenting score at child age 2			1	0.590***	0.080**
4.	Maternal responsive parenting score at child age 3				1	0.117***
5.	Child self-esteem at first grade					1

**p* < 0.05; ***p* < 0.01; ****p* < 0.001.*

DISCUSSION

This study was conducted with two specific goals. The first goal was to identify responsive parenting trajectories among Korean mothers from birth to age three. The second goal was to examine the associations between mothers' responsive parenting trajectories and children's self-esteem at first grade. Here the researcher presents those findings and implications. A discussion of the present study's limitations and suggestions for intervention practices and future research will follow.

First, as expected, distinct multiple responsive parenting patterns appeared among Korean mothers with infants. Korean mothers developed one of three responsive parenting trajectories from birth to age three: low (19%), moderate (66.0%), or high (15%). The current findings propose that mothers' parenting behaviors may be better explained with multiple latent groups rather than a single path model. Regarding the stability of responsiveness, in this study, mothers practicing the highest level of responsiveness at childbirth maintained that quality of parenting up to toddlerhood. On the other hand, mothers practicing the moderate or the low level of responsiveness at childbirth did not maintain or increase the intensity of their responsiveness. Previous studies on stability in parenting quality have yielded inconsistent results. For example, Roskam and Meunier (2012) reported that the supportive parenting of mothers with children aged two to nine years decreased over time. Ettinger et al. (2018), on the contrary, claimed that the parenting practices of low-income ethnically diverse mothers with children under age five improved over time as the children aged. Cook et al. (2012) claimed that the parenting practices of Early Head Start mothers were stable across three time points (at 14, 25, and 36 months). The discrepancies between studies are probably due to differences in their sample populations' characteristics, children's ages, parenting behavior measures, numbers of trials of the data collection, and time intervals between the data collection (King et al., 2018). The current findings suggest that multiple longitudinal responsive parenting patterns exist in the normative sample of mothers with infants, and that each group is distinct in its stability of responsiveness.

It is notable that the hierarchy of responsiveness of the three groups remained stable from birth to age three. No group of mothers showed a dramatic increase or decrease of responsive parenting practices, though there might have been some meaningful mean-level changes within the middle and the low trajectories. The maintenance of the hierarchy between trajectories has been observed in studies of personality developmental paths (Specht et al., 2011). On the other hand, in studies addressing clinical issues such as depressive symptoms (Kim, 2017) or alcohol use (De Genna et al., 2017), groups of people often display dramatic changes in symptoms or behaviors and cross the trajectories of the other groups. The current findings suggest that between-trajectory differences in maternal responsive parenting may be minimal in a normative sample, yet the within-trajectory differences may differ by the initial level of responsiveness.

These features of maternal responsive parenting impose both challenges and opportunities for parent intervention fields. The goal of parent interventions is to promote child outcomes by adjusting parenting behaviors. For some mothers, such as mothers with low responsiveness in parenting at childbirth, stabilizing their parenting responsiveness to the level practiced at childbirth may be difficult. Intervention practitioners must have a thorough understanding of the parenting features of their target group and should set appropriate goals and matching intervention strategies. On the other hand, it is promising that when high responsiveness in parenting is established at childbirth, mothers tend to maintain that quality during early childhood. Thus, for at-risk parents, strong alliances with practitioners need to be forged as early as possible (Landry et al., 2008). During pregnancy or early infancy are considered the best times for responsive parenting practice interventions.

Second, there was a significant main effect of maternal responsive parenting trajectories from childbirth to age three in children's self-esteem at first grade. The main effect was valid after controlling several meaningful confounders such as child sex, maternal depression, and children's behavioral problems. First-graders who experienced the low level of maternal responsive parenting from birth to age three had significantly lower explicit self-esteem as compared to first-graders who experienced the moderate or the high level of maternal responsive parenting. The current findings confirm the existing claim that parenting is associated with children's self-esteem (Milevsky et al., 2007; Pinquart and Gerke, 2019). So far, studies reporting meaningful links between parenting and the self-esteem of children have mostly employed cross-sectional research designs, which leaves uncertainty in the casual direction. The current findings underscore that experiencing stable and responsive parenting from mothers during infancy contributes to later positive and healthy self-esteem development. Also, children's self-esteem in first grade was better explained by the longitudinal trajectories of maternal parenting practices than those observed in a single time point.

TABLE 5 | Main effects of maternal responsive parenting trajectories on self-esteem of first graders.

Variables	Self-esteem (n = 1,403)	
	Partial η^2	p Values
Child sex	0.014	0.000
Birth weight	0.001	0.286
Birth complication	0.001	0.309
Maternal education	0.000	0.964
Paternal education	0.002	0.144
Maternal employment	0.001	0.371
Family monthly income	0.002	0.065
Maternal depressive symptoms	0.004	0.026
Behavioral problems	0.003	0.028
Trajectories of maternal responsiveness parenting	0.014	0.000
	$F_{(2,1,391)} = 10.152$***	

****p* < 0.001.*

This highlights the value of examining latent trajectories of parenting practices in predicting children's outcomes.

Meanwhile, there are no meaningful differences in self-esteem between the children of mothers with the moderate responsive parenting trajectory (the majority group of children) and children of mothers with the high responsive parenting trajectory. The level of responsiveness and the stability observed in the high trajectory group of mothers is desirable, but these may not be the goals or standards applicable to all parents. For children who struggle with developing positive judgments about their self-worth in attachment relations in family contexts, active compensative interventions may be necessary. Considering self-esteem in early adolescence predicts mental health outcomes in late adolescence and early adulthood (Masselink et al., 2018); low self-esteem may indicate unstable developmental foundations or act as a forerunner of other psychological issues. Developmental plasticity is still high in middle childhood (Buttelmann and Karbach, 2017), and self-esteem changes across one's lifespan. Safe and encouraging outside-home relationships may be beneficial for these children. In middle childhood, social bonds with outside-home family members have special meaning in children's lives. Peers and adults can play a crucial role as attachment figures. In close, secure, and reliable relationships with peers and adults, children can build or reshape their self-concepts as worthy and acceptable (Chu et al., 2010; Gorrese and Ruggieri, 2013).

Another emerging intervention approach is cognitive training. A recent study reported that a three-month socio-cognitive training intervention for increasing meta-cognitive perspectives on the self and others induced changes in participants' emotional self-descriptions and concomitant structural changes in the brain regions related to self-concept (Lumma et al., 2018). Training or programs promoting direct changes in children's brain structures related to self-esteem can be considered as options for self-esteem interventions, though intensive empirical research should be conducted to prove their validity and long-term effectiveness for children (Rossignoli-Palomeque et al., 2018).

Taken together, this study identified three longitudinal responsive parenting patterns in a normative sample of Korean mothers with infants: high, moderate, and low. Responsiveness in maternal parenting behavior has longitudinal rank-order stability, indicating that the between trajectory differences are minimal. The within-trajectory differences vary according to the initial levels of maternal responsiveness. The group of mothers showing the highest responsiveness at the time

TABLE 6 | Self-esteem of first graders by trajectories of maternal responsive parenting (n = 1,403).

	Trajectory group			Group comparison
	Low (a)	Moderate (b)	High (c)	
	***M* (*SE*)**	***M* (*SE*)**	***M* (*SE*)**	
Self-esteem	16.691 (0.144)	17.344 (0.078)	17.619 (0.174)	a < b*** a < c***

*Adjusted variables are child sex, child birth weight, child birth complication, maternal education, paternal education, maternal employment, family monthly income, maternal depressive symptoms, and behavioral problems of first graders. ***p* < 0.001.*

TABLE 7 | Effect sizes (Partial η^2): trajectories of maternal responsive parenting vs. maternal responsive parenting scores.

Maternal responsive parenting trajectories	vs.	Maternal responsive parenting score at child age 0
0.011***		000
Maternal responsive parenting trajectories	vs.	Maternal responsive parenting score at child age 1
0.016***		0.002
Maternal responsive parenting trajectories	vs.	Maternal responsive parenting score at child age 2
0.013***		0.001
Maternal responsive parenting trajectories	vs.	Maternal responsive parenting score at child age 3
0.005*		0.001

*No adjusted variables. *p < 0.05; ***p < 0.001.*

of childbirth maintained the intensity of their responsiveness as children aged; the other groups of mothers did not maintain or increase their responsiveness. Parental intervention practitioners should understand the unique features of the maternal parenting practices of their target groups and set appropriate goals and strategies. Meaningful links were found between maternal responsive parenting trajectories from birth to age three and children's self-esteem at first grade. Children of mothers with the low responsive parenting trajectory reported significantly lower self-esteem at first grade than their peers. Low self-esteem in middle childhood linked to prior low-quality maternal parenting may indicate a vulnerability in neuro-psychological foundations. These children should be prioritized in compensatory out-home interventions for building up sound self-concepts and enhancing developmental foundations.

The findings of this study should be considered in light of several limitations. First, the attrition of data may affect the results of this study. The analysis for identifying maternal responsive parenting trajectories utilized 2,101 cases, but the analysis for the main effects of the trajectories on first-graders' self-esteem employed 1,403 cases. According to an attrition analysis about the PSCK (Lim et al., 2022), high-income and well-educated families were more likely to continue participating in the PSKC. The current findings may better represent functioning children and mothers, which lessens the generalizability of the results. Second, maternal responsive parenting was measured using the six-item self-report instrument proposed by the PSKC research team. The self-report method is susceptible to respondents' subjective biases and social desirability. Also, the six items can hardly reflect the complex constructs of responsive parenting. Similarly, the self-esteem of children was measured with five items extracted from the original Rosenberg self-esteem scale, which limits comparisons with the previous research using the original scale. Third, most confounders (i.e., family monthly income, parental education, maternal employment, maternal depressive symptoms, and behavioral problems of children) were extracted when the children were 7 years old. The role of confounders from childbirth may not be fully reflected in the longitudinal relationship between maternal responsive parenting and the self-esteem of children. Fourth, though several confounders were controlled, other meaningful variables might modify the longitudinal paths of maternal responsive parenting or affect children's self-esteem. For example, paternal parenting involvement or parental support may affect the quality or stability of maternal parenting. Stimuli and responses from fathers during infancy may influence children's neuro-psychological foundational development, resulting in self-esteem differences in later years. Children's individual characteristics, such as temperament and physical health conditions, might have a transactional impact on maternal parenting practices and impact the development of their own self-esteem. Further studies should incorporate a diverse range of variables to portray a comprehensive picture regarding parenting and children's self-esteem development.

This study is one of few to identify maternal responsive parenting trajectories in a nationally representative sample. The varied intensity and stability of responsiveness captured in the three parenting trajectories produce meaningful echoes regarding the nature of parenting behaviors and how to help mothers with poor parenting responsiveness. Differences in early maternal responsive parenting in terms of stability and intensity are associated with differences in the self-esteem of school-aged children. Further works should clarify the biological, environmental, and transactional factors that facilitate or weaken the association in a comprehensive frame.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found at: The Panel Study on Korean Children https://panel.kicce.re.kr/pskc/intro_pskc.do.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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Is Distributional Justice Equivalent to Prosocial Sharing in Children's Cognition?

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Distribution and sharing are social preference behaviors supported and shaped by selection pressures, which express individuals' concern for the welfare of others. Distributive behavior results in distributive justice, which is at the core of moral justice. Sharing is a feature of the prosocial realm. The connotations of distribution and sharing are different, so the principles, research paradigms, and social functions of the two are also different. Three potential causes of confusion between the two in the current research on distribution and sharing are discussed. First, they share common factors in terms of individual cognition, situation, and social factors. Second, although they are conceptually different, prosocial sharing and distribution fairness sensitivity are mutually predictive in individual infants. Similarly, neural differences in preschoolers' perception of distribution fairness predict their subsequent sharing generosity. Finally, similar activation regions are relevant to distribution and sharing situations that need behavioral control on a neural basis.

Keywords: distribution, sharing, confusion, distinguish, connection

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INTRODUCTION

The development of children's resource distribution and sharing behavior has been widely concerned by researchers of developmental psychology. Distribution and sharing are social preference behaviors supported and shaped by selection pressures (Silk and House, 2016), expressing individuals' concern for the welfare of others. Across a series of studies, the violation-of-expectation paradigm was used to investigate the detection of distribution norm violation in infants (Geraci and Surian, 2011; Meristo and Surian, 2013; Burns and Sommerville, 2014; Buyukozer et al., 2019). Infants at 4, 9, and 10 months of age looked at the unequal 2:0 distributions significantly longer than the equal 1:1 distributions (Meristo and Surian, 2013). However, they looked at no significant difference between the 3:1 and 2:2 distributions (Buyukozer et al., 2019). Infants' increased sensitivity to distributive justice occurs between 6 and 12 months (Ziv and Sommerville, 2017). The 15-month-old infants looked the unfair outcome (the 3:1 distribution) significantly longer than the fair outcome (the 2:2 distribution), indicating increased sensitivity to the distributive fairness of the third parties (Burns and Sommerville, 2014).

At present, there are few studies on prosocial sharing behavior in infants. It may due to the limited social development level of infants, the naturalistic sharing rarely arises in infants. According to parents' reports in interviews, naturalistic sharing occurs as early as 9 months of age (Ziv and Sommerville, 2017). In the prompted giving task, infants at 15 and 18 months of age were able to engage in sharing behavior after being presented with a series of progressively more explicit cues (Schmidt and Sommerville, 2011; Brownell et al., 2013). The higher the sensitivity of 15-month-old infants to the fairness of third-party distribution, the more inclined they are to perform altruistic sharing (sharing their favorite toys). In contrast, infants with less sensitivity tend to share selfishly in the prompted giving task (sharing toys they do not like; Schmidt and Sommerville, 2011). Moreover, the change in infants' concern about distribution equity can be predicted by their tendency to generously share their favorite toys (Sommerville et al., 2013; Ziv and Sommerville, 2017).

According to the developmental characteristics of children's ownership understanding, children before the age of 4 have limited understanding and reasoning ability of ownership. If the ownership of resources in experimental situations is not clear, children will think that the resources in different situations belong to themselves, so there is no difference in the number of resources distributed to others in different situations (Hamann et al., 2011; Wu et al., 2017). With the increase of age, the individual's ability of ownership understanding gradually improves. When children own resource ownership or resource ownership is not unique to children, the behavior of the two situations gradually appears different. That is, when the ability of ownership understanding is mature, according to the ownership of resources, when resources are jointly owned, children's behavior of distributing resources to others needs to consider fair distribution; When the ownership of resources belongs to themselves, the behavior of children sharing resources to others is a kind of prosocial altruistic sharing, which gradually develops into two different social behaviors. The former is distribution, involving fairness and justice, belonging to the field of morality; The latter is sharing, which is an altruistic behavior.

THERE IS CONFUSION BETWEEN DISTRIBUTION AND SHARING IN RESEARCH

Although distribution and sharing have different meanings and belong to different fields, In developmental psychology, there is confusion regarding distribution and sharing in children.

Our analysis of the literature led us to identify four types of confusion between distribution and sharing. The first type of confusion occurs when researchers confuse the two concepts. For example, prosocial sharing situations appear in studies of the characteristics of children's distributive justice behavior. For instance, experimenters may explicitly instruct the child that the resources belong to him/her, and he/she could choose to share or not to share them with others (Blake and Rand, 2010; Wang and Su, 2013; Li et al., 2014; Reis and Sampaio, 2019; Urbanska et al., 2019). The behavior thus produced would be sharing behavior, in the prosocial domain. Then too, in study of children's sharing behavior, researchers use an allocation design (Hamann et al., 2011; Steinbeis, 2016; Yu et al., 2016; Ji and Gao, 2017; Vonk et al., 2020). In an experimental instruction, if a child is informed that the resources belong to him/her and another recipient or the ownership of the resources are not explained but only that it is up to him/her how the resources are divided, changes the setup of the experiment. That is to say, the setting in which the behaviors occur is irrelevant, and the resulting behaviors may not be what the researchers hope to observe.

In the second type, in study of distribution or sharing behavior, some researchers are unaware of potential confusion in distribution or sharing behavior, which tends to lead researchers to take the sharing research results as the evidence for the development of distribution behavior in the context of children's idea of distributive justice (Paulus and Essler, 2020). By the same token, when discussing the developmental characteristics or neural basis of children's prosocial sharing behavior, findings regarding distributive justice are taken as evidence of prosocial sharing behaviors (Blake, 2018; Steinbeis, 2018; Meng and Moriguchi, 2021).

The third type of confusion is that in the study of distribution justice, researchers have insufficiently analyzed and discussed their results in relation to moral justice but regard distributive justice as a prosocial behavior (Kanngiesser and Warneken, 2012; Smith et al., 2013). However, distribution is an economic term, and distributive justice is in a moral category, so it is inappropriate to discuss the results from a prosocial viewpoint.

The last confusion relates to the fact that the forms of distribution and sharing in dictator's game scenarios are similar, although they are essentially different. Some researchers have unified the concepts of distribution and sharing in their research, dividing prosocial sharing into the categories of autonomous sharing and obligation/responsibility sharing (Wu et al., 2017). Here, autonomous sharing means that children share their resources, as these come to the recipient thanks to a personal effort. Moreover, obligation/responsibility sharing describes a cooperative situation in which children have the obligation or responsibility to distribute resources that come from the joint effort of both parties. Because the joint efforts of both parties obtain the resources, this is a distributive situation, and it is only appropriate for studying distributive behavior.

From sorting, analyzing, and summarizing the relevant core literature, we put forward a few likely causes of the above confusions. First, distribution and sharing may have common influencing factors, divided into three aspects: individual, situational, and social. These factors can affect both distribution and sharing. Second, an internal relationship appears between distribution and sharing. It has been found that whether and how early individuals share can predict their sensitivity to distributive fairness. Third, both sets of behaviors may have a similar neural basis.

DIFFERENCES BETWEEN DISTRIBUTION AND SHARING

The Concept

Distribution refers to the division of social resources, wealth, responsibilities, and obligations in social groups according to certain standards or regulations. It is a process of allocation of social and economic resources. In developmental psychology, the study of distribution among children is mainly concerned with the idea of distributive justice, that is, children's understanding and application of the criteria to be used to distribute resources (Hsu et al., 2008). The premise of distribution is that the allocated resources are owned by the society or the collective, not by individuals. Therefore, individual distribution is a decision-making behavior that considers the interests of the self and others at the same time (Dijk and Vermunt, 2000; Leliveld et al., 2008; Chernyak et al., 2019).

Sharing refers to both having and using things owned by individuals, whether goods or more abstract entities, like rights, emotions, and experiences, with others (Chen et al., 2004; Liao, 2014). In developmental psychology, research on children's sharing focuses on children's willingness and behavior to give part of their possessions to others. Sharing behavior, which is an important part of prosocial behavior, is an important indicator of individual socialization.

The Principle

In distribution, the resources allocated usually do not belong to the distributor but to the collective or society. Following different social goals, the distribution follows different principles, among which the most prominent are the three principles of equality, equity and need (Deutsch, 1975). The ultimate fairness of the distribution involves moral evaluation. We must consider the issue of distributive fairness, that is, distributive justice. The concept of distributive justice relates to the distribution of social benefit and social obligations. Distribution must not be arbitrary, and the corresponding distribution principles must be followed to achieve fairness in the distribution results or procedures. A distributor must abide by such principles in the distribution, or a recipient or a third party may exact punishment.

Sharing behavior is more common in daily life, and it has no specific criterion or principle. Generally, individuals consider themselves to have the right to decide whether and how much of their own to give to others, holding that neither society at large nor individual others have the right to control whether and how they share. Furthermore, no punishment is indicated for the sharer no matter how many resources the recipient receives.

Research Paradigm

Psychological research on children's distribution behaviors mainly uses an economic game paradigm, namely, the dictator game, ultimatum game, and third-party tasks. The self-interest of the individual is activated in the first two contexts. In the third-party task, the subject observes resource allocation performed by others or allocates resources to others, in a context without self-interest at play. In distribution as an economic concept, its related behavior consequences involve distributive justice, so distributive behavior involves moral evaluation (McAuliffe et al., 2017).

In the study of sharing behavior, because the sharer owns the resource, all of the specific aspects of sharing involve the individual's interests. Thus, researchers generally adopt a variation on the dictator game. In a sharing situation, children are allowed to share their items with others unconstrainedly, and this can be used to study individual prosocial motivation and behavior (Benenson et al., 2007). Earlier studies of children's sharing behavior have gathered data from natural observation, teacher or parent reports, and interviews.

Social Function

Because distribution and sharing belong to different fields, their social functions may be disparate. The equitable allocation of resources is conducive to maintaining social order, promoting cooperation and the development of civilization (Baumard et al., 2013; Decety and Yoder, 2017). Prosocial behavior can help individuals build good social relationships, eliminate individual negative emotions, cope with psychological stress, and improve well-being. The concept of the warm glow proposed by Andreoni refers to the good feeling, satisfaction, or happiness generated by prosocial behavior. This effect can explain the difference between altruistic and non-altruistic behavior in an individual. Cross-cultural and child development research strongly supports a universal relationship between prosocial behavior and well-being (Aknin et al., 2013). Studies in children have shown that sharing can positively impact mood and that sharing behavior activates brain regions associated with reward (Cutler and Campbell-Meiklejohn, 2019). Before children engage in sharing behavior, they expect that it will produce positive emotions; further, autonomous sharing can improve children's subjective well-being (Aknin et al., 2012; Wu et al., 2017; Sabato and Kogut, 2019). These findings suggest that individual well-being increases after prosocial behavior, which may be a common proximal mechanism for such behavior and might provide a theoretical explanation for the emergence of early prosocial behavior (Paulus and Moore, 2017).

Some researchers have suggested that there may be a positive feedback loop between positive emotions and prosocial behavior. A previous study that examined the relationship between positive emotions and donating behavior in children aged 7–8 years found that children who imagined happy events donated significantly more than children who imagined sad ones or control groups. (Moore et al., 1973). A study that used short video clips to induce sadness in children aged 5–6 years found that sadness significantly reduced boys' sharing behavior, but it did not affect girls' sharing behavior (Guo et al., 2019). Past studies have shown that positive states predict prosocial behavior and prosocial behavior predicts positive states, but few studies have investigated these relationships together in one experiment (Aknin et al., 2018).

Research on the effects of distributive behavior on children's positive emotions is still lacking. Wu et al. (2017) found that obligation sharing does not affect an individual's positive emotions, that is, it cannot improve the individual's subjective well-being, while autonomous sharing can. The resources at play in obligation sharing situation are obtained through the cooperation of two children, meaning that this is actually a case of distribution. That is, it is different from prosocial sharing. Whether the relationship between distribution and positive emotion is similar to the relationship between sharing and positive emotion should be explored in future work.

CONNECTION BETWEEN DISTRIBUTION AND SHARING

Common Influencing Factors

Individual Cognitive Factors

Theory of Mind

Theory of mind (TOM) is an important cognitive factor of children's distributive justice and prosocial sharing. The multiple forces hypothesis indicates that TOM can help children balance their self-interest and the needs of others in distributive situations (Chen and Wu, 2017). Children who have passed the second-order false belief task allocated more resources to strangers than those who have not. Second-order false beliefs, likewise, did not affect children's allocation to friends and relatives (Yu et al., 2016). These findings are consistent with the multiple forces hypothesis. However, the TOM predicted that children would distribute more stickers to their friends over time (Vonk et al., 2020). Priming children's speculation on recipients' goals in the competitive situation could significantly affect children's allocation behavior and reduce children's resources allocated to competitors (Nilsen and Valcke, 2018). Inducing children's perspective taking significantly increases the rejection of unfair distribution (Tsoi and McAuliffe, 2019).

The multiple forces hypothesis indicates that the effect of the TOM is not obvious in relatively simple sharing situations. A meta-analysis found that children's TOM was significantly associated with helping and cooperative among prosocial behaviors but not with sharing behaviors (Imuta et al., 2016). Nevertheless, in more complex sharing situations, TOM allows children to understand each other's needs more accurately and quickly, thus promoting prosocial sharing behavior (Kogut et al., 2016). These results may indicate that when children have clear social norms to follow, the relationship between TOM and sharing behavior is no longer significant.

Situational Factors

The possible common situational factors for distribution and sharing mainly include the means of resources acquisition and social reputation.

Means of Resources Acquisition

There are two main ways in which for children can obtain resources in an allocation situation: windfall gains and earned rewards. The former are directly provided by adults, making it a windfall for the distributor and recipient. The latter are obtained through effort (participation in collaborative or parallel work). In the case of windfall, infants in the first year of life already have the sensitivity to the fairness of third-party distribution (Buyukozer et al., 2019). The infants expect a reward to be distributed by a third party to the person who protects the victim from attack (Geraci, 2020; Geraci and Surian, 2021). Similarly, infants expect third parties to allocate comforter rewards, that go beyond the principle of equality (Geraci et al., 2021). Studies the use provided by adults have shown that disadvantageous inequity aversion appears around 4 years old, and advantageous inequity aversion appears at 8 years old (Blake and McAuliffe, 2011; McAuliffe et al., 2013). When the resources were obtained by the children's own efforts, however, they can spontaneously distributed the rewards of cooperation equally among everyone as early as 3 years old. When they worked in parallel and received their rewards separately, they accepted the inequality of the results (Hamann et al., 2011). In short, children's distributive equity is particularly sensitive to means of resource acquisition.

In a prosocial sharing study in children, researchers divided the resources into things occasionally gained and things one possesses according to the way in which they were acquired. The things occasionally gained were directly provided by the experimenter and thus were windfalls for the sharer; things one possess marked the rewards that children earned through their own hard work. The probability of natural sharing is very low in infancy regardless of the item. According to parents' reports in interviews, naturalistic sharing occurs at 9 months of age (Ziv and Sommerville, 2017). In the laboratory, infants at 15 and 18 months of age were able to engage in sharing behavior after being presented with a series of progressively more explicit cues (Schmidt and Sommerville, 2011; Brownell et al., 2013; Ziv and Sommerville, 2017). Studies found that preschool children are more willing to share things that are occasionally gained (Wang et al., 2005; Liu et al., 2013). Another study found that preschoolers shared prizes they earned through hard work the most, followed by their favorite toys, and least of all occasionally gained food (Li and Zhao, 2008). This study may be inconsistent with others may be that everything occasionally gained is plasticine, and the items accidentally obtained are small pieces of food. It is possible that different types of resources may entail different levels of attraction to children. For another, it may be that toys are not shared in the same way as food. Therefore, the resource types should be unified in future sharing studies.

Social Reputation

Social reputation relates to how far children are willing to make a reasonable allocation of resources in the name of equity and represent prosocial sharing that meets social expectations. In the distribution situation, children's social reputation indicates that when children realize that others may judge their distribution behavior, they adjust this behavior to behave more fairly to obtain a positive evaluation from others.

Many studies have shown that 5-year-old children are more generous in the presence of peers than when no one is present. When they are with different people, they make different allocation decisions (Dunham et al., 2011; Engelmann et al., 2012; Leimgruber et al., 2012). Children aged 6–8 years may be more concerned with their social reputation, making it more likely that they will behave fairly when their peers are present or when experimenters can learn of their choices. However, if the distribution that they give will not be found by others, the originally fair children may become unfair. In other words, the fair distribution is partly due to the children's desire to appear fair in front of others (Shaw et al., 2014). Children aged 6–9 are more likely to accept an advantageous distribution if their peers are unaware of their advantages (McAuliffe et al., 2020). The results of these studies show that even if children have learned fair norms, internalized norms may also be strategically used in social situations that can improve their reputation. Social reputation concerns can narrow the knowledge and behavior gap in fair distribution among children.

Children's concern for their social reputation can affect their sharing behavior in different sharing situations. In prosocial research, an individual's reputation refers to others' evaluation of his or her prosocial ability and motivation, such as whether others consider that he or she often treats others generously (Engelmann and Rapp, 2018). Children share more resources when they are aware of the presence of the recipient or other observers than when they are not; that is, children are more generous when they realize that their behavior is observed by others (Leimgruber et al., 2012; Sampaio and Neto Pires, 2015). In addition, because 5-year-olds are concerned about their reputation within the in-group, they tend to share more resources when observed by members of their in-group (Engelmann et al., 2013). More recently, study found that 5- to 9-year-old children's sharing with in- and out-group members was affected by reputation in all groups (Yazdi et al., 2020). In conclusion, children's attention to their reputation can affect their generosity in the context of prosocial sharing.

Social Factors

The social factors that could affect distribution and sharing mainly include social distance and social culture.

Social Distance

Social distance reflects the level and degree of closeness or alienation between people and groups. In one study, children aged 3–6 gave significantly more stickers or candy to their friends than to unfamiliar children whom they have never met (Yu et al., 2016). In the event of conflict between social relationships and contributions to allocation, children younger than seven decide based on social relationship. They adjust these allocation decisions in relation to the size of the recipient's contribution (Zhang, 2020). At the group level, social distance affects individuals' response to the unfair behavior of in- and out-group members, and individuals show in-group preferences even if in-group members violate the distribution principle (Zhang and Zhao, 2018). Blake generally explains these findings as indicating a social distance effect, which means that individuals can give more resources to recipients who are more closely related to them (Charness and Gneezy, 2008; Wu et al., 2011; Blake, 2018).

Children will allocate different amounts of resources to different recipients in the process of sharing according to the closeness of the relationship with the recipients. Preschool children aged 3–6 years share more rewards with their friends than non-friends and strangers (Vonk et al., 2020). In another study, in the exploration of whether preschool children choose to share with friends out of reciprocity, the researchers found that there were no differences between 3- and 5-year-olds in giving to friends with and without reciprocity, which shows that children's preference to share with friends is independent of reciprocity (Lenz and Paulus, 2021). More studies are needed to explore the specific effects of social distance on children's prosocial sharing.

Social Cultural

The development of individual social behavior cannot be separated from the social cultural environment. Cross-cultural study of distribution indicates that advantageous inequity aversion varies from culture to culture. In some cultures, advantageous inequity aversion appears in middle childhood, but it not in others (Blake et al., 2015). When a quantity of items presented cannot be distributed equally, children would rather throw away some items than distribute them unfairly. However, unlike American children, Ugandan children tend to allocate resources unfairly rather than throw away extra resources (Paulus, 2015). Moreover, in Uganda, preschool and primary school children show a high level of generosity independent of social relationships (Scharpf et al., 2016). When recipients are different in wealth and contribution, children from individualistic cultures are more likely than those from collectivist cultures to favor fair distribution (more to the poor and to those with greater merit) than equal distribution. When recipients differ in degrees of injury, children from more collectivist culture tend to allocate more resources to more injured recipients than children from more individualistic cultures (Huppert et al., 2019). Recent studies have found that the role of merit in distribution seems to be different across cultures. Compared with Kenyan children, Chinese and German children selectively allocate resources to individuals who have more work. When friendship and merit are opposed, in all three cultures, children tend to share equally between friends who contribute less and less familiar people who contribute more (Engelmann et al., 2021). These results indicated that both commonality and individuality factor into individual equity in different cultures, which illustrates the significance of cross-cultural research in understanding the development of human distribution equity.

There have been few studies on the impact of social culture on sharing. Previous studies have shown that Asian children are more likely to share spontaneously and less likely to share passively (Rao and Stewart, 1999). Children in collectivist cultures tend to live in communities where harmonious interaction is highly valued, and they are more likely to share with their peers than children in individualistic cultures are (Stewart and McBride-Chang, 2000). However, a study on the sharing behavior of nearly 2,500 children aged 3–12 years from 12 countries on five continents did not find the expected significant differences between children from collectivist and from individualist countries (Samek et al., 2020). Therefore, more research is needed to determine whether social culture has an impact on children's prosocial sharing behavior and internal mechanisms.

Possible Mutual Prediction

Infant studies have found that distribution and sharing can predict each other. The higher the sensitivity of 15-month-old infants to the fairness of third-party distribution, the more inclined they are to perform altruistic sharing (sharing their favorite toys). In contrast, infants with less sensitivity tend to share selfishly in the prompted giving task (sharing toys they do not like; Schmidt and Sommerville, 2011). Moreover, the change in infants' concern about distribution equity can be predicted by their tendency to generously share their favorite toys (Sommerville et al., 2013; Ziv and Sommerville, 2017). What is more, the relationship between infants' sharing behavior and their sensitivity to distributive justice cannot be predicted by developmental maturity or their cognitive performance (receptive vocabulary; Sommerville and Enright, 2018). To explain the connection between distribution and sharing in infants, the researchers believe that individual sharing interactions provide rich learning opportunities for studying the core principle of distribution. In the interactions they have the opportunity to experience being either the subject or recipient of fair and unfair behavior. These experiences can help them understand the consequences of inequity, making them pay closer attention to the results of unfair distribution (Sommerville and Enright, 2018).

The relationship between distribution and sharing indicates an important aspect of the relationship between the moral and prosocial fields. It has been found that the late positive potential, more than the early posterior negativity, of moral situation processing can predict the actual generosity of children's later sharing, while children's moral evaluation can predict their generosity of sharing (Cowell and Decety, 2015). The neural difference in distribution fairness and unfairness in early adolescence can predict children's participation in subsequent donation behavior, such that the greater the neural difference between them, the longer that children will persist in participating in donation behavior (Meidenbauer et al., 2018). This is consistent with previous findings that indicate that children's moral reasoning is related to prosocial sharing (Stewart and McBride-Chang, 2000). In conclusion, children's moral development is closely related to prosocial development, so there is sufficient reason to speculate that there may be a close internal relationship between children's distribution and sharing behaviors.

Similar Neural Basis

In distribution, individuals solve conflicts between self-interest and fairness by following social norms, which require ability behavioral control. Neuroscientific studies have shown that increased individual norm compliance is strongly positively correlated with the activation of the lateral orbitofrontal cortex and the right dorsolateral prefrontal cortex (rDLPFC; Spitzer et al., 2007). Disrupting the right DLPFC, but not the left, by non-invasive low-frequency repetitive transcranial magnetic stimulation significantly reduces subjects' willingness to refuse unfair propose without affecting their perception of fairness (Knoch et al., 2006; Ruff et al., 2013). Longitudinal structural magnetic resonance imaging (sMRI) studies have shown that DLPFC takes a long time to mature, completing its development in early adulthood (Gogtay et al., 2004; Shaw et al., 2008). Therefore, the researchers believe that young children's violation of the principle of distributive justice is not due to a lack of understanding of right and wrong but rather to the inability to implement behavior control when tempted by resources. The implementation of self-control depends on the function of the mature brain regions in late ontogeny (Steinbeis et al., 2012). With the maturity of individual brain development, individual self-control ability is gradually enhanced. Therefore, the distribution principle is followed in a broad context, and eventually, the principle will apply to others and to the children themselves (McAuliffe et al., 2017).

There is also a conflict between one's own interests and those of others in sharing situations. However, there have been few studies on the neural basis of sharing behavior. A recent study used functional near-infrared spectroscopy (fNIRS) to record the activation of the DLPFC during sharing in children, which found that DLPFC was activated during cognitive tasks involving behavioral control and sharing tasks involving equal rather than more selfish sharing (Meng and Moriguchi, 2021). This suggests that generous sharing requires self-control, and children's cerebral cortex is activated in a similar way to the case of the distribution situation. Hence, more research is needed in future to explore the neural basis of sharing.

CONCLUSION

Taken together, this review shows that distribution and prosocial sharing differ in their connotation, principles, and social function, but both involve trade-offs between one's own and others' interests. Considerable research has been done on the development of resource allocation behavior in children, but we need to conduct more prosocial sharing research to explore the early developmental origins of both. In recent years, studies have been conducted to compare the two sets of behaviors in terms of motivation and emotion (Krettenauer et al., 2019) and explore the relationship between distributive justice and generous sharing from moral and prosocial perspectives (Meidenbauer et al., 2018), which are the main avenues for future research.

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YZ, JZ, and XL contributed to conception and design of the review. YZ and JZ wrote sections of the manuscript. All authors contributed to the article and approved the submitted version.

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Effects of screen exposure on young children's cognitive development: A review

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The past decade has witnessed a rapid increase in the use of screen media in families, and infants are exposed to screens at younger ages than ever before. The objective of this review is twofold: (1) to understand the correlates and demographic factors determining exposure to screens, including interactive screens, when available, and (2) to study the effects of watching screens and using touchscreens on cognitive development, during the first 3 years of life. We argue that the effects of screen viewing depend mostly on contextual aspects of the viewing rather than on the quantity of viewing. That context includes the behavior of adult caregivers during viewing, the watched content in relation to the child's age, the interactivity of the screen and whether the screen is in the background or not. Depending on the context, screen viewing can have positive, neutral or negative effects on infants' cognition.

KEYWORDS

screens, cognitive development, prevalence, context, quality, language

Introduction

Over the past 30 years, the number of television programs targeting infants has been increasing, resulting in infants spending more time watching screens and an earlier exposure (Chen and Adler, 2019). For example, by using time diary data from 1997 and 2014 Child Development Supplement of the Panel Study of Income Dynamics, Chen and Adler (2019) show that between 1997 and 2014, screen time doubled among children aged 0 to 2 years. Christakis (2009) reported that the average age of first exposure to television was at 4 months. Given the rapid increase of exposure to screens and at a very early age, in 1999, the American Academy of Pediatrics (AAP) recommended that children under the age of 2 should not be exposed to screens (American Academy of Pediatrics, 1999). These recommendations were followed by numerous studies over the next 10 years showing that screen exposure in children under 3 years of age can be both harmful and beneficial for their cognitive development, depending on the context in which viewing occurs (i.e., content of the program, parents' investment in program choice, commenting while children watch screens, screen interactivity and screen in the background). In 2011, after the release of the first interactive screens, the AAP reiterated their recommendations despite the fact that only few studies exist so far on the effects of these new types of screens on infants' development (American Academy of Pediatrics, 2011). In their 2016 statement, the AAP addressed a series of concrete recommendations for parents and caregivers to develop a family media plan. For example, they recommend co-viewing with their parents for young infants and to limit screen use to qualitative programs for only an hour per day for older children (American Academy of Pediatrics, 2016).

The purpose of this article is to understand which kind of screen exposure is harmful for cognitive development and whether some viewing contexts can be beneficial for learning in infants under 3 years of age. Indeed, most of the articles on the subject have not considered the importance of the context of exposure. Here, we will refer to television and mobile devices generally as screens and indicate the type of screen discussed where relevant. In particular, we will review content available about the effect of touchscreens.

In the present narrative review, we propose to highlight the possible links between screen exposure and young children' cognitive development. We selected articles in the last two decades related to the effect of media on the child's cognition, focusing more on the early childhood period that is likely to be the most susceptible to any effect of screens, and excluding entries linked to the effects of violence in the media or in video games on the child's emotions. To reflect these choices, we used Google Scholar as an academic search engine through the software "Publish or Perish," with the following keywords in the title: "infant," or "child," or "children," or "toddler," or "childhood," or "development," and "television," or "screen," or "media," or "video"; excluding those with the keyword "games" in the title, and including the keywords "early" or "young," and "cognition," while excluding the keywords: "autism," "screening," "otitis," "emotion," "violence," "prize." This allowed us to select 478 unique peer-reviewed articles between January 1, 2000 and August 2, 2020, and 102 of which we review here, selected according to the additional criteria below.

We decided to focus on the most studied cognitive areas at that age, therefore excluding studies not focused on the effects on language development, executive functions, imitation, parent's interactions, IQ, and attentional development. We also excluded articles not in English or French, not focused on children below 3 years old or not focused on the effect of screens or touchscreens. We selected among the articles those that were related to the review's topics: (1) the prevalence, correlates and screen viewing patterns, (2) screen viewing as a source of learning, (3) the effects of screen viewing on language development, executive functions, imitation, parent's interactions, IQ, and attentional development, (4) the effects of viewing context, and (5) the causality in the effects of screen viewing on cognition. During this step, each of the authors carefully read the relevant articles for one or more sections he/she was in charge of and reviewed them in a narrative way. Additional related articles could be added. As a narrative review, we are highlighting only a subpart of the literature that is not necessarily representative of the whole field, but that we think can help to understand apparent contradictions in the literature.

We will start by showing the prevalence of screen exposure in infants (for both interactive and non-interactive screens), then we will review the effects of screen exposure on cognitive development, and of the different contexts of viewing on infants' development, before discussing causal effects. We will end up with a discussion on the potential effects of screen exposure and the early development of cognitive abilities and communication.

Prevalence, correlates and viewing patterns

The prevalence of exposure to screens in infants aged between 0 and 3 years has been the subject of many surveys in western countries, most of them conducted with North American populations and some with Europeans. More recent studies investigated the use of interactive screens in young infants specifically.

A recent large study conducted with a French population shows that 84% of 2-year-old toddlers watch television at least once a week, and 68% every day (Gassama et al., 2018). The average time of exposure to television for 2-to-24-month-old infants is 40 min per day and only half of the programs are educational programs, according to the parents (Zimmerman et al., 2007b). Moreover, in a cohort of children aged 6–18 months (Barr et al., 2010a), younger children were more exposed to adult programs than older. This suggests that infants are exposed both to infant- and adult- directed television. They typically attend 50% of the time only (Anderson and Pempek, 2005). These findings are particularly relevant to early cognitive development, as adult-directed content may be detrimental to play, language development and executive functioning, particularly for young infants, as we will see later.

As for interactive screens, a recent French survey shows that roughly 30% of 5-month-old infants use touchscreens and this percentage increases to 90% at 2 years (Cristia and Seidl, 2015). Frequency of exposure did not increase with age and between 5 and 24 months, 21% of infants used touchscreens daily, 32% weekly and 48% less than once a month. Another large, recent French survey showed similar results with 21% to 28% of 2-year-old children playing with a touchpad, a computer or a smartphone at least once a week and 10% to 12% of toddlers doing so daily (Gassama et al., 2018). These percentages are very close to those of the Common Sense Media study with an American sample (Rideout and Robb, 2020). These results suggest that just like television exposure, interactive screen use is present very early on in development and represents a significant time in some infants' daily activities.

More studies are needed particularly for interactive screen use in order to understand whether environmental factors can influence these figures. For example, Kabali et al. (2015) reported even higher rates of use of interactive screens in a sample of low-income minority children, with 75% use among those between 12–36 months. The environmental factors associated with exposure to television have been more documented. For example, it varies according to the type of childcare. The majority of the time spent watching television (about 3 h daily) occurs at home in the presence of parents (Christakis and Garrison, 2009; Tandon et al., 2011). In non-parental childcare, the time spent in front of the television is shorter when in daycare (about 10 min daily) and greater when the care is at the child's home (1.5 h daily), and is negatively correlated with the caregiver's level of education (Christakis and Garrison, 2009).

Why are parents increasingly exposing their children to screens? The motivations that parents report for using television are varied (Garrison and Christakis, 2005; Linebarger and Walker, 2005; Zimmerman et al., 2007b): its used as a nanny (21%), the belief that programs are entertaining for infants, its use as a means of relaxation (23%), and as an educational tool (29%). As for parents' attitudes toward the use of interactive screens include learning, creativity, entertainment, and soothing when distressed (Radesky et al., 2014, 2016; Nevski and Siibak, 2016; Levine et al., 2019; Dardanou et al., 2020).

In conclusion, even though these studies are mainly based on parents' reports and do not prove causation, they show that interactive and non-interactive screens are becoming more pervasive in early childhood. The effects and consequences of that screen time exposure have received considerable attention in research over the past decade and enough work now exists to address the question of the effect of exposure for children younger than 3. In the next sections, we will review experimental research on how infants retain information from screens and then present correlational studies that investigate the effects of screen viewing on cognitive development.

What kind of information can infants process through screens?

Before reviewing in detail the effects of watching screens on cognitive development, we would like to discuss how young children make use of information presented to them on screens and how they learn from videos.

An important perceptual difference between reality and screens is that reality is perceived in depth through stereoscopic vision, whereby the two separate images captured by each eye are combined by the brain. Stereoscopic vision develops around 5 months of age (Takai et al., 2005) although it remains very poor for years, and pictorial depth perception, the ability to perceive depth in 2D images, emerges around 7 months of age and continues to develop during the first 2 years (Yonas et al., 1978). Standard screens do not contain stereoscopic information and screens also differ from reality in other aspects: their luminance is lower, they cover a smaller field of view and some of them cannot be interacted with. These perceptual differences may interfere with infants' ability to learn from videos or to generalize from the screen to the real world. By 6 months of age, infants can reproduce new actions directed at objects shown on a screen, actions that they would otherwise not produce spontaneously, after simply manipulating the objects (Meltzoff, 1988; Barr and Hayne, 1999; Hayne et al., 2003; Barr et al., 2007a, 2010b; Barr and Wyss, 2008; Strouse and Troseth, 2008). At this age, a video model yields the same level of imitation as a live model (Barr et al., 2007a). However, by 12 months, it takes twice as many demonstrations (Barr et al., 2007b) and exposure time (Strouse and Troseth, 2008) for infants to imitate actions from a 2D model on screen than from a real 3D model. Thus, whilst young infants may be able to reproduce actions they saw on a screen, overall, they do not seem to view video as relevant to real life. This effect is called the "video deficit effect." The perceptual impoverishment hypothesis suggests that the deficit is a result of the poorer stimulation on screens when compared to the real world (Barr and Hayne, 1999).

Many studies have explored how infants associate information from TV screens with real objects (Troseth and DeLoache, 1998; Troseth, 2003; Deocampo and Hudson, 2005; Troseth et al., 2006; Krcmar et al., 2007) or generalize information to the real world when it is learned from a touchscreen (Zack et al., 2009). In general, these studies show that 15–24 months old infants have difficulties generalizing an action learned on a TV screen to a real situation and vice versa, or to locate an object in the room when clues are given through a screen. Children also imitate the adult more when the on-screen model interacts in real time with the child than when the model is filmed in advance and cannot interact with him/her. Children can indeed locate an object in the room using clues provided by the adult interacting on the screen (Troseth et al., 2006): interaction with others remains a privileged source of learning and information.

By the age of 24 months, children start looking for different durations at *Teletubbies* when it is presented with backwards speech (each utterance is run backwards although occupying the same video frames) rather than with normal speech (Pempek et al., 2010). Therefore, it is not clear that infants can understand speech from video before the age of 2. There is anecdotal evidence that toddlers can learn words from watching television (Rice, 1983). More ecological studies (DeLoache et al., 2010) showed that learning new words through educational videos is negligible between 12 and 18 months of age. Infants were asked to point to objects while they were listening to the names of these objects, either from a video or by interacting with the parents. Infants did not learn any words in the video condition, unlike the adult-interaction condition, despite that these videos were considered very educational by the parents. Note that the context is important: the narration of the action favors its imitation (Seehagen and Herbert, 2010; Simcock et al., 2011). Thus, the percentage of children who imitate increases considerably when the objects presented on screen are named or commented by the parents or by the video, compared to presentations without parental comment or support (Barr and Wyss, 2008).

Finally, we would like to open a methodological discussion on the use of screens during experiments in laboratories studying infant's behavior (Esseily et al., 2017). Given what infants perceive on a screen, how does it affect experimental conclusions? For example, when using the preferential looking paradigm, some conclusions might not generalize to real life stimuli, given the video deficit effect.

To summarize, learning from screens in infants appears to be negligible without parental or adult guidance, mainly because of the video deficit effect and difficulties to process speech on video. How does it affect the development of language?

The effects of screens on the development of language

The relationship between the effects of watching screens and the development of children's cognitive skills is complex as the time spent viewing screens *per se* is only one factor among others. We start by reviewing correlational studies showing the effects associated with screen time on language development. Later, we will review the factors modulating the effects associated with screen exposure on language, attention, executive functions, adult interactions and school readiness.

The link between screen viewing and language development is one of the most explored in the literature. It is clear that language learning takes place in an active way and that interactions play a primary role in it (Bruner, 2011). However, television viewing is generally non-interactive, except for programs specifically designed for interaction, therefore one can expect deficits in language development from over-exposure to television.

Indeed, 2 h a day spent watching television between 15- and 48-months of age multiplied by four the probability of a delay in language development. This delay was multiplied by six when children started watching television before 12-months (Chonchaiya and Pruksananonda, 2008). In this case-control study, the authors also evidenced that children at age 2 who had language delay usually started watching television earlier than a control group, and also spent more time watching television than other children (around 3 h per day vs. less than 2 h per day). Children who started watching television during their first year and who watched television more than 2 h/day were approximately six times more likely to have language delays than the ones who did not. Lin et al. (2015) also evidenced that children who were exposed to television 1 h daily before the age of 2 had an increased risk of delayed language development. Furthermore, the amount of time spent watching television alone before the age of 3 was associated with poorer syntax levels at ages 3 and 4 (Naigles and Mayeux, 2001). In addition, 6-month-old children exposed to television for an average of 2 h per day had poorer cognitive performances and lower language levels at 14 months of age than unexposed children (Tomopoulos et al., 2010). Zimmerman et al. (2007a) tested the association of media exposure with language development in children under the age of 2. Parents were asked to assess their child's vocabulary through the short form of the MacArthur-Bates Communicative Development Inventory (CDI). Among infants (ages 8 to 16 months), each hour per day of viewing infant-directed DVDs/videos was associated with a decrease in CDI scores in a fully adjusted model. In older toddlers (ages 17 to 24 months), there were no significant associations between any type of media exposure and CDI scores.

Nonetheless, other authors (Ferguson and Donnellan, 2014) reanalyzed Zimmerman et al. (2007a)'s dataset and showed that opposite conclusions could be drawn depending on the chosen statistical analysis. For one of them, infants exposed to no screen actually had lower levels of language development compared to infants with some exposure. This highlights recent concerns over methodological degrees of freedom and the possibility of increased false positives in the psychological literature. It is also possible that other studies exist with the same conclusions but that could not be published because of non-significant results.

One possibility to explain the negative effects is that young children have reduced interactions with adults while watching television. This point seems important, as interactions are known to be the core format for language development in young children (Bruner, 2011). Another possibility is that the programs children were exposed to in these studies were produced for adults (Zimmerman and Christakis, 2005). Because children of this age pay little overt attention to such programs and likely have little comprehension of them, adult programing can be considered background television from the perspective of the child. Overall, this particular context in which children watch adults' programs on television seems to reduce the quantity and quality of parental language addressed to their 12- and 24-month-old children (Christakis et al., 2009; Pempek et al., 2014). These aspects will be discussed in the next section.

As a summary, studies investigating the association between the amount of screen viewing and language development, without differentiating between child and adult programs viewed, found an overall negative association in children younger than 3. However, the amount of viewing does not seem to be the most important factor to consider. In recent years, evidence was provided that the focus should be on the quality (or context) of viewing, not the quantity.

The importance of the context of viewing

A factor analysis of viewing patterns in bilingual toddlers (Hudon et al., 2013) extracted two factors having opposite effects on language development: quantity and quality. Quantity of viewing was not correlated with language outcomes, but poor quality was related to lower vocabulary. Poor quality was defined as television unintended for children, background television, solitary viewing, and earlier age of viewing.

Inspired by these results, we define the context of viewing as four aspects that modulate the effects of screens on cognitive development: (1) the type of content viewed and its structure, depending on the child's age, (2) the caregiver's behavior during viewing, (3) whether the program is watched or in the background while doing something else, and (4) the screen interactivity.

The type of content viewed and the content structure

It is important to distinguish between the effects of exposure to contents created specifically for infants and young children and those intended for an adult audience (Anderson and Pempek, 2005). Below, we review how the type of content modulates the effects of screen viewing on school readiness, executive functions, attention skills, child-adult interactions and language development.

Regarding school readiness, Wright et al. (2001) collected time-use diaries of television viewing and found that 2-year-olds who were exposed more to child-directed educational programing, such as *Sesame Street*, reached higher scores on general measures of school readiness (knowledge of letters, numbers, colors, shape, spatial and size relations) at ages 3 and 4, than those who were primarily exposed to adult directed television programs. Conversely, heavy viewing of general-audience programs at age 2 predicted poorer performance on measures of mathematical skills and receptive vocabulary.

Regarding executive functions, screen exposure at 4 months was related to worse inhibitory control 10 months later, controlling for covariates through propensity scores, though there was no association between screen exposure and working memory or cognitive flexibility in this parental report study (McHarg et al., 2020a). Furthermore, screen exposure at 24 months was negatively associated with the development of executive functions from 24 to 36 months (McHarg et al., 2020b). Nevertheless, when looking at the content watched, a different picture emerged. Executive functions were reduced by exposure to programs aimed at adults when compared to programs aimed at children (Linebarger and Walker, 2005). Indeed, children who had higher levels of exposure to adult-directed television programs during infancy were rated by their parents as worse on executive functioning skills, like inhibitory self-control at age 4, in comparison to children who had lower levels of exposure (Barr et al., 2010c). On the contrary, early exposure to child-directed content was not associated with cognitive ability at age 4. Along similar lines, exposure to educational programs before age 3 was not linked to attention issues when reaching age 7 (Zimmerman and Christakis, 2007), while exposure to adult television content was negatively associated with executive functioning and cognitive skills at older ages (Christakis et al., 2004; Zimmerman and Christakis, 2005; Landhuis et al., 2007).

Concerning attentional skills, the number of hours of television watched daily at ages 1 and 3 predicted measures of hyperactivity at age 7, according to a large longitudinal survey (Christakis et al., 2004). However, children of different ages do not pay attention to the same types of content: looking time to child-directed programs is high, averaging approximately 70% for 12- to 18-month-olds (Barr et al., 2008) as these programs often have very dense perceptually salient features (Huston et al., 1981), which facilitates and scaffold comprehension of the content (Calvert et al., 1982). Thus, some educational programs designed for young children may well be beneficial while others indifferent or, in the case of adult programs, detrimental for cognitive outcomes. Indeed, educational television watched before age 3 was not associated with later attentional problems, while each hour of entertainment television was associated with doubled odds of attention problems, after adjusting for covariates (Zimmerman and Christakis, 2007).

Regarding language development, watching adult programs vs. child-directed programs between 15- and 48-months of age multiplied by 3 the probability of delaying language acquisition (Chonchaiya and Pruksananonda, 2008). More specifically, a population survey analyzed the characteristics of the content watched by two groups of 18-month-old children, one with delayed language development (Okuma and Tanimura, 2009). The delayed-language group watched more "detailed realistic animations" (like *Pinocchio* or *Spirited Away*) and "baby education" (e.g., videos teaching vocabulary) than the other. Their videos contained less close-ups of faces, more uninterrupted stories with constant movement or transformation of characters, had a higher frame rate, and adults readily kept on watching these videos even with the sound off. Another study using parental reports (Linebarger and Walker, 2005) found higher levels of language associated with watching programs containing a strong narrative and characters that address the child directly, providing pauses for the child to respond (e.g., *Dora the Explorer*). On the other hand, watching programs that show a loose narrative and contain complex stimuli (e.g., *Teletubbies*) is associated with poor language skills in children.

As a summary, the content of the videos is critical. Adult programs yield negative effects on the development of cognition before the age of 3, while child-directed programs are associated with either a positive effect or no effect. Furthermore, child-adult interactions are also affected differently, with less interactions during adult programs than child-directed programs (Mendelsohn et al., 2008). In the section about language development, it was also clear that interactivity with adults was a key factor to unlock the positive impacts of screen viewing in young children. Therefore, in the next section, we explore whether the parent's behavior plays a role in modulating the effects of screen viewing on cognitive development.

The caregiver's behavior during viewing

As early as 6 months of age, having a parent who participates and comments on television program content has a positive effect on the child's attention, as quasi-experimental studies show (Barr et al., 2008; Fidler et al., 2010). Indeed, the presence vs. absence of interactions during television viewing between 15- and 48-months of age modulates by 8 the probability of a delay in language development (Chonchaiya and Pruksananonda, 2008). Educational programs can also form a basis for play and creativity between parents and babies in the first 2 years of life, for example encouraging parents to name objects, in *Baby Einstein,* or to imagine new activities, in *Sesame Stree*t (Pempek et al., 2011). Whereas parents speak less to their infants during co-viewing of infant-directed television programs (compared with no television), they also tend to use richer vocabularies both during and immediately after viewing (Lavigne et al., 2015).

Although there have been no comparable studies on the impact of interactive screen media during infancy, there is some experimental evidence that toddlers (24 to 36-month old) can more readily learn from touchscreen devices than they can from television (Kirkorian et al., 2016). However, mobile devices have been shown to considerably reduce parental interactions with young children (Radesky et al., 2014). Thus, it appears that both television and interactive media may reduce at least the quantity of parent-child interactions, which are crucial for the development of cognitive skills, especially language and executive function. In addition, a telephone survey showed that only 32% of parents say that they watch television with their children (Zimmerman et al., 2007b).

In these studies, television is always the direct attentional target of the child and parents. But what happens when the television is turned on in the living room where children are present without specifically focusing on the screen, which creates background noise for all ongoing activities?

The effect of television in the background

Background television can refer to two situations: (1) when the television is switched on in the background while the child is participating in other activities, (2) when a very young child is in front of or in the immediate vicinity of an adult program on a screen (Anderson and Evans, 2001). In the latter case, infants do not process information presented on screens for more than 3–5 s (for a summary, see Kirkorian et al., 2017), and have trouble processing speech (adult- and infant-directed speech) on screen until the age of 2 (Pempek et al., 2010; Anderson and Subrahmanyam, 2017; Hipp et al., 2017). The foreground screen becomes similar to a screen in the background and it is difficult to disentangle the effects of adult programs from the effects of the screen in the background. We have already reviewed the effects of adult programs in the section about content type and we will now summarize the results of the few studies that have more directly explored the effects of television in the background on the cognitive development of children under 3 years of age. We should note that exposure to background screens is more applicable to television than to mobile media, as the nature of mobile devices usually requires active engagement.

The consequences of early exposure to television in the background are twofold. On the one hand, the quantity and quality of parent-child interactions are affected, on the other hand, children are distracted from their ongoing activity.

Indeed, experimental findings show that parents talk less to 12- and 24-month-old children, and more passively, when the television is in the background than when it is turned off (Kirkorian et al., 2009). Questionnaire-based data also show that mothers use less vocabulary while playing with their 13-month-old child when the television is switched on vs. off (Masur et al., 2016). The decrease mediates the negative impact of screens on the lexicon size of these children at 17 months. This is of importance considering that the number of words heard before the age of 3 is a good predictor of future cognitive and linguistic performance (Hart and Risley, 1995; Risley and Hart, 2006; Zimmerman et al., 2009).

Another issue associated with background television is that it distracts the child from the action in progress, diverting their attention from play and learning. Experimental studies (Schmidt et al., 2008; Kirkorian et al., 2009; Setliff and Courage, 2011) have shown that television in the background interrupts the play sessions of children at 6, 12, 24, and 26 months of age. Even if children do not watch the screen much (5% of the time), the audiovisual changes that frequently occur on television cause the child to repeatedly orient toward the screen, draining the cognitive resources necessary to instantiate and execute action schemes. Advertisements in particular attract children's attention because young children still have little control over their attentional focus (Ruff and Rothbart, 2001). Studies that looked at the quality of play reveal shorter play episodes, and shorter periods of focused attention in the presence of television in the background, resulting in less rich and less complex solitary play compared to when the television is off (Schmidt et al., 2008; Kirkorian et al., 2009; Masur et al., 2016).

We have seen the importance of sustained interactions between child and adult and how screens can decrease these interactions, even when in the background. Nowadays though, touchscreens have opened the doors to more interactivity. Could interactive screens replace to our advantage some of these interactions with the adult, or be used to enrich them, for the benefit of the child?

The effect of interactive screens on learning

Here, we review the effects of interactive screens on cognitive development. This section does not include contingent communication through screens which is another area of research. A recent meta-analysis (Xie et al., 2018) showed that young children (0 to 5) could learn from touchscreens. When children were physically interacting with the screens, they learned better than other groups, like traditional classroom teaching, or could learn from video chats (Roseberry et al., 2014; Myers et al., 2017; Strouse et al., 2018). However, the effect of interactive screens with young infants is complex and depends on several factors, like age, content or comparison group. For example, older children learned better from touchscreens than younger ones; however younger ones learned better when the content was related to science as opposed to other material such as language comprehension, and when compared to non-interactive videos than when compared to manipulating physical objects.

Infants can learn from touchscreens, but can they transfer what they have learnt to real objects? Indeed, 15-month-old infants who have learnt from touchscreens only transferred their learning to touchscreens, and those who have learnt from real scenes only transferred their learning to real scenes, arguing for a video deficit effect extending to touchscreens, as experimental studies show (Zack et al., 2009; Barr, 2013). However, this deficit effect can be overcome through contingent communication with an experimenter on a screen. Indeed, 2- to 3-year-old children can learn new words and use clues given by an experimenter on a screen to find a hidden object only when the experimenter on the screen is interacting with the infant (Lauricella et al., 2010; Strouse and Ganea, 2017; Troseth et al., 2018). Other studies show a developmental trend between 24 and 30-months of age where younger infants do not learn from a touchscreen without interaction with a live partner, whereas 30-month-olds can learn without (Kirkorian et al., 2016). The authors argue that interactive videos may facilitate learning by directing attention to relevant information, thereby supporting limited attention skills that otherwise might rely on bottom-up, stimulus-driven features (Frank et al., 2009; Kirkorian et al., 2012).

Studies investigating the context of learning show that interaction with the parents enhances learning from touchscreen and transfer between-dimensions: infants were 19 times more likely to succeed and transfer learning between the touchscreen and real object if they were in a high-quality interactional dyad during a semi-naturalistic teaching task (Zack and Barr, 2016). The importance of the adult's role in accompanying their child when interacting with a screen was also observed using a word-learning app (Walter-Laager et al., 2017). Infants who were accompanied by an adult had the largest growth in vocabulary, and those who used the word-learning app without adult accompaniment showed the second largest growth. Less successful were the children who played with the picture cards (with or without adult accompaniment). Social facilitation was also observed with peers: the presence of a 9-month-old peer increased vocabulary learning through a touchscreen (Lytle et al., 2018). Authors suggest that the presence of similarly aged peers may have increased their arousal and motivation to learn as they showed more vocalization than when alone with their caregiver. In addition, the authors found a positive correlation between learning and the number of new infant peers were paired with through trials arguing that novelty heightens arousal and may thus have enhanced learning.

At the moment though, it is not clear whether interactive screens disrupt social interactions like other types of screens, or on the contrary, if they support social interactions. Studies on electronic books and reading comprehension in young infants might bring some answers to this question. However, the existing studies show opposite results, some showing a positive effect of electronic books in engaging children in the story and in the interaction with the parent compared to classic paper books (Strouse and Ganea, 2017) and others showing negative effects, with less dialogic verbalizations from parents and less engagement from infants with electronic books (Strouse and Ganea, 2017; Munzer et al., 2019). Lastly, studies focusing on very young infants before 2-years of age are also scarce and would be necessary in order to understand the implications of early use of interactive screens.

Is there a causality in the effects of watching screens on cognition?

Establishing causality relationships in science can be challenging, especially when experimental evidence cannot be collected for ethical reasons, as in the case of the potential harming effect of screen viewing on very young children. In that regard, we followed Suppes' probabilistic theory of causality: "one event is the cause of another if the appearance of the first event is followed with a high probability by the appearance of the second, and there is no third event that we can use to factor out the probability relationship between the first and second events" (Suppes, 1970, p10). In other words, if one can establish a statistical association between two variables, show evidence of directionality and rule out the effects of likely confounding variables, one can build a solid case in favor of causality.

The majority of the studies cited in this article are cross-sectional studies establishing an association between screen viewing and cognitive development but no directionality. While it is possible that watching screens has a negative causal effect on attention, for example, it may very well be that toddlers with attention control problems are less likely to refrain from watching screens. It is also possible that the parents of toddlers with attention control issues use the screens more often as a nanny, in which case viewing is not the cause of attention control disorders but a consequence.

A couple of studies have investigated directionality between these variables for children below 3. A path analysis (Wright et al., 2001) revealed that more time spent watching children's educational programs during age 2 and 3 predicts better reading, mathematics, receptive vocabulary, and school readiness scores 1 year later, while children scores did not predict educational screen time 1 year later. On the contrary, the time spent watching non-education children programs or programs not intended for children generally predicts lower scores 1 year later, but some of the effect can be explained by the fact that lower scores generally predict more watching of content not intended for children 1 year later. However, for an unknown reason, the authors used the scores between ages 3 and 4 to predict viewing patterns 1 year later rather than the scores between ages 2 and 3. A similar statistical method estimating the directional effects that one variable has on another at different timepoints (random-intercepts, cross-lagged panel model) was applied on a large cohort of children assessed at ages 2 and 3, using a parent-report scale to measure cognitive development (ASQ-3) (Madigan et al., 2019). Children's screen time at 2 was linked to lower cognitive scores at 3, but the reverse was not true, indicating precedence of screen time on cognitive development in children younger than 3. The effect size was small, equivalent to a loss of 0.06 to 0.08 standard deviation for every daily hour spent in front of a screen (Guez and Ramus, 2019). In this study, screen time encompasses television but also active screen usages like video gaming that is known to have causal positive effects on cognition in school-age children (Franceschini et al., 2013; Gambacorta et al., 2018; Franceschini and Bertoni, 2019).

Interestingly, the two studies also spent significant efforts to factor out the effect of other likely variables. The first study ruled out the effect of important demographic factors through the Home Observational Measure of the Environment score and the language used at home (Wright et al., 2001). The second study also ruled out important demographic factors, including sleep time (Madigan et al., 2019). Indeed, even if screens have a causal effect on cognitive development, such an effect can still be indirectly mediated through another variable, for example, through a change in the child's sleep pattern. Television and touchscreen use have been associated with a decrease in sleep quality (Cheung et al., 2017), and reduced night sleep (Ribner et al., 2019) in children younger than 3. An alternative mediation hypothesis is that watching screens does not have a direct detrimental effect but distracts children from other important daily engagement in play or learning with others (Kucirkova and Zuckerman, 2017). More research is needed to understand the precise causal structure through which screen watching can affect cognition in infants. At the moment, we can state that at least two studies established a solid case in favor of some causality of screen viewing on the toddler's cognition. While the debate is still open, only experimental research can bridge the remaining gap to a definitive answer.

Conclusion

In this review, we mainly focus on the potential impacts of early screen exposure on the development of cognitive abilities, but there might be other impacts on health and physical developmental associated with early screen exposure (e.g., sleep, physical activity, motor development) that we do not discuss.

From our review, it is clear that (1) interactive and non-interactive screens are becoming more pervasive in early childhood (Gassama et al., 2018); (2) between 12 and 30 months of age, there is a video deficit effect, for interactive and non-interactive screens (Barr, 2013), and until age 2, infants have trouble understanding speech on screens without adult guidance (Pempek et al., 2010). It helps explain why infants learn less from screens than from the real model, and generalize less the information on screens; (3) screen viewing is associated with lower cognitive development when viewing is unsupervised, when content is not appropriate for the age, or when in the background (Kirkorian et al., 2009); (4) therefore, it is not watching screens *per se* that determines the effects on development but rather the viewing context. Indeed, supervised viewing of appropriate-age content in the foreground can be beneficial, particularly when interactions occur; and (5) the effect of screens is likely causal (Madigan et al., 2019) but more work is needed in that respect. Screen viewing in the wrong context mainly impairs language development, school readiness, executive functions, attention capacities and parent-child interactions (Wright et al., 2001; Chonchaiya and Pruksananonda, 2008; Kirkorian et al., 2009; McHarg et al., 2020b).

There are at least two routes through which watching screens can have deleterious or beneficial effects on development. The first is linked to the inappropriateness of the program structure for the young child. Weak narrative, fast pace and editing, complex stimuli, or stimuli too different from reality, can make it difficult for the child to extract or generalize information. However, when screen content is appropriate for the child's age, it can be beneficial, or have no detrimental effect, particularly when the content is designed to foster child's interactions (Linebarger and Walker, 2005).

The second route is that viewing time may replace more appropriate learning activities, like social interactions. Interactions are also decreased during adult programs and when the screen is in the background (Kirkorian et al., 2009). Indeed, some studies evidenced that child-parent interactions were less communicative, and therefore less beneficial to the children, in presence of any types of screen exposure compared to other types of activities (e.g., books reading, playing with toys) and in the absence of screens (Nathanson and Rasmussen, 2011). It is therefore legitimate to question the effect of exposure to watching screens before the age of two, especially since exposure to screens is increasingly precocious (Wartella et al., 2010). However, when screens are used as a tool to support joint attention and adult-child interaction, they are beneficial (Fidler et al., 2010). Screens are impossible to remove from homes and are gradually making their way into school systems. It is imperative to inform caregivers of children younger than 3 about the risks associated with prolonged exposure to screen viewing in the wrong context and instead reinforce contexts that promote learning, such as viewing chosen age-adapted content and viewing with adult supervision.

One perspective for research is to develop more objective measures for screen viewing time in young children and to establish the reliability and validity of these measures. Current research mainly relies on parental reports. One possibility is to use media tracking apps from direct behavioral measures (eye-tracking) in the future. Further research is also necessary to distinguish between correlates for infants (under 12 months) and toddlers, as well as different kinds of media (television, mobile screens, touchscreens, video games) and media content. Existing research mostly focuses on one media at a time or no comparison is made between different media. Touchscreen media requires further attention, to assess for instance the effectiveness of specific touchscreen apps on children's cognitive development. These could be developed to inform the efforts of parents, educators, and policymakers.

The associations of several environmental and contextual correlates with screen time still need to be clarified (e.g., maternal age, maternal education, household income). Further research could focus on clearly defining these factors and elucidating their role as well as the mechanisms by which they shape infant's screen habits. Similarly, certain environmental and behavioral factors remain understudied, such as daily sleep duration, infant crying duration, or co-viewing habits. They may provide additional opportunities for intervention.

Viewing and using screens outside the home, in day care and pre-school settings adds to the total amount of time that children spend with screens and exposes them to additional, and perhaps different screen media contents that may lead to different developmental outcomes. Therefore, exploring screen media use in these settings and examining its impact on children's development is also worthy of investigation.

Author contributions

BG was in charge of harmonizing the text. AC was in charge of coordinating the work. All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

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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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Parental tuning of language input to autistic and nonspectrum children

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Caregivers' language input supports children's language development, and it is often tuned to the child's current level of skill. Evidence suggests that parental input is tuned to accommodate children's expressive language levels, but accommodation to receptive language abilities is less understood. In particular, little is known about parental sensitivity to children's abilities to process language in real time. Compared to nonspectrum children, children on the spectrum are slower to process language. In this study, we ask: Do parents of autistic children and those of nonspectrum children tune their language input to accommodate children's different language processing abilities? Children with and without a diagnosis of autism (ages 2–6years, N=35) and their parents viewed a display of six images, one of which was the target. The parent labeled the target to direct the child's attention to it. We first examined children's language processing abilities by assessing their latencies to shift gaze to the labeled referent; from this, we found slower latencies in the autistic group than in the nonspectrum group, in line with previous findings. We then examined features of parents' language and found that parents in both groups produced similar language, suggesting that parents may not adjust their language input according to children's speed of language processing. This finding suggests that (1) capturing parental sensitivity to children's receptive language, and specifically language processing, may enrich our models of individual differences in language input, and (2) future work should investigate if supporting caregivers in tuning their language use according to children's language processing can improve children's language outcomes.

KEYWORDS

parent, caregiver, language, receptive language, autism, processing, eye-tracking

Introduction

Children learn the language or languages of their community by forming mental representations of the language they are exposed to. However, language input is not directly represented in children's minds but is instead filtered through their own cognitive skills and linguistic knowledge. Their *intake* of the input is therefore limited by their own abilities (e.g., Trueswell and Gleitman, 2007; Kidd et al., 2013; Lidz and Gagliardi, 2014; Omaki and Lidz, 2015; He and Arunachalam, 2017; Arunachalam and Luyster, 2018; He, 2022). If, for example, parents produce language input that is too complex for the child's current abilities, the child may not benefit from it (e.g., He, 2022). Therefore, to best support intake, input must be tuned to children's language abilities.

There is evidence of this kind of tuning (also called accommodation) in caregivers' language input. For instance, caregivers provide more complex linguistic input to children with larger expressive vocabularies or more advanced production of syntax than those with less advanced skills (e.g., Bernstein Ratner, 1984; Pan et al., 2005; Bornstein et al., 2007; Huttenlocher et al., 2010). Leung et al. (2021) found that parents adjust their way of speaking about animals based on their child's lexical knowledge. They provide longer referential expressions (e.g., "the spotted yellow leopard") if they report that the child does not yet produce the word than if they report that the child does produce the word (e.g., "the cat"). This prior research, however, has focused primarily on children's *expressive* language levels. We know much less about whether caregivers' language is tuned to children's language *comprehension* abilities. This is an important gap to fill, for two reasons. First, children's intake from the input is determined by their abilities to comprehend (not necessarily produce) the language they are exposed to. Second, language comprehension is harder to gauge in children; while parents know about children's expressive skills from what they say, receptive skills can only be discerned indirectly, by observing behaviors such as whether children respond successfully to prompts (e.g., Tomasello and Mervis, 1994). If parents are less confident about what their child understands, they may have difficulty tuning their language input to their child's language comprehension abilities.

One recent study looked at parent tuning to children's receptive language: Arunachalam (2016) found that children processed noun phrases with postnominal modifiers (e.g., an umbrella with stripes) more quickly than those with prenominal modifiers (e.g., a striped umbrella), and correspondingly, parents more often labelled objects with postnominal modifiers, especially when the task was harder. This suggests that parents were attuned to what their child would find easier and more difficult to process and adjusted their language accordingly. The current study is a replication and extension of Arunachalam's (2016) work, and we return to and describe it in more detail below. For the moment, we address why language *processing* is particularly important to consider in this context.

By language processing, we are referring to real-time language comprehension. This requires the child to access representations for the words they hear, build a syntactic parse, and integrate this information with real-world knowledge about what the speaker is likely to be speaking about. Language processing speed is typically measured by showing the child two pictures and labelling one of them (e.g., "where's the cat?"); the child's latency to look to the cat is taken as a measure of how quickly they have processed the auditory label and identified the correct referent (e.g., Fernald et al., 2008b). Children who are faster to process the language they hear have larger vocabularies (e.g., Fernald et al., 2006; Weisleder and Fernald, 2013) and have more opportunities to learn new words (e.g., Fernald et al., 2008a; He et al., 2020).

For some children, real-time language processing is a particularly difficult task. Children on the autism spectrum, for example, show slower language processing than their nonspectrum peers, both when the groups are matched on chronological age (e.g., Bavin et al., 2014; Bavin and Baker, 2017) and when they are matched on language level on standard assessments (e.g., Ellis Weismer et al., 2016; Hartley et al., 2020). This suggests that language processing may be particularly affected in autism above and beyond aspects of language that are measured on standard assessments, such as vocabulary size. Therefore, it may be especially important for autistic[1] children that their caregivers' language is tuned to their language processing abilities (e.g., Adamson et al., 2009; Bottema-Beutel et al., 2014; Yoder et al., 2015; Fusaroli et al., 2019). Perspectives from autistic adults are valuable for understanding the autistic experience of linguistic processing demands; one blogger writes on her blog "Musings of an Aspie": "I have all sorts of communication glitches. I struggle with verbal instructions. If there's background noise or other distractions, my auditory processing lags to the point that it can take a few seconds to process speech from noise into words" (Kim, 2013).

In the current study, we ask whether parents of autistic children, like the parents of nonspectrum children in Arunachalam (2016), tune their language input by producing language that is easier to process. We chose this population for two additional reasons. First, some autistic children have relatively more impaired receptive language than expressive language (e.g., Artis and Arunachalam, submitted; Charman et al., 2003; Luyster et al., 2007; Ellis Weismer et al., 2010; but see Kwok et al., 2015). Second, just as language comprehension is difficult to measure in nonspectrum children because it relies on their response to prompts, the difficulty is amplified in autistic children, who are likely to show differences in social reciprocity and responsiveness (APA, 2013). Because of both of these factors, parents of autistic children may find it especially difficult to gauge—and tune to—their child's language comprehension and processing abilities.

1 Due to their ages, we did not directly ask the participants in the study whether they prefer to be referred to as "autistic" or "on the spectrum" (or something else), and so we use both interchangeably throughout the manuscript. We use "nonspectrum" to indicate children whose parents report that they are developing typically and do not have autism.

Indeed, we are not aware of any previous studies examining how parent language input is tuned to autistic children's language comprehension or language processing specifically. But there is an ample literature comparing caregiver language input provided to autistic children and input provided to nonspectrum children, which offers a relevant backdrop. In general, many of these studies report group similarities in the input: parents of autistic children use similar language as parents of nonspectrum children with respect to broad measures such as MLU, word tokens, word types, and lexical diversity (e.g., Swensen, 2007; Swensen et al., 2007b; Warren et al., 2010; Bang and Nadig, 2015; Nadig and Bang, 2017; Fusaroli et al., 2019; see Bang et al., 2019 for a review), at least when the groups are matched on expressive language level. Even with infants who have not (or yet) received an autism diagnosis but are at either higher or lower likelihood of receiving such a diagnosis based on whether they have an older autistic sibling, children in both groups receive a similar amount of infant-directed speech (see Woolard et al., 2021 for a recent scoping review) and this input is similar in features such as number of word tokens and types (although by 18 months, infants with higher autism likelihood hear language with a lower MLU; Choi et al., 2020).

These findings suggest a puzzle. Autistic children, who often have a different developmental profile (e.g., slower processing speed) may require *different* kinds of language input for optimal intake, and given parents' sensitivity to children's language abilities, we might predict that parents would therefore provide different kinds of input. Indeed, when more specific parent language features are studied, group differences do appear. For example, parental input to autistic children (compared to that to nonspectrum children) contains fewer questions (e.g., Venuti et al., 2012; Goodwin et al., 2015; Luyster et al., 2022), fewer comments related to story characters' mental states (Slaughter et al., 2007), and more utterances differing in pragmatic appropriateness (Landa et al., 1992; Losh et al., 2008; Stern et al., 2017). Moreover, because first-degree relatives of autistic individuals are more likely to have traits in the broader autism phenotype than the general population, some parents of autistic children also show some traits associated with autism that differ from parents of nonspectrum children. In particular, some of these parents use a slower speech rate and have prosodic characteristics associated with autism (e.g., Patel et al., 2020).

Some of these features of parent speech could facilitate language comprehension in autistic children. For example, differences in play behavior and responsiveness in autistic children may mean that some kinds of parent interaction and parent language input are more effective than they are for nonspectrum children (e.g., Haebig et al., 2013; Bottema-Beutel et al., 2014). Bani Hani et al. (2013) found that when parents introduced novel words to their child, parents of children on the spectrum used multiple nonverbal cues (e.g., eye gaze, pointing) accompanying the new word, perhaps in order to maintain the child's attention given their knowledge of attentional differences in autistic children (generally) or their child (specifically). With infants, the review paper mentioned above (Woolard et al., 2021) also reported evidence of group differences in subtle behaviors––parents of higher-likelihood and later-diagnosed children produce infant-directed speech with more attention bids and more follow-in commenting. They also use the infant's name more often (He et al., 2018) and produce more gestures (Talbott et al., 2015). All of these behaviors may help the parent get and maintain the child's attention, the importance of which has been noted elsewhere for both naturalistic and clinical settings (Constain et al., 2018). Thus, previous findings are consistent with the hypothesis that parents of autistic children are sensitive to their child's attentional skills and tune their input accordingly.

However, we do not yet know the extent to which parental language input is specifically tuned to children's language processing abilities. Slower processing speed in children on the spectrum (e.g., Bavin et al., 2014; Ellis Weismer et al., 2016; Bavin and Baker, 2017; Hartley et al., 2020; Horvath and Arunachalam, under revision) may mean that the best input for them is slower and/or consists of easier-to-process constructions (e.g., active instead of passive, e.g., Abbot-Smith et al., 2017 and Messenger et al., 2011; or postnominal modifiers instead of prenominal modifiers, as we investigate in the current study, e.g., Sekerina and Trueswell, 2012).

To summarize, past work suggests that there are both similarities and differences in the parental language input directed to autistic vs. non-spectrum children. However, one remaining gap that we think is particularly important is whether (and if so, how) the input might be tuned to children's real-time language processing.

In the current study, we ask whether parents' language input is tuned to autistic children's real-time language processing abilities by replicating and extending a study with nonspectrum children by Arunachalam (2016). In that study, parent–child dyads played a finding game. On each trial of the game, an array of six pictures was displayed on an eye-tracking monitor. The parent was directed to describe one of them so that their child could identify it. Parents were not told what to say, only which picture they should talk about. Arunachalam examined both children's speed of looking to the target—their language processing speed, a real-time index of language comprehension—and features of parental language input. Task difficulty was manipulated across two conditions[2]. In the Hard condition, the target object had a competitor in the display from the same basic-level category that differed in some salient property (e.g., two books: one open, one closed). In the Easy condition, there were no competitor objects from the same basic-level category. In the Hard condition, parents would have to use a more complex referential expression to label the object (e.g., "the open book" or "the book that's open"); in the Easy condition, although parents were still free to use those

2 Note that Arunachalam (2016) referred to these conditions as "Same" and "Different"; for ease of comprehension, we have changed them to "Hard" and "Easy," respectively.

complex expressions, the additional modifiers would be unnecessary for target identification.

A large psycholinguistics literature establishes that young children can process noun phrases incrementally and can correctly interpret modifiers as disambiguating information when multiple objects from the same category are present. This holds not only for nonspectrum children (e.g., Thorpe and Fernald, 2006; Fernald et al., 2010; Huang and Snedeker, 2013; Davies et al., 2021), but also for children on the spectrum (e.g., Bavin et al., 2016; Bavin and Baker, 2017). Thus, Arunachalam's (2016) method applies well to autistic children. In the current study, we therefore replicate and extend this study, focusing on autism, with nonspectrum children as a comparison.

With respect to children's processing, Arunachalam (2016) found that children had shorter latencies to look to the target, that is, they were faster to process the parent's referential expression, in the Easy condition than in the Hard condition. In the current study, we predict the same to be true for both the nonspectrum and autistic groups. Further, we expect children in the autistic group to be slower overall than those in the nonspectrum group, reflecting the slower language processing speeds found throughout the literature.

With respect to parental input, Arunachalam (2016) examined two main features: speech rate and type of referential expression. Because a slower speech rate can better support children's language comprehension, particularly in difficult tasks (e.g., Haake et al., 2014), she expected a between-condition difference––slower speech rate in the Hard condition than the Easy condition. But this hypothesis was not borne out. However, in the current study with two groups of children––autistic and nonspectrum, given their differences in processing speeds, there might still be a between-group difference (despite a potential lack of between-condition difference)––specifically, it might be the case that parents of children on the spectrum would use a slower rate (than parents of nonspectrum children) in order to accommodate their slower processing speeds.

With respect to type of referential expression, Arunachalam (2016) coded whether parents labeled the target object with just a content noun (e.g., "the book") or whether they added modifiers, and if the latter, whether the modifiers appeared before the noun (e.g., "the open book") or after it (e.g., "the book that's open"). Prenominal modifiers have been shown to be difficult for children to process (e.g., Sekerina and Trueswell, 2012; Huang and Snedeker, 2013; Arunachalam, 2016; but see Davies et al., 2021) and so postnominal modifiers should be preferable. What Arunachalam (2016) found was that parents did produce more postnominal modifiers, but only in the Hard condition—when the child's task was more difficult, parents alleviated the difficulty by producing an easier-to-process referential expression. In the Easy condition, parents appeared less concerned about processing difficulty; even though modifiers were unnecessary to uniquely identify the referent (e.g., there was only one book in the display), parents did sometimes produce modifiers, and half of these were prenominal as compared to postnominal. This is interesting given that unnecessary modifiers increase processing load, even in adults (e.g., Engelhardt et al., 2006, 2011) as well as in children (e.g., He et al., 2020). Based on these findings, for the current study, we predict that parents will use more postnominal modifiers in the Hard condition than the Easy condition. This between-condition difference might be larger for the autistic group than the nonspectrum group, due to autistic children's slower processing. Further, given that unnecessary modifiers also place an additional processing burden on the child, we predict that parents of autistic children will produce fewer unnecessary modifiers (i.e., fewer modifiers in the Easy condition) than parents of nonspectrum children.

Finally, we included exploratory analyses relating children's processing to features of parents' referential expressions. These analyses are exploratory because the number of data points of each type is unequal, and determined by parents' referential choices. However, the findings provide hypotheses to test in future controlled experiments. Specifically, we examine whether children's latencies to look to the target are predicted by the parents' choice to include unnecessary modifiers in the Easy condition, as well as whether they are predicted by modifier position (prenominal or postnominal) in either condition.

To summarize, our goal in the present study was to replicate Arunachalam's (2016) work with nonspectrum children and their parents, and to extend it to autistic children and their parents. Our overarching hypotheses were that we would replicate prior findings that autistic children are slower to process language than their nonspectrum counterparts, and that their parents would tune to this difference in processing speed by producing easier-to-process language: slower, with fewer modifiers, and with postnominal rather than prenominal modifiers.

Like Arunachalam (2016), we focused on young children (i.e., preschool and early school-aged), who are old enough to understand the task. Several studies have assessed online language processing in autistic children or children with an older autistic sibling in this age group (e.g., Swensen et al., 2007a; Venker et al., 2013; Brady et al., 2014; Chita-Tegmark et al., 2015; Horvath et al., 2018; Zhou et al., 2019). Further, this age group is optimal for studying language input and intake in parent–child dyads because these children are young enough that parents are still an important source of language input but old enough that parents have had ample time to observe their child's language growth and evaluate their expressive and receptive language skills.

Materials and methods

Participants

Nonspectrum and autistic children participated with one of their parents. Participants were primarily recruited from the greater Boston area in the United States using online advertisements and our lab's databases of families who expressed interest in participating in research. Some children in the autistic group were recruited through the Simons Foundation Powering Autism Research for Knowledge (SPARK) database (SPARK Consortium, 2018). All recruitment and testing procedures were approved by Boston University's Institutional Review Board. A total of 20 autistic children (3 female, 17 male) and 15 nonspectrum children (8 female, 7 male) were included in the final sample. In each group, three of the participating parents were male; the rest were female. Six additional children participated in at least some elements of the study protocol but were excluded from the final sample: 4 had been assigned to the autistic group based on parent report of an autism diagnosis but failed to meet diagnostic criteria during the study (see below); 1 had been assigned to the nonspectrum group but scored above the autism threshold on the Social Communication Questionnaire (SCQ, see below); and 1 (in the autistic group) was unwilling to complete the experimental task.

The autistic group's mean age was 4:9 (range 3:6 to 6:10) and the nonspectrum group's mean age was 3:6 (range 2:1 to 4:5). We intentionally recruited nonspectrum children at younger ages to yield two groups that did not significantly differ on language or cognitive ability (see below). In both groups, dyads were included if parents reported that children were English learners with no more than 30% exposure to another language and had no known developmental disorders aside from either autism (for the autistic group) or those that are often comorbid with autism such as ADHD.

For the autistic group, diagnosis was confirmed using the Autism Diagnostic Observation Schedule-2nd Edition (ADOS-2; Lord et al., 2012), the gold standard diagnostic instrument for autism spectrum disorder, by a research-reliable examiner. The ADOS-2 is appropriate for children with a chronological and developmental age of at least 12 months through adults. None of the participating parents nor other adults in their household self-reported as being on the spectrum.

For the nonspectrum group, we used the SCQ (Rutter et al., 2003) to confirm *via* parent report that the child was not exhibiting features indicative of autism. This questionnaire is normed for children 48 months and older, but it has been widely used with younger children (e.g., Marvin et al., 2017). Following Corsello et al. (2007), we used a threshold of ≥15 for children 48 months (and older) and a downward adjustment to ≥12 for younger children. All 15 nonspectrum children included in the final analyses scored below the relevant cutoff. None of the nonspectrum children were reported to have a household member with autism.

To obtain a picture of children's language and developmental profiles and to ensure that the two groups did not significantly differ from each other, we asked parents to complete the MacArthur-Bates Communicative Development Inventory II Short Form A: Words and Sentences for expressive vocabulary (Fenson et al., 2007; three nonspectrum children did not have MCDI scores). This form is designed for typically-developing children ages 16–30 months; however, the publishers note that it "may be used with older, developmentally-delayed children" (CDI Advisory Board, n.d.) and many studies do so (e.g., Hambly and Fombonne, 2012; Robertson et al., 2017; Arunachalam et al., 2022). We also note that neither group was at ceiling (see Table 1). Most children also completed the Visual Reception, Receptive Language, and Expressive Language subscales of the Mullen Scales of Early Learning (MSEL; Mullen, 1995; due to scheduling difficulties, 1 autistic child and 4 nonspectrum children did not complete the MSEL). The MSEL is designed for children from birth to 68 months. The Visual Reception subscale serves as a rough proxy for nonverbal cognition, while the Receptive and Expressive Language scales serve as an additional measure of language level. *T*-tests showed no between-group differences on any of the scores: MCDI expressive vocabulary, MSEL Visual Reception, MSEL Receptive Language, MSEL Expressive Language (all *p*s greater than 0.1). See Table 1. Unsurprisingly given the heterogeneity of the autistic population, the standard deviations were larger for the autistic group than the nonspectrum group. Some of the children also participated in an unrelated experimental task (Clancy et al., 2019).

Materials and apparatus

The experimental task had 16 trials and 2 conditions, both within-subjects. On each trial, an array of 6 images arranged in 2 rows of 3 was shown (see Figure 1). Each image was contained in an invisible square measuring 570 pixels (px) × 410 px, with 65 px of white space between the columns and 255 px of white space between the rows. The images were similar to those used by Arunachalam (2016). To control somewhat for perceptual and conceptual complexity, we used clip-art images of highly familiar objects, animals, and people. In pilot work for this study, these images elicited referential expressions from parents that were similar to those in Arunachalam (2016) and that successfully and uniquely identified the target referent.

The two conditions, Hard and Easy, each had 8 trials. In the Hard condition, trials were characterized by having one pair of images from the same basic-level category but differing in some salient property (e.g., two stars, one red and one blue); one of these objects was the target. In the Easy condition, trials had no distractor objects from the same basic-level category as the target, and there were no pairs from the same basic-level category within the distractors. See Figure 1 for a sample trial.

All of the target images depicted common household objects, people, and animals; see Supplementary Materials for a full list. The properties on which the two competitor objects differed included color (e.g., red, blue) and size (e.g., big, small) as well as other properties that were easily discernible from the images (e.g., open, closed; asleep, awake; spotted, striped). Although parents were free to use any kind of modifiers they wished to describe the objects, the most salient property differences were describable by adjectives that children at this age would know. These included adjectives denoting color and size concepts (e.g., red, big). Note that particular modifiers may differ in whether they are more

TABLE 1 Children's language and cognition scores on standard assessments.

	N	Age, months mean (SD)	MB-CDI 2 mean (SD)	Mullen VR raw score mean (SD)	Mullen RL raw score mean (SD)	Mullen EL raw score mean (SD)	SCQ mean (SD)
Nonspectrum	15	41.93 (6.95)	87.18 (19.83)	41.60 (6.31)	40.18 (6.03)	40.64 (5.48)	4.91 (3.30)
Autism	20	57.85 (10.21)	69.30 (32.69)	37.33 (11.81)	35.44 (9.85)	35.11 (10.10)	14.28 (6.39)

MB-CDI 2, MacArthur-Bates Communicative Development Inventory Words and Sentences Short Form A (total number of words, out of 100, reported to be in the child's expressive vocabulary); Mullen VR/RL/EL, Mullen Scales of Early Learning Visual Reception, Receptive Language, Expressive Language subscales. There were no significant differences between the two groups on these measures.

FIGURE 1
Sample trial in the Hard condition. The target image was the open book, top row middle.

likely to be used prenominally than postnominally (e.g., color adjectives almost universally appear prenominally in English; Thorpe and Fernald, 2006). However, because our goal is to investigate differences between the Hard and Easy conditions, we were not concerned about potential differences at the level of individual modifiers.

The stimuli were presented on a Tobii T60XL eye-tracker sampling at 60 Hz, operating Tobii Studio software. Children sat in a car seat 20 in. in front of the eye-tracking monitor. The parent sat next to the child, approximately 3 feet away, and wore laser safety glasses that blocked the near-infrared wavelengths used to detect gaze but not shorter wavelengths. The parent could therefore see the screen, but their own gaze was not tracked.

Procedure

The visit began with children playing with toys and parents completing paperwork, including providing informed consent on behalf of themselves and their child. The instructions were administered as in Arunachalam (2016). First, the experimenter explained to the parent that the dyad would see six images on the computer screen and the parent's job was to get the child to identify the target image as quickly as possible. The parent was told they would need to describe the target image so that their child could identify it. The parent was instructed that they could say whatever they wanted to encourage their child to identify the correct image, but that because it was a guessing game, they could not point or use their hands. We explained that each of the 6 possible image locations was numbered, and for each trial, we would indicate to the parent which image was the target on each trial by referring to its numbered location.

Then, the parent and child entered the testing room, where the child was seated in front of the eye-tracker and the parent next to the child. The child first underwent a 5-point calibration procedure using Tobii Studio software. Before each trial, the experimenter, who sat behind and to the side of the parent, out of view of the child, held up a card depicting six numbers arranged in a two-by-three grid (from left to right: top row 1, 2, 3; bottom row 4, 5, 6). The same grid appeared on the computer screen, but displaying images instead of numbers, with each image on the screen corresponding to one number on the card. When the experimenter pointed to a number on the card, the parent thus knew which image was the target image on that trial, but the child, who could not see the card with the numbers, did not know. Therefore, parents were not told what to say, only which picture they should talk about.

On each trial, the experimenter operating the eye-tracking software from behind a curtain advanced the display so that the array of images was shown. The experimenter waited approximately 5 s to allow both the parent and child to examine the images and then showed the parent a new card with the target image's number, after which the parent described the image that corresponded to the number. Children were not required to point to the image, as we were concerned that some autistic children might not point (and several in fact did not); if they did not point, the experimenter waited approximately 10 s or until the parent asked to move to the next trial. The duration of the task differed depending on how much or little the parent said, but the average duration was 7 min 46 s ($sd = 163$ s) for the autistic group and 6 min 46 s ($sd = 120$ s) in the nonspectrum group.

After the experimental task, most children completed the subscales of the MSEL with a trained researcher. Children in the autistic group only were administered the ADOS-2 to confirm autism diagnosis on a second visit to the lab, approximately 1 week later.

Coding and analysis

Children's processing and parents' language were coded and analyzed as follows.

Children's processing. Following past work in the language processing literature with both children on the spectrum and nonspectrum children (e.g., Fernald et al., 2008a; Venker et al., 2013), we used latency to look to the target as an index of processing speed. That is, we measured how quickly children shifted their eye gaze toward the target image from the offset of the referential expression produced by the parent––for instance, upon hearing "Look at the bear who's sleeping," how much time elapsed before the child's first look toward the image of the sleeping bear. Following Arunachalam (2016), latencies were calculated from the offset of the referential expression, but negative latencies (i.e., looks after the onset but before the offset of the expression) were included (only one negative latency occurred in the final data set). (See more about referential expression coding below.) A look was defined as three consecutive frames for which the child's gaze fell within the target area of interest (i.e., one of the six invisible squares); the first of these frames was used to calculate latency.

For gaze analysis, we excluded children and trials with excessive track loss (i.e., sampled frames without gaze coordinates, due to blinks or excessive movement). We first excluded children with 65% or more track loss across the entire experiment (4 children from the autistic group) and then excluded individual trials from the remaining children with 65% or more track loss (autistic, 48 trials; nonspectrum, 11 trials). We further excluded trials on which children did not look at the target at all before the trial ended (autistic, 8 trials; nonspectrum, 13 trials). Finally, we excluded from this analysis trials on which parents' referential expressions were not codable, as discussed below. Therefore, the final sample for eye gaze analyses included 203 trials from 16 autistic children and 194 trials from 14 nonspectrum children.

To analyze children's gaze, we conducted linear mixed-effects regressions with the lme4 package version 1.1.28 (Bates et al., 2015) in R version 4.1.2 (R Core Team, 2016). The lmerTest package version 3.1.3 (Kuznetsova et al., 2017) provided p-values, using t-tests fit by Satterthwaite's method. Pairwise comparisons of estimated marginal means were used to examine significant interactions using the emmeans package version 1.7.4–1 (Lenth, 2022). Figure 2 was made using the ggplot2 package (Wickham, 2009). The goal of these analyses was to understand whether autistic children were slower to process their parents' referential expressions than nonspectrum children, whether children were slower in the Hard condition than the Easy condition, and whether there was an interaction between group and condition such that autistic children had particularly long latencies in the Hard condition. Because groups differed significantly on chronological age (although they did not differ significantly on language or cognitive measures), we included age as a fixed factor in the analyses.

Parents' input. For analyses of parental input, parents' speech was first transcribed by a trained experimenter and coded by two trained coders using Praat (Boersma and Weenink, 2020). Then, *speaking rate* and *referential expression choices* were analyzed. Speaking rate was calculated by dividing the referential expression

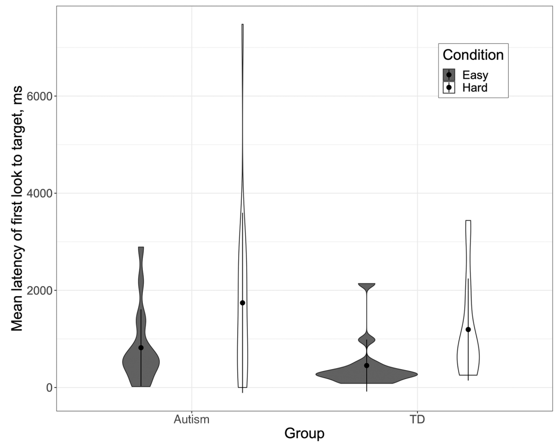

FIGURE 2
Violin plot depicting mean latency by participant of first look to the target, in ms, by group and condition. The black dot indicates the mean, and the shape indicates the probability density of the data at different values.

duration (in seconds) by the number of syllables it contained. Referential expression durations were the period of time from the onset and offset of the referential expression. For referential expression choices, we specifically coded whether a referential expression was modified or not––in particular, to what extent unnecessary modification (i.e., overmodification) was used; and for modified, where the modifiers were positioned (i.e., before or after the noun).

Referential expressions were defined as a noun plus any modifiers from any syntactic category (excluding determiners, because preliminary coding showed that it was difficult to code their onset reliably given their brief duration). Examples of referential expressions produced by parents included: "little piano," "book that's open," "doll in a pink dress," "green hat with green dots on it." Note that we included modifying information as part of the referential expression whether or not it was critical for identifying the target (that is, the offset of entire phrase, "green hat with green dots on it," was used even if there was only one hat in the display).

For this analysis, we excluded trials on which parents produced referential expressions that could not be coded (31 trials in the autistic group, 24 in the nonspectrum group). These were trials on which the parent made a reference that was specific to their family (e.g., "Which one is Aunt Debbie's favorite?"), trials on which the parent spoke about the incorrect target image, and trials in the Hard condition on which the parent did not provide sufficient disambiguating information to uniquely identify the target (e.g., saying "Where's the book?" when there were two books in the array). One parent in the nonspectrum group produced only referential expressions of the family-specific type and this dyad was therefore excluded from all analyses. The final sample for parent speech analyses included 278 trials from all 20 parents of autistic children and 202 trials from 14 parents of nonspectrum children.

As with children's gaze, we used linear mixed-effects regression to understand parents' referential expression choices. We also used this approach in exploratory analyses to look for relations between children's processing and parents' referential expression choices. Models are specified in detail in the Results section below.

Results

Children's processing

We ran a linear mixed-effects model with latency as the dependent measure; child age (centered around its mean), group (autistic vs. nonspectrum, contrast coded with autistic as 0.5 and nonspectrum as −0.5), condition (Hard vs. Easy, contrast coded with the Easy condition as −0.5 and the Hard condition as 0.5), and the interaction between group and condition as fixed factors; and participant and trial as random factors. This analysis yielded no significant effect of age ($\beta = -19.58$, $p = 0.27$), but it did reveal significant main effects of group ($\beta = 790.86$, $p = 0.04$) and condition ($\beta = 750.22$, $p = 0.04$). The interaction between group and condition was not significant ($\beta = 149.76$, $p = 0.74$).

These results indicate, first, that autistic children's latency to identify the target ($m = 1{,}327$ ms, $sd = 2{,}755$ ms) was significantly slower than that of nonspectrum children ($m = 796$ ms, $sd = 1895$ ms). Thus, as predicted, autistic children were slower to process their parent's speech. Second, latencies were longer in the Hard condition ($m = 1{,}459$ ms, $sd = 3{,}084$ ms) than the Easy condition ($m = 686$ ms, $sd = 1{,}303$ ms). Thus, also as predicted, children across both groups showed more difficulty in identifying the target when there was a competitor object than when there was not.

Parents' input

Parents' speaking rate and referential expression choices were analyzed.

Speaking rate. Across all trials, mean speaking rate was 0.39 syllables per second for parents of autistic children ($sd = 0.77$) and 0.33 for parents of nonspectrum children ($sd = 0.20$). A linear mixed-effects model with speaking rate as the dependent measure, participant and trial as random factors, and group (autistic vs. nonspectrum) as a fixed factor (contrast coded as described above for child gaze analyses) revealed no main effect of group ($\beta = 0.068$, $p = 0.27$).

Referential expression choices––Overmodification. In the Easy condition, where modifiers were not needed in order to specifically identify the target, parents nevertheless often produced unnecessary modifiers (replicating Arunachalam, 2016). For the autistic group, parents did so on 51% of trials, and for the nonspectrum group, 60%. Although this numerical difference between the groups was in the predicted direction (that is, we expected that parents of autistic children to more actively avoid overmodification in order to reduce the child's processing burden on the child), it was not statistically significant (Fisher's exact test $p = 0.20$).

Referential expression choices––Modifier position. Recall that we predicted that parents would use more postnominal modifiers in the Hard condition than the Easy condition, and that this between-condition difference might further be larger for the autistic group. The proportion of modifiers that were postnominal as compared to prenominal (excluding trials on which no modifiers were produced or on which both pre- and postnominal modifiers were produced) for each condition and group is shown in Table 2. As predicted, more postnominal modifiers were produced in the Hard than the Easy condition in both groups, and Fisher's exact tests demonstrate that the difference in pre- vs. postnominal modifiers between conditions is significant for the autistic group ($p = 0.008$) but not for the nonspectrum group ($p = 0.3$). Thus, the results suggest that parents of autistic children may be particularly sensitive to the difficulty of the Hard condition as compared to the Easy condition.

Exploratory comparisons linking child latencies and parent input characteristics

Because parental input was unscripted, we do not have balanced numbers of trials with different parent input features. Therefore, we cannot robustly analyze how specific parent input features might be associated with children's processing. Nevertheless, to provide a basis for future work, we conducted some exploratory analyses. First, for the Easy condition, we compared latencies by whether the parent produced an unnecessary modifier (autistic group mean = 724 ms, $sd = 969$ ms; nonspectrum group mean = 318 ms, $sd = 824$ ms) or did not (autistic group mean = 1,093 ms, $sd = 1{,}602$ ms; nonspectrum group mean = 712 ms, $sd = 1{,}727$ ms). The number of data points in each of these cells is small and unequal, given that it depended on what parents chose to produce rather than our own manipulation (but recall that the use of unnecessary modifiers was relatively balanced; 51% for the autistic group and 60% for the nonspectrum group). Examining this pattern statistically, with latency as dependent measure, random effects of participant and trial, and fixed effects of group and modifier use and their interaction, we found no significant effects of group ($\beta = 391.51$, $p = 0.13$) or modifier use ($\beta = -302.92$, $p = 0.10$), and no significant

TABLE 2 Proportion of modifiers that were postnominal as compared to prenominal produced by parents by condition and group (trials with no modifiers or with both pre- and postnominal modifiers were excluded).

Group	Hard condition	Easy condition
Autism	0.31	0.13
Nonspectrum	0.26	0.18

interaction ($\beta = -121.59$, $p = 0.73$). This suggests that unnecessary modifiers did not substantially decrease processing efficiency.

We also examined latencies in the Easy and Hard conditions by whether the modifier, when present, occurred prenominally or postnominally. Again, this analysis is exploratory and limited by the number of data points per cell, which is uneven and very small in some cases. See Table 3. Like Arunachalam (2016), postnominal latencies were shorter than prenominal for the nonspectrum group in both conditions. However, this pattern did not hold for the autistic group. A model with latency as dependent measure, random effects of participant and trial, and fixed effects of group and modifier position and their interaction revealed a significant effect of group ($\beta = 1096.53$, $p = 0.005$), and of modifier position ($\beta = 675.04$, $p = 0.048$) and their interaction ($\beta = 1861.72$, $p = 0.006$). (We did not include condition in this model because both conditions showed the same pattern and we did not want to overfit the model.) We further explored the interaction with pairwise comparisons of the estimated marginal means, which revealed that the difference in latencies between modifier positions was significant for the autistic group ($t(254.6) = -3.35$, $p = 0.005$) but not the nonspectrum group ($t(255.8) = 0.52$, $p = 0.95$).

This intriguing difference suggests that prenominal modifiers are more supportive than postnominal modifiers for comprehension for autistic children, contrary to what prior research has shown for nonspectrum children (and contrary to the trend, though not significant, for nonspectrum children in the current study); thus, they may benefit from different kinds of linguistic contexts for referential expressions than nonspectrum children.

TABLE 3 Children's mean latency to look at the target by group, condition, and modifier position (trials with no modifiers or with both pre- and postnominal modifiers were excluded).

Group	Condition	Modifier position	Number of data points	Mean latency, ms (sd)
Autism	Hard	Post	26	3,105.23 (6,148.79)
Autism	Hard	Pre	71	1,112.23 (1,795.23)
NS	Hard	Post	24	721.58 (962.93)
NS	Hard	Pre	63	994.32 (2,058.98)
Autism	Easy	Post	8	957.88 (883.31)
Autism	Easy	Pre	41	608.59 (910.67)
NS	Easy	Post	9	117.78 (346.08)
NS	Easy	Pre	41	388.17 (974.36)

Discussion

To understand children's language development, it is important to consider not only the language *input* they experience but also their *intake* from that input. The goals of the current study were to assess intake by measuring children's comprehension of their parents' language and to explore how parents might tune their speech to make the task of language comprehension easier for their child. We compared these features across groups, evaluating autistic and nonspectrum preschoolers, because for children on the spectrum, differences in understanding and making use of social cues, as well as less robust linguistic skill and slowed processing, may mean that they process less of the language input directed to them and/or may process language more slowly (e.g., Arunachalam and Luyster, 2016, 2018; Crandall et al., 2019). Although parents have been shown to tune their language input to their child's expressive language, we suggested that they may be less attuned to their child's real-time language *processing* skills, and therefore less able to tune their language input to support comprehension specifically.

Child–parent dyads played a game in which the parent verbally labelled one image from an array and the child's task was to identify the correct image as quickly as possible. Children's gaze was tracked while they participated. This paradigm allowed us to analyze children's language processing and features of the parents' language input in the same setting and in real time. Specifically, we examined features of parent language input when labeling the image, how quickly children looked to the correct referent, whether these two measures were related, and whether these patterns differed for autistic children as compared to nonspectrum children.

The primary findings were twofold. First, language processing speed in the autistic group was significantly slower than in the nonspectrum group. This finding is consistent with prior reports that language processing as measured in a variety of tasks, with and without eye-tracking, is on average slower in autistic children (e.g., Bavin et al., 2014; Ellis Weismer et al., 2016; Bavin and Baker, 2017; Marini et al., 2020). The current study further adds evidence that the difference in processing speed occurs even with unscripted speech from a speaker the child is very familiar with (as compared to pre-recorded speech streams typically used in eye-tracking studies).

Second, parents of autistic children did not significantly differ from parents of nonspectrum children on any of the measured language properties: speaking rate, use of unnecessary modifiers in their referential expressions (just over half the time), or position of those modifiers (which were primarily prenominal, but less so in the Hard condition than the Easy condition). The literature is mixed on whether parent language input differs to children on and off the spectrum (see, e.g., Bang et al., 2019; Woolard et al., 2021 for two recent reviews). The current study provides another finding to add to this literature from a specific situation—we suggest that when it comes to labelling a single image from an array in a finding game, parents of autistic children do not differ from parents of nonspectrum children in the rate of delivery or kind of language they use.

Taken together, the results suggest that although there is a group difference between nonspectrum and autistic children in language processing speed, the language input of parents of autistic children is not adapted *specifically* to support slower processing. This is not to say that parents are not aware of their child's language abilities or that their input is not tuned in other ways; indeed, parents of children on the spectrum are very sensitive to their child's language development and often delays in language are the parent's first indicator that their child might need an autism evaluation (e.g., Chawarska and Volkmar, 2007; Garrido et al., 2018). Moreover, in the current study, parent input *was* adapted to the difficulty of the task across both nonspectrum and autistic groups. Specifically, in the harder condition in which there were competitor objects (the Hard condition), parents were more likely to place modifiers postnominally than in the easier condition in which there were no competitors from the same category (the Easy condition). Therefore, although parent speech is adapted to support children's processing, it is not differentially so for nonspectrum versus autistic children.

Moreover, although we interpret this finding cautiously due to the nature of the experimental design—the number of relevant data points is constrained by what parents choose to produce—our exploratory analyses suggest children on the spectrum may benefit from different kinds of referential expressions than nonspectrum children. Specifically, while nonspectrum children showed a trend toward faster latencies with referential expressions that had postnominal rather than prenominal modifiers, and this is consistent with Arunachalam (2016), autistic children showed a significant difference in the opposite direction—they were faster with prenominal than postnominal modifiers.

In what follows we turn to how these findings contribute to the literature, theoretically and methodologically.

Tuning of parental input

It is well established that the trajectory of a child's development of language has many influences, including bidirectional influences between parent and child language, even beginning in infancy, and in autism as well as nonspectrum development (e.g., Huttenlocher et al., 2010; Bani Hani et al., 2013; Warlaumont et al., 2014; Wu and Gros-Louis, 2014; Yurovsky, 2018; Fusaroli et al., 2019; Choi et al., 2020; Odijk and Gillis, 2020; Quigley and Nixon, 2020; Leung et al., 2021). For example, in a longitudinal study, Fusaroli et al. (2019) found reciprocal associations between child and parent language in nonspectrum and autistic children. In addition to affirming previous findings that parent language features predict child language, they also documented the reverse, that children's language features predicted parent language: children's language at one visit predicted parent language at a subsequent visit. This work focused on classic measures of expressive language like MLU and word types/tokens. In a more recent study, Fusaroli et al. (2021) focusing on caregivers' alignment (i.e., re-use of the child's language in dyad conversations) showed that caregivers of autistic children tended to use less and different kinds of alignment in comparison to caregivers of nonspectrum children. Thus, parents appear to be tuned to their child's expressive language abilities and to tune their own speech accordingly.

However, children's expressive language is not the only domain to which parents are sensitive. For example, parents use infant-directed speech to infants and not older children, even before the infants use any expressive language at all (e.g., Fernald and Simon, 1984), and recent evidence shows that parents fine-tune how they label objects depending on their child's knowledge about the object (Leung et al., 2021). Roy et al. (2009) found that the parents of one child produced a word in shorter utterances just *before* the child began to produce that word.

Despite these intriguing individual findings, what we know about how parents tune their speech to their child is limited, because most previous work showing reciprocal parent–child influences in both nonspectrum and autistic groups has focused on expressive language ability rather than language comprehension and processing. Chronological age is unlikely to be the sole factor, as is illustrated by evidence from autistic children and intellectual disability who show a gap between chronological age and expected language—these children receive input that is more tuned to their language level but not necessarily their chronological age (e.g., Bang et al., 2019). It is unsurprising that expressive language ability is an important factor that parents are sensitive to, because it is a salient part of how parents experience their child's developing language ability. In the present study, we instead chose to focus on receptive language, aiming to tap into children's intake of the input by investigating how quickly children comprehend the language produced by their parent. Although receptive and expressive language scores on standard assessments are strongly correlated in autistic children just as in nonspectrum children (Luyster et al., 2008), they are not perfectly correlated, and receptive language is often a domain of relative difficulty (e.g., Luyster et al., 2008; Hudry et al., 2010). It might be that parents are less sensitive to their child's receptive abilities because they are less easily observed. Certainly, nonverbal communication, too, can provide a signal to parents of the child's language level (e.g., Yoder and Warren, 1993), and parents respond accordingly, producing slightly more sophisticated language at each stage of the child's development. However, the current study suggests that at least one aspect of receptive language ability, the speed with which children process language, is not a primary driver of parent tuning. Thus, the current study paves the way for examining which aspects of receptive language, over and above expressive language, parents are sensitive to.

Methodology

In addition to the above implications, the current study also makes important methodological contributions, in two ways. First, in terms of measuring children's language, our focus on language processing is important because language processing speed is related to children's abilities to comprehend and learn from language in real time. Here, we used eye-tracking to measure processing, which provides an implicit measure of comprehension without requiring that the child execute motor actions or comply with instructions to speak—which may be difficult for autistic children (e.g., Kasari et al., 2013; Venker and Kover, 2015; Plesa Skwerer et al., 2016; Horvath and Arunachalam, 2019). This method offers strong potential for assessing receptive language in autism (Tager-Flusberg and Kasari, 2013).

Second, in terms of assessing parent–child interaction, prior work has mostly used either tightly controlled experimental designs to assess children's language processing (e.g., Venker et al., 2013, 2019; Horvath and Arunachalam, 2019) or naturalistic observation of parent–child interaction to assess spontaneous parental input (see Bottema-Beutel and Kim, 2021). The relation between parents' unscripted input and children's intake *in the moment* had not previously been examined either in typical development or in autism (e.g., Bottema-Beutel and Kim, 2021). This work therefore moves beyond the pre-recorded stimuli used in most language processing experiments; we hope that it might generate future hypotheses that are testable within more controlled paradigms.

Critical to our study is Arunachalam's (2016) paradigm, in which parents describe objects to children whose eye gaze is tracked, allowing analyses of both parental language and children's processing in the same setting and in real-time. With respect to parents' language, the game context offers some useful constraints over open-ended play sessions, because all participants are speaking about the same things and there are limited sources of variance in parents' speech. This has some advantages for research aiming to look at very specific phenomena, as in the current study, where we looked at the referential expressions parents use to uniquely identify a referent in the context of distractors. With respect to children's processing, this paradigm offers insight into how children process the language they are likely hearing in real life (i.e., from a familiar parent and in the way that person speaks given this kind of context). A recent word learning study finds that 2-year-olds with a higher likelihood of autism diagnosis process their parent's voice effectively, allowing them to learn new words (van Rooijen et al., 2022). The current study, too, shows similar findings with slightly older children, in the context of unscripted speech.

Limitations and future directions

Despite these advantages of the paradigm, it is also important to recognize several limitations of the current study. First, due to the nature of the methodology, parents' speech in this study is inevitably less natural than everyday speech. In ongoing work, we are examining parents' speech as they produce an unscripted narrative from a picture book (Shukla et al., 2022); we aim to be able to understand whether and how the patterns observed in the current study differ in more natural contexts. Second, relatedly, because of the unscripted nature of the task and the consequent variability in the language children are hearing, the findings about children's processing are exploratory, particularly for features that were rarely produced by parents (e.g., postnominal modifiers) and for which our analyses are underpowered. Our sample, though comparable in size to several other experiments involving preschool-aged children on the spectrum (e.g., Naigles et al., 2011; Tenenbaum et al., 2017; Venker, 2019; Venker et al., 2019; Luyster and Arunachalam, 2020), is small, which is a limitation. We intentionally recruited from a relatively wide age range, intending to yield groups that were similar on language while acknowledging that they might differ greatly in chronological age; future studies, however, might benefit from concentrating on a narrower range.

Further, our sample does not fully capture the wide heterogeneity of the autism spectrum, and we expect that not all autistic children will have slow language processing. Moreover, our sample was limited by the fact that, like many experimental studies, we required families to visit the lab in order to participate, which might pose barriers related to family factors such as socioeconomic status and access to transportation as well as child factors such as interest in participating in activities outside the home.

We also recognize that parent–child interactions (e.g., Prevoo and Tamis-LeMonda, 2017) are culturally embedded, and that these patterns of dyadic engagement are likely to vary across samples that differ in communication traditions. However, it is also true that cross-cultural research attests to the capacity of adults to strategically modify their behaviors in order to improve communication efficacy (Agredo-Delgado et al., 2022).

Finally, another important limitation—perhaps one that especially highlights avenues for future work—is the fact that none of the participating parents reported having a diagnosis of autism themselves. (Note that although there has been research on parental traits within the broader autism phenotype, recent work has cautioned against treating this as the same as having a formal autism diagnosis; Sasson and Bottema-Beutel, 2021.) A particularly exciting area for future research involves parents with a diagnosis of autism. Many autistic adults report more successful communication and better social rapport with other autistic adults than with nonautistic adults (see, e.g., Bascom, 2012). Research on the double empathy problem (e.g., Milton, 2012) has not thus far focused on parent–child communication specifically. It would be particularly instructive to examine whether autistic parents use different communication strategies with their autistic children and whether such differences might sometimes lead to more successful communication and learning; we are pursuing these questions in ongoing research.

Conclusion

We have framed children's language acquisition as dependent not only on input, but crucially, also on intake—that is, how children process that input and the resulting linguistic representations they form. The current study supports prior work in documenting striking similarities between the input provided by parents of nonspectrum children and parents of autistic children, but we extend beyond prior work to show that children's processing of this very input is slower in the autistic group than the nonspectrum group. Thus, the input is similar in many ways.

However, potential effects on language learning are cascading (e.g., Naigles and Tek, 2017; Arunachalam and Luyster, 2018), so slower processing may mean that autistic children could have less intake even with similar input. Although we examined only a brief interaction, in daily life, children who are slow language processors may be likely to miss opportunities to learn more language. Suppose that instead of simply naming an object, parents had continued their utterances to introduce something new, e.g., "there's an open book… that's on a desk." A child who is slow to identify the open book will be less likely to have the opportunity to learn the meaning of "desk." Prior work shows that difficulty processing the beginning of a sentence can indeed interfere with children's abilities to learn new words that occur afterward (Fernald et al., 2008a; He et al., 2020; He et al., in prep). Therefore, less intake due to slower processing may have cascading effects on development of language skills, potentially contributing to explanations for the language difficulties seen in many autistic individuals throughout the lifespan.

Data availability statement

The dataset analyzed for this study can be found at: 950 https://osf.io/fkhns/?view_only=3e5ae0ce585e40f6881f10fedf3901b0.

Ethics statement

The studies involving human participants were reviewed and approved by Boston University Institutional Review Board. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

SA conceived of the study questions. SA and AH contributed to the design of the study and coded and analyzed the data. AH contributed to data collection. RL contributed to data interpretation. All authors contributed to the article and approved the submitted version.

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Conflict of interest

RL is an author on the ADOS-2 and receives royalties from sales.

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.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.954983/full#supplementary-material

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Exploring the role of COVID-19 pandemic-related changes in social interactions on preschoolers' emotion labeling

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During the COVID-19 pandemic people were increasingly obliged to wear facial masks and to reduce the number of people they met in person. In this study, we asked how these changes in social interactions are associated with young children's emotional development, specifically their emotion recognition *via* the labeling of emotions. Preschoolers labeled emotional facial expressions of adults (Adult Faces Task) and children (Child Faces Task) in fully visible faces. In addition, we assessed children's COVID-19-related experiences (i.e., time spent with people wearing masks, number of contacts without masks) and recorded children's gaze behavior during emotion labeling. We compared different samples of preschoolers (4.00–5.75 years): The data for the *no-COVID-19-experience sample* were taken from studies conducted before the pandemic (Adult Faces Task: $N = 40$; Child Faces Task: $N = 30$). The data for the *with-COVID-19-experience* sample ($N = 99$) were collected during the COVID-19 pandemic in Switzerland between June and November 2021. The results did not indicate differences in children's labeling behavior between the two samples except for fearful adult faces. Children with COVID-19-experience more often labeled fearful faces correctly compared to children with no COVID-19 experience. Furthermore, we found no relations between children's labeling behavior, their individual COVID-19-related experiences, and their gaze behavior. These results suggest that, even though the children had experienced differences in the amount and variability of facial input due to the pandemic, they still received enough input from visible faces to be able to recognize and label different emotions.

KEYWORDS

COVID-19, facial masks, emotion recognition, children, gaze behavior

1. Introduction

Since the beginnings of the COVID-19 pandemic in early 2020, this historic event has dramatically changed people's social life: People had to communicate *via* video calls, keep distance when encountering each other, reduce the number of people they meet in person, and stay at home whenever possible. Among other factors, these changes have led to decreased wellbeing and higher stress and depression levels (Lannen et al., 2020; Russell et al., 2020; Cerniglia et al., 2021).

Additionally, the World Health Organization (WHO) recommended wearing facial masks as part of the strategy to slow down the spread in June 2020. Not only adults but also children had to adapt to these different ways of interacting with others. In this study, we explored whether and how differences in social interactions (with a focus on seeing fewer people without masks and an increased amount of facial masks) relate to children's facial emotion recognition, more specifically, emotion labeling.

Facial emotion recognition is particularly interesting in this context because its development is influenced by the input children receive (e.g., Pollak et al., 2009). This input is dependent on the context in which children live and is likely to have changed in the pandemic. For instance, during the pandemic, children saw fewer people and the same faces more often (i.e., their parents). The variability in their facial input may therefore have been reduced. Furthermore, facial masks cover the mouth and nose region, concealing facial features important for recognizing emotions (Gori et al., 2021; Schneider et al., 2021). To our knowledge, there are only few studies on preschoolers' emotion recognition (Gori et al., 2021; Schneider et al., 2021), which investigated the recognition of emotions like joy, anger, fear, sadness, and neutrality in adult faces with and without facial masks. However, these studies only compared children's emotion recognition in faces with versus without mask in a limited number of emotions, ignoring the role of pandemic experiences. Consequently, they cannot speak to broader effects of the pandemic and whether such effects would transfer to emotion recognition in faces without masks. In this study, we investigated children's emotion recognition *via* their ability to label emotions depicted in static faces. We sought to extend previous findings in multiple ways. First, we aimed to gain broader insights into pandemic effects, including potential effects of changed social interactions. For this, we compared children with COVID-19 experience to children without COVID-19 experience regarding their emotion labeling in fully visible faces. Second, in the with-COVID-19-experience sample, we assessed two variables that might be related to children's emotion labeling: The time children spent with others wearing facial masks and the number of contacts without facial masks. Third, we aimed to provide a more fine-grained investigation of children's emotion labeling. Therefore, we included a larger number of different emotions, depicted by children and adults. Finally, we wanted to explore potential associations between children's gaze behavior and their emotion labeling. For this, we assessed children's gaze behavior by using eye tracking. Taken together, this study aimed at understanding children's facial emotion recognition *via* labeling in fully visible faces and how it is associated with pandemic-related changes, such as changes in social interactions and differences in facial input children receive. This provides first insights into how children's emotion recognition might be influenced beyond situations in which masks are worn and therefore beyond the pandemic.

1.1. The relevance of facial emotion recognition

Facial expressions are one of the primary social signals, allowing people to draw conclusions about their interaction partners' feelings, intentions, and beliefs (Baron-Cohen, 1995; Ekman, 2007). Moreover, Ekman and Friesen (1971) provided evidence that the recognition of the facial expressions of basic emotions (i.e., surprise, fear, disgust, anger, happiness, and sadness) is universal, meaning that basic emotions are similarly expressed in the face and decoded across cultures worldwide (Ekman and Friesen, 1971).

The ability to recognize and respond to other people's expressive behavior constitutes a fundamental base for social and emotional development (Caron et al., 1982). Furthermore, facial emotion recognition in particular is associated with children's cognitive and linguistic development (Blair, 2002), including social skills and teacher-rated academic competence (Izard et al., 2001; Denham et al., 2015). The likelihood of showing psychopathology (Southam-Gerow and Kendall, 2002) or externalizing and internalizing problems (Trentacosta and Fine, 2010) rises with the difficulty to understand emotions shown in faces. Moreover, despite an overall improvement in facial emotion recognition with age, early individual differences persist across the lifespan (Pons and Harris, 2005).

1.2. The measurement and development of facial emotion recognition

The ability to read others' emotions through facial expressions develops across childhood (Herba et al., 2006). However, it is difficult to draw a consistent picture of this development because assessment methods differ with children's age. In the current study, we focus on emotion labeling, the most widely used method within our age group of interest (e.g., Gagnon et al., 2014; Guarnera et al., 2017). In these tasks, children see an emotional facial expression and either freely label it or choose from a certain set of labels. Based on these tasks, it has been proposed that children initially evaluate emotions valence-based (Widen and Russell, 2008; Widen, 2013; Martins et al., 2016) and gradually change to a category-based recognition throughout development (Widen and Russell, 2008). Furthermore, children seem to acquire emotion labels in a certain developmental order (Widen and Russell, 2003, 2008). For instance, between 3 and 4 years, children correctly label happiness, anger, and sadness. Whereas, they show the greatest accuracy for happy expressions, anger is used for both, angry and disgusted faces, and sadness for sad and fearful faces (Widen and Russell, 2003). Later, at the age of 5 years, children label happy, angry, sad, surprised, and fearful faces correctly.

Furthermore, children's early experiences play a critical role in the development of face and probably also emotion recognition (e.g., Taylor-Colls and Pasco Fearon, 2015). For instance, early experience with specific types of faces leads to lasting advantages in processing these faces (Kelly et al., 2007; Park et al., 2009). In a similar vein, early experiences with certain facial emotions may also explain why children recognize these emotions better, as supported by findings on children, who were exposed to high levels of parental anger and physical threat. Not only were these children able to recognize anger with fewer facial cues than children not being exposed to these stressors, but also their parents' reported degree of anger/hostility was related to how fast the children recognized anger (Pollak et al., 2009). Similarly, maternal depression in combination with negative parenting (i.e., parental hostility or high expression of frustration) is associated with reduced emotion recognition in preschoolers (Kujawa et al., 2014).

In sum, experience seems to shape children's emotion recognition. This might be particularly important when children interact in a social world that has changed due to the pandemic: They increasingly interact with adults wearing facial masks, with fewer adults without facial masks, and might encounter certain emotions in different frequencies than before the pandemic (e.g., more negative emotions based on increased stress, fear, and depressive states). These experiences may influence their ability to recognize emotions in others' faces, even in situations where their faces are not covered with a facial mask.

1.3. The role of certain facial features for emotion recognition

Adults process faces holistically (Tanaka and Sengco, 1997). For children, the picture is less clear. Carey and Diamond (1994) suggested that already 4- to 6-year-old process faces holistically like adults. However, Schwarzer (2002) provided evidence that 2- to 5-year-old rely more on individual facial features and less on holistic processing when categorizing faces. Which role do facial features play in emotion recognition? Like adults, children recognize different emotions from certain facial features. For instance, when being asked to recognize facial emotions, children until 9 years preferably process the eye area, and occluding other features of the face (such as the mouth) does not impair their emotion recognition (Roberson et al., 2012). In contrast, Guarnera et al. (2017) provided no evidence for differences in looks to the eyes and mouth for emotion recognition in 6- to 7-year-old children. Furthermore, Kestenbaum (1992) found that fear, surprise, and anger were better recognized from the eyes than from the mouth, while happiness was better recognized from the mouth by 5- to 7-year-old. In another study with 5-year-old, fear was best recognized from the upper face half and surprise from the lower face half as well as from the complete face (Gagnon et al., 2014). Guarnera et al. (2015) found that 6- to 7-year-old children generally recognize emotions better when pictures represent the whole face, except for sadness, which is best recognized from the eyes, whereas anger can be identified from the eyes as well as from the whole face.

Although the existing research regarding the processing of specific emotions and the importance of different facial features is not always consistent, most studies indicate an emotion-specific processing of facial expressions. This might be particularly important when investigating the effect of facial masks on the processing of emotions because masks cover only the lower part of the face while the eyes remain visible. Previous studies on the influence of facial masks on emotion recognition showed that emotional expressions are correctly recognized in faces that were covered with masks (Calbi et al., 2021), but that 7- to 13-year-old children were more accurate when faces were fully visible (Ruba and Pollak, 2020). Carbon (2020) suggests that emotion recognition in faces wearing masks is reduced with the exception of fearful and neutral expressions. However, so far little is known about the long-term effects of seeing people wearing masks on children's emotion recognition in fully visible faces.

In sum, previous studies suggest that the occlusion of faces with facial masks has an influence on children's emotion recognition (Carbon, 2020; Ruba and Pollak, 2020) and that this influence might depend on the emotion expressed (Kestenbaum, 1992; Gagnon et al., 2014). Furthermore, children's early experiences seem to alter how they perceive others' facial emotions. Therefore, long-term exposure to people wearing facial masks, reduced number of contacts without facial masks, and changed frequencies of observing certain emotions (*COVID-19-related experiences*) may provide children with fewer and different learning opportunities with emotional expressions in fully visible faces. This could lead to altered emotion recognition, even when there is no facial mask present in the processed face.

1.4. The present study

With the present study, we aimed to answer the following research question: Do preschoolers of a sample assessed during the COVID-19-related changes in social interactions show a different emotion recognition (assessed *via* emotion labeling) in fully visible faces than preschoolers from another sample assessed before the COVID-19-related changes?

We deem this question particularly relevant because it investigates one of the major concerns parents and the society repeatedly expressed, namely whether the changes in social interactions might have long-term consequences on emotion recognition, that is, when children process fully visible faces. To address this research question, we applied a cross-sectional research design using the COVID-19 pandemic-related changes in social interactions as a natural intervention. We compared data of preschoolers' emotion labeling from two studies published in 2010 by Widen and Russel and in 2020 by Streubel and colleagues (*no-COVID-19-experience samples*) to data of a new sample of children who had substantial experience with COVID-related changes (*with-COVID-19-experience sample*), which was recruited for this study. We measured children's emotion recognition *via* emotion labeling in fully visible faces in two tasks. In one task, children freely labeled emotional facial expressions of adults (*Adult Faces Task*; task adapted from Widen and Russell, 2010). In a second task, the children did the same with emotional facial expressions of children (*Child Faces Task*; task adapted from Streubel et al., 2020). We chose adult and child faces to make the stimuli more ecologically valid and to mirror previous research which also explored both types of stimuli (Boyatzis et al., 1993; Gagnon et al., 2014). Furthermore, in the with-COVID-19-experience sample, we assessed a subset of children's COVID-19-related experiences (i.e., time seeing people wearing facial masks, number of contacts without facial masks) with a parental questionnaire (self-developed items) and recorded children's gaze behavior *via* eye tracking to explore potential associations with children's emotion labeling.

As the target group we chose children of four to five years. By this age, children can already recognize and name most of the basic emotions, whereas their emotion categories are still developing (Widen and Russell, 2008). As a result, children at this age show some variance in terms of their ability to label different emotions (Widen and Russell, 2003, 2008).

We formulated two hypotheses: First, even though some studies argue that children preferably focus on the eye region (Roberson et al., 2012) and masks would therefore not influence their emotion recognition, the literature is inconsistent with respect to the specific information children use to process facial emotions. For instance, studies show that in general children process faces in a holistic way (Carey and Diamond, 1994) and therefore are better in recognizing emotions shown in the whole face (Guarnera et al., 2015). Furthermore, some studies showed that emotion recognition is more accurate when faces are fully visible compared to faces with masks (Carbon, 2020; Ruba and Pollak, 2020). As a result, children might show less accurate emotion labeling after the COVID-19-related changes, even when processing fully visible faces. Additionally, children with more experience with people wearing masks and fewer contacts without facial masks (i.e., more COVID-19-related experiences) might show less accurate emotion labeling than children with less COVID-19-related experiences.

Second, because children's emotion recognition depends on the specific emotions (Gagnon et al., 2014; Guarnera et al., 2015) and some emotions are better recognized from certain facial parts than others, preschoolers' emotion labeling of fully visible faces after the COVID-19-related changes might depend on the specific emotion they see.

2. Methods

We preregistered the study (https://osf.io/qaxp7) and made the data collected in the present study and codes available on the Open Science Framework (OSF, https://osf.io/tmj2c/).

2.1. Participants

The data collected before the COVID-19 pandemic (no-COVID-19-experience sample) were taken from studies by Streubel et al. (2020) (Child Faces Task) and Widen and Russell (2010) (Adult Faces Task) with the kind permission of the authors[1]. The sample by Streubel et al. (2020) was collected in Germany in 2019 and consisted of 30 children (11 girls, 19 boys) at the age of 4.54–5.59 years (M = 5.05 years, SD = 0.33 years). In this sample, 71% children had at least one parent with a college degree. The sample by Widen and Russell (2010) was collected in the United States before 2010 and consisted of 40 children (20 girls, 20 boys) at the age of 4.00–5.75 years (M = 4.91 years, SD = 0.46 years). In this sample, parents' mean education level was a master's degree.

The final with-COVID-19-experience sample consisted of 99 children (49 girls, 50 boys) at the age of 4.50–5.50 years (M = 5.01 years, SD = 0.27 years). All children had a normal birth weight (>2,500 g), were born full term (37–42 weeks gestation), and had no diagnosed developmental disorders as reported by the parents. The sample included 51 monolingual and 48 bilingual children. The mean of parents' highest level of education was some form of higher education (e.g., higher technical college) with 77% of children having at least one parent with a university degree (either bachelor's or master's degree). Additional eight children participated but were excluded from all tasks for different reasons. One girl had to be excluded because of her limited language skills to understand the questions and stories. One girl did not give understandable answers to the questions and her data could therefore not be coded. With one boy the tasks could not be performed because of difficulties with calibrating the eye tracker. Two girls did not provide any answers and could therefore not be coded. Three girls had to be excluded because of technical problems. The participants were recruited through the database of the research unit Developmental Psychology: Infancy and

1 In the following, we report parents highest level of education as an approximation of children's socioeconomic status (SES). However, because the no/with-COVID-19-experience samples were collected in different countries and non-comparable education systems, we only report SES descriptively.

Childhood of the University of Zurich. The database consists of children whose parents are interested in participating in studies and therefore signed up at an earlier point in time. Each child received a certificate and a small present (value ∼5$) for their participation. Parents gave written informed consent. The ethics commission of the UZH Faculty of Arts and Social Sciences had approved the general procedure. All procedures were performed in accordance with the ethical standards of the 1964 Helsinki declaration and its later amendments. The data collection took place between July and November 2021. At this point in time, families had experienced two lockdowns (March–May 2020 and December–February 2021) with schools and kindergartens remaining closed during the first lockdown. From July 2020 to February 2022, a mask obligation for all public indoor places (including public transportation) had been established for people aged 12 years and older.

2.2. Instruments

2.2.1. Facial emotion recognition

Both tasks were presented on a 17" (800, 600 px) computer screen. The Child Faces Task [adapted from the *Intelligence and Development Scales* (IDS); Grob et al., 2009] consisted of a set of 10 pictures of children showing one of five different emotional facial expressions (happiness, anger, fear, surprise, sadness; each emotion depicted twice by two different children). In line with the original task (Grob et al., 2009), the pictures were presented in a fixed order, beginning with the picture of the emotion happiness. The children were asked to indicate the emotion of the child in the picture by verbally labeling it. There was no time limit. If the child's answer was not specific enough (e.g., the child said the child on the picture was feeling "good" or "bad"), the experimenter asked the child to specify the answer. If the child described an appearance or behavior, the experimenter asked the child to name the emotion in this specific appearance or behavior. If the child named more than one emotion for a picture, the experimenter asked the child to choose the most fitting one. In order to categorize the answers as correct (score 1) or incorrect (score 0) in each trial, we used the scoring key of the original test in Standard German. We categorized children's answers as incorrect, if they described the positive or negative valence of the emotions ("good," "bad"), if they gave no answer, or if they said that they did not know the answer. The dependent variable for the Child Faces Task was children's score of zero or one, considered separately for each trial[2].

The Adult Faces Task (replication of Widen and Russell, 2010) included nine pictures of adults showing different emotional facial expressions (happiness, anger, fear, surprise, disgust, contempt, shame, embarrassment, and compassion; pictures originally from Haidt and Keltner, 1999). The task started with the emotion happiness, which was followed by the other emotions in random order. Before the task, a priming was performed to ensure that the target emotion labels were accessible to the children. The experimenter introduced each of the target emotion labels by asking the children, whether they sometimes encounter the different emotions ("What about angry? Do you sometimes feel angry?"). Then the experimenter led the children through the pictures by telling a story about a woman. The children were asked to verbally label the emotions shown in the pictures. There was no time limit and children's answers were not corrected. If they gave no answer, the experimenter tried different prompts (i.e., repeating the question, or asking the child to look closely; see Widen and Russell, 2010). If the child still did not respond, the experimenter moved on to the next emotional expression. After presenting all emotions, the experimenter returned to any expression to which the child had not responded. The experimenter did not use the word "emotion" at any time, provide any emotion labels, or otherwise instruct the child to use an emotion label, other than asking how the woman was feeling. We categorized children's answers as in the Child Faces Task (see above) but using the scoring key from the original study developed by Widen and Russell (2003). The dependent variable for the Adult Faces Task was children's score of zero or one, considered separately for each trial.

2.2.2. Emotion-specific vocabulary

To control for emotion-specific vocabulary, we used an adapted version of the *Children's Emotion Vocabulary Vignettes Test* (CEVVT) by Streubel et al. (2020). We only used a selection of the original 20 vignettes, testing for the six basic emotions (joy, anger, disgust, sadness, surprise, and fear) and four secondary emotions (guilt, shame, envy, and pride) in 10 vignettes. The selection was based on variance in response rate in the original sample (Streubel et al., 2020) at our target age of 4.5–5.5 years. Furthermore, we translated the selected vignettes of the original CEVVT from Standard German to Swiss German and ran a prestudy with adults for validation[3].

The 10 vignettes showed a child in a typical emotion-provoking situation with emotion-specific facial and bodily expressions, physiological reactions, and thoughts. Each vignette comprised a picture and an audio-recorded gender-matched text that was presented simultaneously. The pictures and audio recordings were presented on a Microsoft Yoga laptop with a 14" touch-screen display using PowerPoint. Children were asked a comprehension question about the vignette itself and prompted

2 We pre-registered that children would be excluded if they had one missing label of the five emotions. However, the majority of children did not provide answers to all emotions. To avoid major data loss, we decided to include data from children who had missing labels.

3 The results of this prestudy are summarized in the Supplementary material and available on the OSF https://osf.io/tmj2c/.

to indicate how the child in the vignette was feeling. For further details on the randomization and procedure of this task see the original paper by Streubel et al. (2020). To categorize children's answers as correct (score 1) or incorrect (score 0), we used a self-developed scoring key based on the original study (Streubel et al., 2020), the scoring key of the IDS (Grob et al., 2009), and the answers of the adults in the prestudy. The measure was used to assess how many of the labels needed for the Child Faces Task the children actually produced. The dependent variable was a score ranging from 0 to 5, counting the number of correctly labeled emotions that were also used in the Child Faces Task (happiness, anger, fear, surprise, sadness).

2.2.3. COVID-19-related-experiences questionnaire

We measured children's experience with pandemic-related changes in social interactions *via* a self-developed parental questionnaire. The questionnaire was filled out on a tablet by the parent accompanying the child during study participation. As a measure of exposure to facial masks, we assessed the number of hours per week children spent with adults wearing a facial mask (*mask exposure*, see Figure A1 for the distribution of parents' answers). To help caregivers with estimating the time their children spent with adults wearing masks, we asked separately about different places and situations (e.g., time spent in Kindergarten; see Appendix). For our analyses, we created a sum score across all these places/situations. As a measure of how many people children saw without facial mask we assessed the number of contacts per week children had with adults not wearing a facial mask with a single question (*without-mask contacts*, see Appendix for questionnaire).

2.2.4. Gaze behavior

We measured children's gaze behavior during the emotion labeling tasks with an eye-tracking system (Eyelink 1000Plus, SR Research, sample rate: 500 Hz). A five-point calibration with an animated target was performed. After every three trials, a drift check and, if necessary (deviation $> 1^\circ$ visual degrees), a re-calibration were performed. We analyzed children's fixation duration to the eyes and the mouth of the person on the picture presented. Fixations were defined using the default parameters of EyeLink 1000Plus (Data Viewer software). For each data sample, a parser computes instantaneous velocity and acceleration and compares these to velocity and acceleration thresholds. Under default settings, saccade onset (fixation offset) is signaled when either velocity or acceleration go above thresholds of 30 $^\circ/s$ and 8,000 $^\circ/s^2$ respectively, and the eye has traveled at least 0.1°. To further analyse children's fixations, we drew areas-of-interest (AOI) around the mouth and the eye area of the person shown in each picture. The mouth area was drawn to resemble a facial mask in size and form. The eye area was drawn to match the mouth area in size (in pixel). We analyzed children's fixation duration (in ms) to these two AOIs by calculating an eyes-to-mouth index (fixation duration to the eyes/eyes + mouth AOIs) for each picture and participating child. This normalization accounting for differences in overall looking behavior (for details see Supplementary material) allowed us to include the fixation behavior of all children in all trials in our analyses (i.e., there was no threshold of minimum overall looking behavior per trial for a child to be included in the analyses).

2.2.5. Other measures

We assessed children's vocabulary in their mother tongues with the BILEX (for details, see Gampe et al., 2018), a touch-screen based vocabulary test. Children's Theory of Mind was measured *via* a parental questionnaire with the *Children's Social Understanding Scale* (CSUS; Tahiroglu et al., 2014). We also asked parents for demographic information on the number and order of siblings, birth year of the siblings, day-care hours, and parental education as an approximation of the socioeconomic status (SES). Furthermore, this procedure included two additional eye-tracking tasks (administered before the Adult and Child Faces Tasks) and one interactive task on gaze following behavior (administered after the Adult and Child Faces Tasks) for another study. These measures were not analyzed for this paper.

2.3. Procedure

All children were tested individually with at least one parent present. During the testing session, the experimenter and parents wore facial masks. For approximately 15 min, each child and their parent were in a reception room where the experimenter described the test procedure to the parent and handed them the consent form to sign. The experimenter played with the child until they seemed comfortable. The experimenter then asked child and parent to move to the laboratory.

The laboratory was unfurnished except for the test equipment. The children were seated in a highchair which was placed in front of a table or the eye tracker, depending on the task. The parents were always seated on a chair behind the child and were asked to fill out the questionnaire. One test session lasted up to 75 min. To keep children motivated throughout the whole study, we included a cover story about a treasure hunt at the end of which the children could select small gifts. To be in line with Streubel et al. (2020), we decided to use a fixed order for the tasks by introducing the CEVVT before the Child Faces Task (Grob et al., 2009) followed by the Adult Faces Task.

3. Results

3.1. Between-group analyses

To analyse the impact of pandemic-related changes in social interactions on children's emotion recognition, we ran three mixed models on children's labeling behavior in the Child Faces and the Adult Faces Task. The first two models included emotion (Child Faces Task: 5; Adult Faces Task: 9; with reference category "happiness"), group (no/with-COVID-19-experience; with reference category "no-COVID-19-experience"), their interaction, and age in months as fixed effects and participant as random effect. The third model was an additional model for the Child Faces Task, which also included children's emotion-specific vocabulary as a factor[4].

3.1.1. Child faces task

The results of the Child Faces Task showed a significant effect of the emotion sadness (*Estimate* = −0.310, *SE* = 0.080, $p < 0.001$) in such that sadness was recognized less accurately than happiness in child faces. Furthermore, older children labeled the emotions more accurately than younger children (*Estimate* = 0.012, *SE* = 0.005, $p = 0.018$). No other significant effects were found (see Table 1). Therefore, no significant difference between the two groups (no/with-COVID-19-experience sample) emerged in the Child Faces Task (*Estimate* = −0.118, *SE* = 0.070, $p = 0.095$, see Figure 1).

In line with the first model, the results of the model including children's emotion-specific vocabulary revealed a significant effect of the emotion sadness (*Estimate* = −0.310, *SE* = 0.080, $p < 0.001$), age (*Estimate* = 0.010, *SE* = 0.005, $p = 0.036$), and emotion-specific vocabulary (*Estimate* = 0.309, *SE* = 0.061, $p < 0.001$). The more labels of the Child Faces Task children produced in the CEVVT, the more accurate their emotion labeling was. No other significant effects emerged (see Table A1 in Appendix).

3.1.2. Adult faces task

Except for the emotion of anger, children labeled all emotions less accurately than the emotion happiness (see Table 2). Furthermore, older children were more accurate in labeling the emotions than younger children (*Estimate* = 0.005, *SE* = 0.002, $p = 0.036$). The model also revealed a significant interaction of the emotion fear and group (*Estimate* = 0.384, *SE* = 0.080, $p < 0.001$). Children in the with-COVID-19-experience sample labeled the fearful face more accurately than children in the no-COVID-19-experience sample. No other significant effects were found (see Table 2 and Figure 1).

4 All variance inflation factors (VIFs) of the linear predictors of the models were around 1, indicating no multicollinearity.

TABLE 1 Child faces task: association with pandemic-related changes in social interactions.

Variables	*Estimate*	*SE*	*df*	*t*	*p*
Intercept	0.121	0.308	130.900	0.391	0.696
Anger	−0.052	0.080	1135.000	−0.647	0.518
Fear	−0.034	0.080	1135.000	−0.431	0.666
Sadness	−0.310	0.080	1135.000	−3.881	< 0.001
Surprise	−0.014	0.080	1135.000	−1.725	0.085
Group	−0.118	0.070	782.500	−1.670	0.095
Age	0.012	0.005	124.000	2.399	0.018
Anger * Group	0.052	0.091	1135.000	0.568	0.570
Fear * Group	0.131	0.091	1135.000	1.444	0.149
Sadness * Group	0.025	0.091	1135.000	0.271	0.787
Surprise * Group	−0.041	0.091	1135.000	−0.446	0.655

The reference category for emotion was happiness and for group the no-COVID-19-experience sample.

3.2. Within COVID-19-experience sample analyses

3.2.1. COVID-19-related experiences

To assess the association of children's COVID-19-related experiences and their labeling behavior, we ran two mixed models on children's score in the Child Faces and the Adult Faces Task respectively in the with-COVID-19-experience sample only. We included emotion, mask exposure or without-mask contacts respectively, and their interaction as fixed effects and participants as random effects.

3.2.1.1. Child faces task

The model on the association of children's mask exposure with their labeling behavior revealed a significant effect of the emotion sadness (*Estimate* = 0.204, *SE* = 0.094, $p = 0.030$). Sadness was labeled less accurately than happiness. No other significant effects were found (see Table A2 in Appendix). Similarly, the model including without-mask contacts showed a significant effect of the emotion sadness (*Estimate* = 0.288, *SE* = 0.084, $p < 0.001$) but no other significant effects (see Table A3 in Appendix). Sadness was labeled less accurately than happiness.

3.2.1.2. Adult faces task

Similar to the between-group analyses, the models including mask exposure or without-mask contacts revealed that children labeled all emotions except for anger less accurately than happiness (see Tables A4, A5 in Appendix). No other significant effects were found.

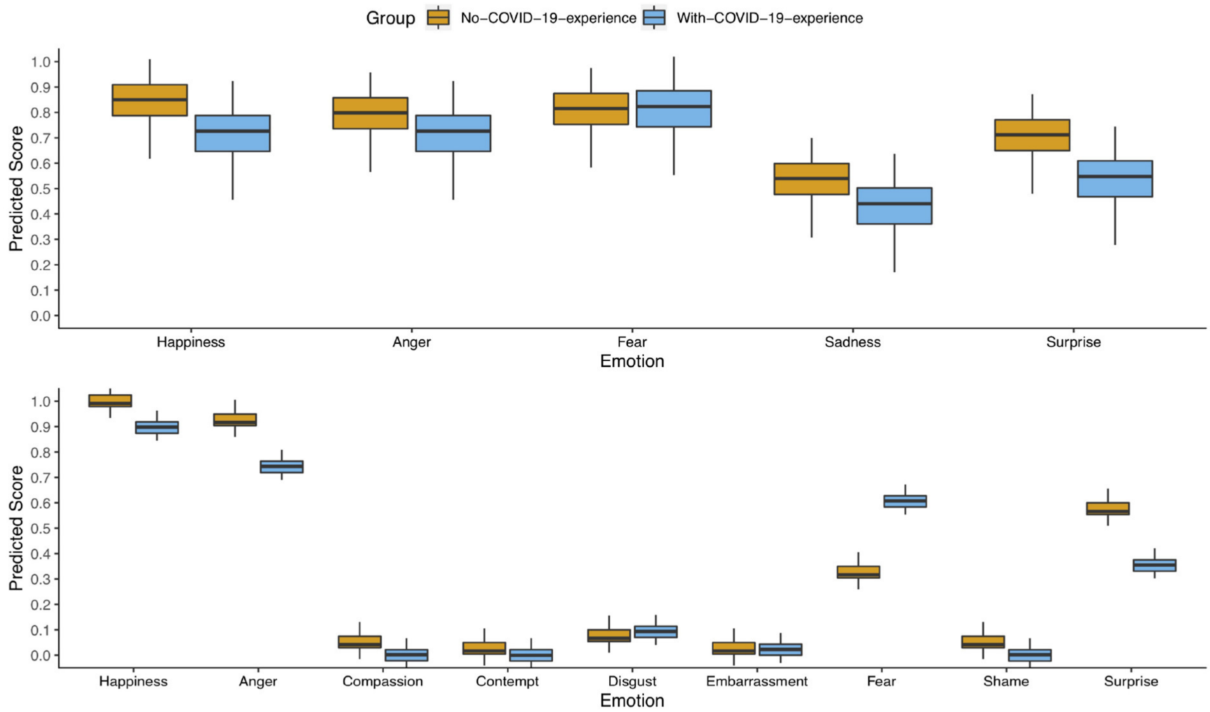

FIGURE 1
Children's predicted labeling score based on the according models in the Child Faces Task **(top)** and the Adult Faces Task **(bottom)** for the no-COVID-19-experience samples (orange) and the with-COVID-19-experience sample (blue). The higher the score, the more accurately children labeled the emotions depicted in the faces.

3.2.2. Gaze behavior

To explore the association of children's gaze behavior with their labeling and their COVID-19-related experiences, we ran two mixed-linear model on children's eyes-to-mouth index in the Child Faces and the Adult Faces Task. We included emotion, children's labeling behavior, their mask exposure, and without-mask contacts as fixed effects and participants as random effects.

In the Child Faces Task, children had a greater eyes-to-mouth index, that is, looked longer to the eye area, in all emotions compared to the emotion happiness (see Figure 2 and Table A6 in Appendix). There was no significant effect of children's labeling behavior, *Estimate* $= 0.002$, *SE* $= 0.011$, $p = 0.810$, mask exposure, *Estimate* $= 0.001$, *SE* $= 0.001$, $p = 0.599$, or without-mask contacts, *Estimate* $= -0.004$, *SE* $= 0.003$, $p = 0.222$.

In the Adult Faces Task, the model revealed significant effects for all emotions except for fear (see Figure 2). For the emotions anger, compassion, contempt, disgust, and shame children had a greater eyes-to-mouth index, looked longer to the eye area, than for the emotion happiness. In contrast, children's eyes-to-mouth index for the emotions embarrassment and surprise was lower than for the emotion happiness (see Table A7 in Appendix). There was no effect of children's labeling behavior, *Estimate* $= -0.004$, *SE* $= 0.019$, $p = 0.842$, mask exposure, *Estimate* $= -0.001$, *SE* $= 0.001$, $p = 0.230$, or without-mask contacts, *Estimate* $= -0.003$, *SE* $= 0.003$, $p = 0.326$.

4. Discussion

The COVID-19 pandemic has changed people's social life. Children have increasingly interacted with adults wearing facial masks, seen fewer adults without facial masks, and probably encountered certain emotions in different frequencies than before the pandemic (e.g., more negative emotions). In this study, we explored whether these experiences are associated with children's emotion recognition. To address this question, we asked children to label emotions depicted in child and adult faces and assessed their gaze behavior. We compared data from other studies that assessed emotion recognition before the pandemic to data of other children measured in our own lab during the pandemic. In addition, we tested for potential associations with COVID-19-related experiences within the sample assessed during the pandemic.

Overall and in line with previous work on preschoolers (Gori et al., 2021; Schneider et al., 2021), the results of our study indicate no evidence for pandemic-related differences in

TABLE 2 Adult faces task: association with pandemic-related changes in social interactions.

Variables	*Estimate*	*SE*	*df*	*t*	*p*
Intercept	0.709	0.146	163.000	4.855	< 0.001
Anger	−0.075	0.067	1080.000	−1.118	0.264
Compassion	−0.950	0.067	1080.000	−14.157	< 0.001
Contempt	−0.975	0.067	1080.000	−14.529	< 0.001
Disgust	−0.925	0.067	1080.000	−13.784	< 0.001
Embarrassment	−0.975	0.067	1080.000	−14.529	< 0.001
Fear	−0.675	0.067	1080.000	−10.059	< 0.001
Shame	−0.950	0.067	1080.000	−14.157	< 0.001
Surprise	−0.425	0.067	1080.000	−6.333	< 0.001
Group	−0.109	0.057	1207.000	−1.905	0.057
Age	0.005	0.002	134.000	2.114	0.036
Anger * Group	−0.080	0.080	1080.000	−0.999	0.318
Compassion * Group	0.053	0.080	1081.000	0.665	0.506
Contempt * Group	0.078	0.080	1081.000	0.980	0.328
Disgust * Group	0.120	0.080	1080.000	1.506	0.133
Embarrassment * Group	0.100	0.080	1081.000	1.243	0.214
Fear * Group	0.384	0.080	1081.000	4.804	< 0.001
Shame * Group	0.053	0.080	1081.000	0.665	0.506
Surprise * Group	−0.118	0.080	1081.000	−1.482	0.139

The reference category for emotion was happiness and for group the no-COVID-19-experience sample.

social interactions in children's emotion labeling. We assume that children still received enough and enough variable input of non-masked faces to support their normal development of emotion recognition. This input may have come from their home environment (i.e., parents, siblings) or their peers. In (country, blinded), where the study was conducted, preschoolers were never obliged to wear masks, only their teachers were. Since emotion recognition from child and adult faces does not differ (Hall et al., 1999; Guyer et al., 2007), children's performance may have benefitted not only in the Child Faces Task but also in the Adult Faces Task from the unchanged facial input from their peers. In addition, the children participating in the current study were already at preschool age. Therefore, they had 3–4 years of experience with non-masked faces before the beginning of the pandemic. While children's performance was still not at ceiling, their previous years of normal facial input may have contributed to the current findings.

4.1. Comparing children with and without COVID-19 pandemic-related experiences

Across the samples assessed before and during the pandemic, there were some differences in how accurately the different emotions were labeled. In line with previous research (Boyatzis et al., 1993; Widen and Russell, 2008), some emotions (e.g., happiness) were recognized more accurately from both child and adult faces than others (e.g., sadness). Furthermore, in accordance with an ongoing development of emotion recognition in preschool years (Widen and Russell, 2003; Herba et al., 2006), the analyses revealed a significant effect of age. Independent of the sample, older children more often labeled the emotions shown in child and adult faces accurately than younger children.

In the Child Faces Task, children who knew more emotion labels were more accurate in recognizing emotions. This speaks to an influence of emotion label knowledge on children's performance. That is, the task cannot distinguish between children who do not recognize the emotion and children who do not know the respective emotion word. Therefore, measuring children's emotion recognition *via* labeling behavior may result in a biased picture in such that emotion recognition of children with a low emotion-specific vocabulary is underestimated.

Similar to the Child Faces Task, no significant effect of no/with-COVID-19-experience sample emerged in the Adult Faces Task. However, we found a significant interaction of group and fear in such that children during the pandemic recognized fear better than children before the pandemic. Children may have experienced more fearful adult faces in the two pandemic years than before (Ayenigbara et al., 2020; Chee, 2020; de Leo and Trabucchi, 2020). Especially their parents are likely to have shown more concern, anxiety, and depressive symptoms (Russell et al., 2020; Cerniglia et al., 2021). Staying at home during lockdowns has posed a strain on families. Many parents worked in home office while taking care of their children. In combination with lower social support this led to increased stress levels, and exhaustion (Lannen et al., 2020). The increased input of negatively valenced and especially fearful faces could have resulted in children's more accurate emotion recognition. Supporting this, the effect was specific to adult faces and we found no interaction of group and the emotion fear in the Child Faces Task. Alternatively, in line with previous work (Kestenbaum, 1992; Gagnon et al., 2014; Kim et al., 2022), children may have focused mostly on the eyes when labeling fearful faces. Since the eyes remain visible even when masks are worn, the increased input of masked faces might have supported children's recognition of fear in faces. Accordingly, our eye-tracking results do show a focus on the eyes, similar to recent findings in adults (Barrick et al., 2021). However, this effect was not specific to fear and children looked longer to the eyes than the mouth for most of the emotions. Furthermore, because gaze behavior was not recorded in the two studies that provided the data for the no-COVID-19-experience sample, it was not possible to compare children's gaze behavior in the Adult Faces Task to before the pandemic. In sum, based on our data we cannot draw a definite conclusion on the reason for children's increased recognition of fearful faces during the pandemic.

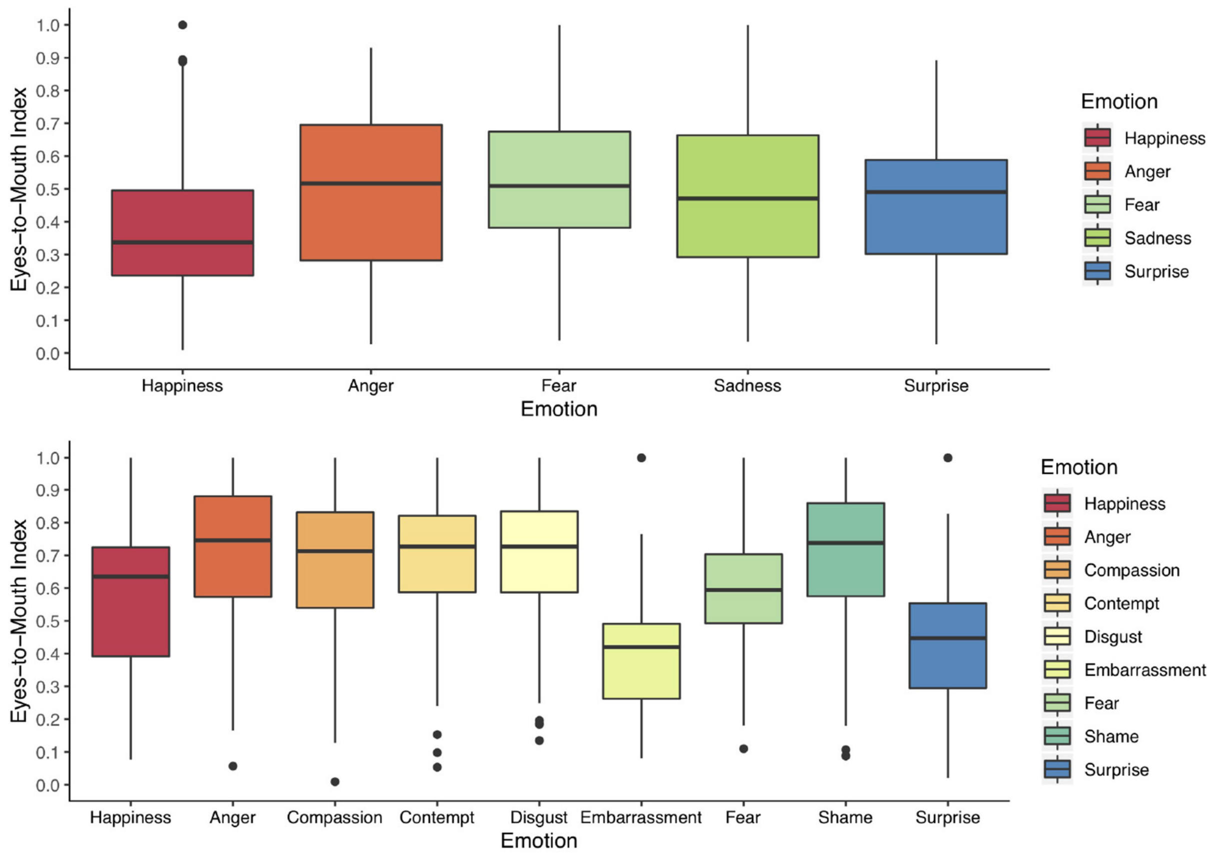

FIGURE 2
Children's eyes-to-mouth index for each emotion in the Child Faces Task **(top)** and the Adult Faces Task **(bottom)**. The greater the eyes-to-mouth index the longer children looked at the eye area compared to the mouth area. An eyes-to-mouth index of 0.5 indicates equivalent fixation duration to the eyes and the mouth area.

4.2. Associations between pandemic-related experiences, emotion labeling, and gaze behavior

Equivalent to our between-group analyses, the analyses within the COVID-19-experience sample showed no significant association of our measures of pandemic-related changes in social interactions (mask exposure, without-mask contacts) with children's emotion labeling. In accordance with previous studies (Kestenbaum, 1992; Guarnera et al., 2017), we found that children's gaze behavior differed between emotions. For most emotions, children seemed to look longer to the eyes than the mouth, while the reverse pattern emerged for emotions such as embarrassment or surprise. There was no significant association of children's labeling behavior and their gaze behavior. In contrast to previous work (Kestenbaum, 1992; Gagnon et al., 2014; Guarnera et al., 2015), our data therefore suggest that there is no "optimal" looking pattern, which is related to a better emotion recognition.

4.3. Limitations

As mentioned before, measuring emotion recognition *via* labeling behavior has its pitfalls and relies on children's emotion-specific vocabulary. Furthermore, especially the stimuli used in the Adult Faces Task may not have captured children's true emotion recognition. The pictures were more than 10 years old, black-and-white, and emotions were acted out in an exaggerated way. This contrasts children's everyday experiences with emotions. There, children encounter and read emotions of different intensities based on multimodal cues, which include facial features but also the tone of voice or body posture (Meeren et al., 2005; Aviezer et al., 2008). Therefore, the stimuli (i.e., static pictures) may not have measured children's every day ability to recognize emotions. Also, the number of items in these emotion recognition tasks is quite limited so that the response to each individual item has a relatively strong influence on the overall score. However, since this study is based on a "natural intervention," we had to rely on data assessed before the pandemic that was available and accessible. Consequently, we had to use the measures of emotion recognition employed in previous studies. For the same reason, we were also not able to compare children's gaze behavior during and before the pandemic (i.e., there was no behavioral data available that included gaze behavior). This additional data would have allowed analysing whether explicit (i.e., labeling behavior) and implicit (i.e., gaze behavior) measures converge or whether they measure different behaviors and processes. Furthermore, any differences between the samples in our study may not have been due to pandemic-related but cultural reasons. While the sample for the Child Faces Task was assessed right before the pandemic in Germany, a culture very similar to (country, blinded), the children in the Adult Faces Task were from the United States and their emotion labeling was measured before 2010. However, we are not aware of any differences between the cultures in (country, blinded) and the United States that influence children's emotion labeling. Additionally, the fact that our findings are largely consistent between the Child Faces and the Adult Faces Task speaks toward their robustness and validity. Finally, while our study suggests no significant short-term effects of pandemic-related changes in social interactions on children's emotion labeling, it does not rule out any long-term influences that occur later in children's development. This should be the target of future research.

4.4. Conclusion

In sum, our study indicates that the COVID-19 pandemic and the according changes in social interactions such as meeting fewer people, or seeing more people wearing masks, do not substantially relate to preschoolers' emotion labeling. Preschoolers likely have received enough input of non-masked faces to support their normal development of emotion recognition.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://osf.io/tmj2c/.

Ethics statement

The studies involving human participants were reviewed and approved by UZH Faculty of Arts and Social Sciences. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

SW and LM: conceptualization, data analyses, supervision of SA, and writing, review and editing the paper. SA: conceptualization, data collection and coding, some data analyses, and writing and editing the paper. MD: conceptualization and writing, review, and editing the paper. All authors contributed to the article and approved the submitted version.

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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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Is maternal negative affectivity related to psychosocial behavior of preterm and term-born toddlers through mother–child interaction?

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Introduction: Children born moderately to late preterm (MLP) are more prone to psychosocial difficulties than their term-born counterparts. Maternal negative affectivity (NA)–a relatively stable personality trait characterized by the tendency to experience negative thoughts, feelings and emotions–has been related to more psychosocial problems in their offspring, and to a lower quality of mother–child interactions. As MLP children seem more sensitive to their early caregiving environment, they might be more affected by maternal NA and interaction style than their term-born peers. The current study investigated whether maternal NA predicted child's psychosocial outcomes through quality of mother–child interaction, and if these associations differed between MLP and term-born children.

Methods: The sample consisted of 108 MLP and 92 term-born children and their mothers. At 18 months corrected age, maternal NA was measured using a self-report questionnaire and mother–child interaction was observed during two structured tasks. Five subscales of mother–child interaction were assessed: negative interaction, reciprocal engagement, emotional support, maternal stimulation and mother-led interaction. At 24 months corrected age, social–emotional difficulties, internalizing, and externalizing problems were assessed using mother-report.

Results: For MLP children, maternal NA directly, positively, predicted social–emotional difficulties (b=0.57) and internalizing problems (b=0.45), but no mediation effect of mother–child interaction was found. For term-born children, no direct effect but a mediation effect of mother-led interaction was found. Higher levels of maternal NA predicted less mother-led interaction which in turn predicted more problems. Birth status did not moderate any of the relationships, showing that the differences in patterns of effects found within the MLP and term-born group did not reach statistical significance.

Discussion: Maternal NA was found to be a risk factor for psychosocial outcomes in toddlers, either directly for MLP children or indirectly through mother-led interaction for term-born children. These findings suggest that the process through which maternal NA affects psychosocial outcomes may be different for MLP and term-born children. However, as the examined moderation effects of birth status did not reach statistical significance, more research using larger sample sizes is needed to study mother–child interaction in greater detail.

KEYWORDS

negative affectivity, mother–child interaction, moderate to late preterm, social emotional development, moderated mediation, structured task, internalizing and externalizing problems, psychosocial problems

Introduction

Approximately, 1 in 10 children is born preterm (i.e., gestational age of <37 weeks), of which 85% is considered moderate to late preterm (MLP; gestational age 32–37 weeks) (Chawanpaiboon et al., 2019). Compared to term-born children, MLP children are more prone to psychosocial difficulties, such as internalizing – e.g. anxious and depressed moods – and externalizing problems – e.g. attentional problems, aggression, and a lower self-control (Talge et al., 2010; Potijk et al., 2012). However, not every MLP child develops psychosocial difficulties, indicating that other factors play a role. Research has shown that the early caregiving environment – e.g. parenting behaviors, parental characteristics – forms an important contributor to the psychosocial development, with evidence that preterm children are more affected by this than their full-term counterparts (Gueron-Sela et al., 2015). Therefore, it is important to identify which early caregiving factors increase the risk of developing psychosocial difficulties in MLP children. Possibly, interventions for psychosocial difficulties in MLP children can be adjusted towards targeting such relevant risk factors.

For both MLP and term-born children, maternal depressive and anxiety symptoms have been studied extensively and have repeatedly been linked to more internalizing and externalizing problems in their offspring (Brennan et al., 2000; Barker et al., 2011; Goodman et al., 2011; Rogers et al., 2013). Premature infants however, including MLP infants, were found to be exceptionally hormonally sensitive to maternal depressive symptoms, as they showed higher cortisol levels compared to full-term children who were also at medical risk (Bugental et al., 2008). Furthermore, mothers with depression reported lower social abilities – e.g. ability to make friends, share with others, play independently – for preterm born toddlers but not for term-born toddlers (Silverstein et al., 2010). Additionally, high maternal emotional distress, as measured by anxiety, stress and depressive symptoms, was found to impact social competences of all children, but especially in preterm children (Gueron-Sela et al., 2015). This indicates that the emotional state of mothers is particularly important for preterm infants.

Recent literature showed that especially the *stable* trait portion of maternal anxiety and depressive symptoms – more than the transient elevated anxiety and depression symptomatology–is predictive for child's psychosocial outcomes at age 2 (Prenoveau et al., 2017) and also at age 12.5 (Missler et al., 2021). These effects were also found for subclinical levels of maternal depression and anxiety, highlighting the need to shift the research focus from clinical depressive and anxiety diagnosis to subclinical, stable traits that underly these disorders (Kingston et al., 2018; Missler et al., 2021). A relatively stable personality trait that is described as an underlying common risk factor for depressive and anxiety disorders is negative affectivity (NA) (Watson and Clark, 1984; Watson et al., 2011; Stanton and Watson, 2014). NA is characterized by the tendency to experience negative thoughts, feelings and emotions across time and regardless of situations (Watson and Clark, 1984; Denollet, 2013). High NA individuals tend to take a gloomy view of things and are prone to feelings of dysphoria, anxiety and irritability even in the absence of an objective stressful event (Watson and Clark, 1984; Denollet, 2013). Maternal NA has not widely been studied yet in relation to MLP versus term-born psychosocial outcomes, which is why the current study will investigate the role of maternal NA further. Due to the lack of research on this topic, we will mostly discuss previous literature about maternal depressive and anxiety symptoms as these concepts are close to NA.

There is evidence that mothers with depression behave differently towards their child, resulting in a lower quality of mother–child interaction, which in turn may lead to more psychosocial difficulties (Dubois-Comtois et al., 2013; Villodas et al., 2015). Therefore, quality of mother–child interaction may be a mediating factor between maternal NA and child's psychosocial outcomes. For term-born children, previous research showed that mothers with depressive symptoms displayed more mother–child aggression – e.g. aggressive interactions, harsh disciplining – during early childhood, which in turn predicted more externalizing behavior during middle childhood (Villodas et al., 2015). Furthermore, maternal psychosocial distress predicted a lower quality of mother–child interaction – i.e. characterized by low levels of reciprocated, open and balanced communication – which in turn predicted more child's reported internalizing and externalizing problems at age 8.5, showing a mediation effect of mother–child interaction (Dubois-Comtois et al., 2013). Another study in children aged 8–12 years with externalizing problems showed that maternal depressive symptoms predicted lower maternal warmth during mother–child interaction and more mother-reported internalizing and externalizing problems in the child. However, maternal warmth did not mediate the relation between maternal depressive symptoms and the child's internalizing and externalizing behavior (van Doorn et al., 2016). These studies indicate that higher levels of depressive symptoms or psychosocial distress in mothers may lead to a lower quality of mother–child interaction, which in turn affects children's psychosocial outcomes. However, previous findings are inconsistent regarding the mediating role of mother–child interaction.

The question is whether preterm children are more affected by a lower quality of mother–child interaction than full-term children. It seems that preterm children may be more sensitive to their early caregiving environment. To illustrate, if mothers were consistently responsive to their child in the first 4 years of life, cognitive growth was faster for all children, but this effect was stronger for preterm children than for term-born children (Landry et al., 2001). Additionally, an intervention targeting maternal responsiveness led to better social and emotional skills, again especially in the preterm group (Landry et al., 2006). A study by Gueron-Sela et al. (2015) also found evidence that premature born children are more affected by their early caregiving environment than term-born children. They found that in families with high maternal stress and a lower quality of parent–child interaction at 6 months, social competences at 12 months were lower for preterm children than full-term children. Conversely, when maternal stress was low and the quality of interaction was high, preterm children outperformed their full-term peers in terms of social competences (Gueron-Sela et al., 2015). This indicates that prematurely born children might be more affected by their early caregiving environment than term-born children.

The current study will investigate whether the relation between maternal NA and toddler's psychosocial functioning (i.e., social–emotional difficulties, internalizing, and externalizing problem behavior) is mediated by the quality of mother–child interaction, and whether these relationships are different in MLP versus term-born children (i.e., birth status) (see Figure 1). It is hypothesized that higher levels of NA in the mother will predict more psychosocial difficulties in their offspring. It is expected that this relationship is stronger for preterm children as these children seem more sensitive to depressive symptoms of the mother – a concept that is related to NA (Bugental et al., 2008) (See c' path Figure 1). It is expected that this link between maternal NA and psychosocial outcomes is mediated by the quality of mother–child interaction, with higher levels of maternal NA being related to a lower quality of mother–child interaction (See *a* path Figure 1) which predicts more psychosocial difficulties in the child (See *b* path Figure 1). This mediation effect is expected to be stronger in preterm children than in term-born children as premature children may be more sensitive to both maternal NA and the quality of mother–child interaction.

Materials and methods

Participants and procedure

This study is part of a larger longitudinal study called the Study on Attention of Preterm children (STAP) project, in which MLP and term-born children took part, all born between March 2010 and April 2011. Data was collected from March 2011 to March 2013. All children were recruited in nine hospitals around Utrecht, Netherlands. Pediatricians and midwives asked parents to participate when the child was 10 months old. Exclusion criteria were severe congenital malformations, dysmaturity, multiple births, admission to a tertiary Neonatal Intensive Care Unit (NICU), maternal antenatal substance abuse or chronic antenatal use of psychiatric drugs. The STAP project was approved by the Utrecht Medical Center Ethics Committee (identification code NL34143.041.10) and both parents provided written informed consent.

The initial sample consisted of 226 participants. Assessments took place when the child was 18 months and 24 months of corrected age for prematurity. At 18 months, mothers were asked to fill out a questionnaire to measure NA, and mother–child interaction was assessed. At 24 months, the mother filled out the measurements regarding the child's psychosocial functioning.

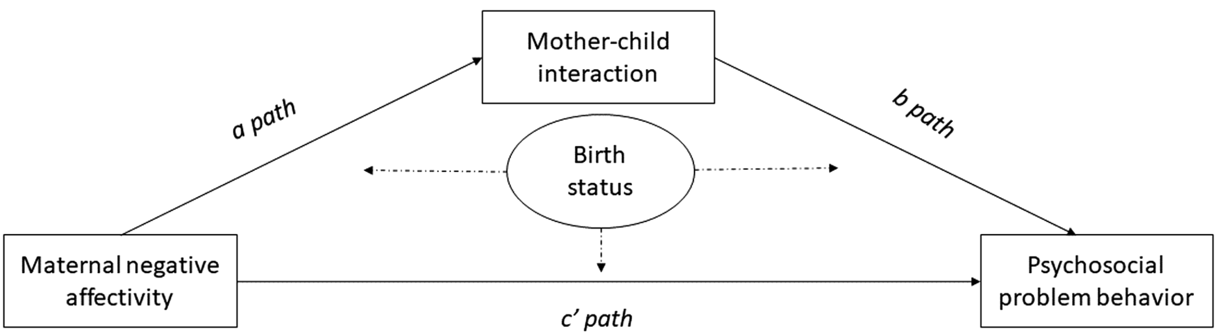

FIGURE 1
The proposed model. Dashed lines indicate moderation effects.

Participants that had no data on maternal NA, mother–child interaction or none of the psychosocial outcomes were removed from the dataset, and one participant that exceeded the age range for filling out the Ages and Stages Questionnaire 24 month version (i.e., 30 months). The final sample consisted of 200 children, of which 108 MLP and 92 term-born. See Table 1 for the participant's characteristics.

Negative affectivity (18 months)

Maternal NA was measured using the Type D Scale-14 (DS14) (Denollet, 2005). The DS14 measures two scales: Negative Affectivity (7 items) and Social Inhibition (7 items) of which we only used the former scale to assess NA. The NA scale covers dysphoria (e.g., "I often feel unhappy"), worry (e.g., "I often find myself worrying about something") and irritability (e.g., "I am often irritated") and items are answered on a scale from 0 = "false" to 4 = "true." Sum scores were calculated by adding the seven NA items, leading to sum scores within the range of 0 to 28, with higher scores indicating more NA. The DS14 has shown to be a psychometrically sound instrument (Denollet, 2005), also cross-culturally (Kupper et al., 2013). The NA scale was previously shown to be internally consistent ($\alpha = 0.88$) (Denollet, 2005). The internal consistency was $\alpha = 0.87$ in the current study.

Mother–child interaction (18 months)

Mother–child interaction was observed during structured tasks, as such tasks are known to elicit more differential mother–child interactions than free-play settings in which interactions are mainly positive and less varied (Ginsburg et al., 2006). Mothers were asked to perform two structured tasks with their child: (1) reading a book (5 min), (2) making a puzzle together (5 min). Interactions were videotaped and trained raters coded the behaviors using the Coding Interactive Behavior Manual (CIB; Feldman, 1998). The CIB is a global rating scheme for children aged 2 to 36 months and assesses the frequency of certain behaviors (e.g., joint attention, intrusiveness, positive affect). These behaviors are measured from the child's perspective (16 items), from the mothers' perspective (21 items) and their dyadic interaction (5 items). All items were scored by a trained assessor on a 5-point Likert scale ranging from 1 (little) to 5 (much). Inter-rater reliability was calculated based on 21% double coded videos, and was acceptable (ICC = 0.76).

There are no pre-distinguished subscales for the CIB and studies differ in which behaviors are grouped together to form subscales (Feldman et al., 2002; Feldman, 2010; Weisman et al., 2015). We therefore conducted an exploratory factor analysis to discover which subscales best represented the mother–child interaction characteristics in the current study. This led to the following 5 subscales: (1) Negative interaction, consisting of child's positive affect (reversed), child's negative emotionality, child's labile affect, child's avoidant behavior, dyadic constriction and dyadic tension ($\alpha = 0.89$); (2) Reciprocal engagement, consisting of child's joint attention, child's on task persistence, child's withdrawal (reversed), child's compliance to parent, child's initiation, dyadic reciprocity, dyadic affect-regulation, dyadic fluency ($\alpha = 0.85$); (3) Maternal stimulation, consisting of parents' elaborating, parents' resourcefulness, parents' on task persistence, parents' limit setting ($\alpha = 0.81$); (4) Emotional support consisting of parent's acknowledgement, parents' positive affect, parents' negative affect (reversed), parents' supportive presence, parents' appropriate range of affect ($\alpha = 0.75$); (5) Mother-led interaction, consisting of parent's intrusiveness, child-led interaction (reversed), child's affection towards parent, child's reliance on parent for help ($\alpha = 0.68$). Average scores were calculated by adding the items of the relevant behaviors per subscale and dividing it by the number of items. Scores on each subscales could range between 1 and 5, with higher scores indicating that the behaviors of the subscale are more characteristic for the mother–child dyad.

TABLE 1 Participant characteristics per group of birth status.

	MLP (*n* = 108)	Term (*n* = 92)
Gender		
Male, *n* (%)	63 (58.33%)	41 (44.57%)
Female, *n* (%)	45 (41.67%)	51 (55.43%)
Corrected age in months, wave 1		
Mean (SD)	17.22 (0.44)	17.32 (0.47)
Range	17–19	17–18
Corrected age in months, wave 2		
Mean (SD)	23.32 (0.54)	23.59 (0.63)
Range	23–25	23–26
Ethnicity, *n* (% Dutch)	104 (96.30%)	88 (96.30%)
Gestational age		
Mean (SD)	34.69 (1.34)***	39.47 (0.99)
32 weeks, *n* (%)	11 (10.19%)	
33 weeks, *n* (%)	11 (10.19%)	
34 weeks, *n* (%)	19 (17.59%)	
35 weeks, *n* (%)	27 (25.00%)	
36 weeks, *n* (%)	40 (37.04%)	
37 weeks, *n* (%)		4 (4.35%)
38 weeks, *n* (%)		9 (9.78%)
39 weeks, *n* (%)		31 (33.70%)
40 weeks, *n* (%)		36 (39.13%)
41 weeks, *n* (%)		12 (13.04%)
Birth weight in grams		
Mean (SD)	2584.77***	3575.44
Range	1,420–3,850	2,795–5,330
Education level mother[a]		
Low, *n* (%)	7 (6.48%)	2 (2.17%)
Medium, *n* (%)	36 (33.33%)***	10 (10.87%)
High, *n* (%)	65 (60.19%)***	80 (86.96%)

MLP, moderate to late prematurely born children; SD, standard deviation. To test for groups differences, *t*-tests and Fisher's exact tests were used.
[a]Low: no education, special education, elementary school, lower secondary education; Medium: secondary or vocational education; High: college, university or higher.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Social–emotional difficulties (24 months)

Social–emotional difficulties of the child was measured at 24 months corrected age using the Dutch translation of the Ages and Stages Questionnaire-Social Emotional (ASQ-SE; Squires et al., 2002). The ASQ-SE is a parent-report screening instrument that aims to detect children with social–emotional difficulties and delays by addressing seven behavioral dimensions: self-regulation, compliance, social-communication, adaptive functioning, autonomy, affect, and interaction with people. The 24 months age version, which can be used for children from 21 to 26 months of age, consists of 26 scored items which are answered with "most of the time" (0 points) "sometimes" (5 points) and "rarely/never" (10 points). For every question, the parent can express concerns regarding the child's behavior, leading to an additional 5 points. A sum score is calculated by summing the points of the 26 items including the points of the concerns, in which a higher score relates to more social–emotional difficulties or delays. Scores could range between 0 and 390. When no more than 3 items were missing on the ASQ-SE, mean imputation was used as recommended (Squires et al., 2002). The ASQ-SE has shown good psychometric properties in the United States (Squires et al., 2002) and the Dutch translation has shown good specificity (De Wolff et al., 2013; Krijnen et al., 2021) and sufficient sensitivity (Krijnen et al., 2021) to slightly below the cut-off for sufficient sensitivity (i.e., 66%) (De Wolff et al., 2013). Internal consistency for the 24 months version has shown to be good, $\alpha = 0.80$ (Squires et al., 2001). For the current sample, internal consistency was on the lower side, i.e., $\alpha = 0.45$, though some studies still consider this sufficient (for an overview, see Taber, 2018). This lower internal consistency can be explained by the broad domain of social–emotional development that the ASQ-SE assesses, whereas an uni-dimensional structure is assumed for internal consistency measures. As the current study aims to get an indication of the social–emotional development of the child, the lower internal consistency in the current study is considered to not be of major concern.

Internalizing and externalizing problem behavior (24 months)

The Child Behavior Checklist 1½-5 (CBCL) (Achenbach and Rescorla, 2001) is a parent-report questionnaire measuring behavioral and emotional problems of children aged 1.5 to 5 years old over the past 2 months. For the current study, the two broad-band scales of internalizing and externalizing problem behavior were used. The internalizing scale (36 items) consists of the following 4 domains of behavioral problems: emotionally reactive (e.g., "disturbed by any change in routine"), anxious/depressed (e.g., "nervous, high-strung or tense"), somatic complaints (e.g., "headaches"), and withdrawn (e.g., "seems unresponsive to affection"). The externalizing scale (24 items) consists of 2 domains: attention problems (e.g., "cannot concentrate") and aggressive behavior (e.g., "angry moods"). Questions are answered on a three-point scale ranging from 0 = "not true," 1 = "somewhat or sometimes true" and 2 = "very true or often true." Scores were calculated by summing the behaviors and standardized T scores were calculated, with higher scores indicating more problem behavior. T scores for the internalizing scale could range between 29 and 100, and for the externalizing scale between 28 and 100. The CBCL 1½-5 has shown good reliability and validity (Achenbach and Rescorla, 2001). The internal consistency of the two broad-band scales was good, with $\alpha = 0.89$ for internalizing and $\alpha = 0.92$ for the externalizing scales (Achenbach, 2011). In the current study, the internal consistency for the internalizing and externalizing scale was 0.75 and 0.88, respectively.

Statistical analyses

R version 4.0.3 was used to analyze the data. Bivariate Pearson correlations among the variables were investigated and descriptive analyses were executed using independent *t*-tests to check for group differences between the MLP and term-born group. The PROCESS macro, written by Hayes (2017) was used to test the moderated mediation model. PROCESS uses ordinary least squares regression-based path analysis and estimates the moderating and mediating relationships simultaneously using observed variables or observed variable proxies (i.e., sum scores or averages of indicators) (Hayes et al., 2017). A single test procedure is used in which one statistic accounts for the indirect effect of X on Y through the mediator, enhancing its power and making it an increasingly used method in psychology research.

Maternal NA was added as the predictor variable and the five mother–child interactions were added as parallel mediators within one model (i.e., negative interaction, reciprocal engagement, maternal stimulation, emotional support and mother-led interaction), allowing the mediators to be correlated and estimating the parameters of each mediator while controlling for effects of the other mediators. Both the predictor and the mediators were mean centered to avoid multi-collinearity. Gender of the child (0 = male, 1 = female) and education level of the mother (low/medium/high, resulting in 3 dummy variables with low as the reference category) were added to the model as covariates, as both are known to be related to children's psychosocial outcomes (Potijk et al., 2015; Stene-Larsen et al., 2016). Birth status was added as a dichotomous moderator (0 = term, 1 = MLP) and the moderated mediation model was run using PROCESS model 59. The moderated mediation model produces estimates of effects per level of the moderator, while testing whether these effects are significantly different between each other. The models were run three times, for every outcome measure separately (i.e., social–emotional development, internalizing problem behavior, externalizing problem behavior). Robust standard errors were used to protect against heteroscedasticity. Indirect effects were tested using a bootstrapping procedure with 10,000 iterations to protect against non-normality using seed 654321 for the random number generator. Indirect effects were considered significant when the 95% bootstrapped confidence interval excluded 0. Unstandardized regression coefficients were reported, following the recommendations of Hayes stating that these are easier to interpret as the unstandardized metric directly maps onto the scale of the variables (Hayes, 2017).

Results

Descriptives

See Table 2 for the scores on maternal NA, mother–child interaction and psychosocial behavior per group. MLP children scored significantly higher on internalizing problems than term-born children [$t(193.37) = -3.02$, $p = 0.002$]. No differences were found on social–emotional difficulties [$t(189.86) = -1.56$, $p = 0.12$] and externalizing problems [$t(181.49) = -1.77$, $p = 0.08$]. Concerning the mother–child interaction behaviors, differences were found for reciprocal engagement, which was significantly lower in the MLP group [$t(197.81) = 2.46$, $p = 0.01$]. Levels of maternal NA were not different between the groups [$t(197.56) = -0.09$, $p = 0.92$].

See Table 3 for the correlations between the variables, per MLP group (upper diagonal half) and term-born group (lower diagonal half).

TABLE 2 Descriptive statistics.

	MLP ($n = 108$)	Term ($n = 92$)
Social–emotional difficulties[a]		
Mean (SD)	18.17 (11.99)	15.45 (12.50)
Range	0–50	0–65
Internalizing problems[b]		
Mean (SD)	44.76 (8.85)**	41.10 (8.15)
Range	29–67	29–58
Externalizing problems[b]		
Mean (SD)	48.87 (7.96)	46.73 (8.80)
Range	32–71	28–64
Mother-led interaction		
Mean (SD)	2.53 (0.85)	2.66 (0.83)
Range	1.00–4.50	1.00–4.25
Maternal stimulation		
Mean (SD)	3.71 (0.84)	3.89 (0.78)
Range	1.50–5.00	2.00–5.00
Reciprocal engagement		
Mean (SD)	3.61 (0.68)*	3.83 (0.60)
Range	1.75–5.00	2.38–4.88
Negative interaction		
Mean (SD)	1.31 (0.53)	1.28 (0.50)
Range	1.00–3.50	1.00–3.83
Emotional support		
Mean (SD)	4.78 (0.39)	4.82 (0.40)
Range	3.00–5.00	3.20–5.00
Maternal negative affect		
Mean (SD)	6.42 (5.17)	6.35 (4.61)
Range	0–21	0–22

MLP: moderate to late preterm born children; SD, standard deviation. To test for groups differences, *t*-tests were used.
[a]Data of 1 MLP child was missing.
[b]Data of 2 term-born children and 1 MLP child were missing.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Moderated mediation model

Three models were run; one per psychosocial outcome measure. First, results are shown for maternal NA on mother–child interaction, representing only the a path (see Table 4). Table 5 shows the b, c' and ab paths per outcome measure, including the index of moderated mediation effects. See also Figures 2, 3 for a visual representation of the results per MLP and term-born group, respectively.

Mother–child interaction

See Table 4 for all results on mother–child interaction. In the term-born group, maternal NA negatively predicted negative interaction ($b = -0.02$, $p = 0.02$) and mother-led interaction ($b = -0.04$, $p = 0.03$). In the MLP group these relationships were not found ($b_{\text{negative interaction}} = <-0.01$, $p = 0.78$; $b_{\text{mother-led interaction}} = -0.02$, $p = 0.28$). These relations did not significantly differ between the groups, as no significant moderation effect of birth status was found. Maternal NA did not predict emotional support, maternal stimulation and reciprocal engagement in both groups.

Social–emotional difficulties

See Table 5 for the results on social–emotional difficulties. The total model explained 22% of the variance in social–emotional difficulties ($p < 0.001$). The results showed a significant positive, direct effect of maternal NA on social–emotional difficulties for the MLP group ($b = 0.57$, $p = 0.02$). A non-significant positive effect was seen for the term-born group ($b = 0.34$, $p = 0.31$). These relations were not significantly different between the groups, as no moderation effect of birth status was found ($p = 0.59$). Reciprocal engagement negatively predicted social–emotional difficulties in term-born children ($b = -7.84$, $p = 0.003$), but not in MLP children ($b = -4.21$, $p = 0.09$). No moderation effect of birth status was found for this relation ($p = 0.31$), indicating that the relationship between reciprocal engagement and social–emotional difficulties was not significantly different between the groups. No significant relationships were found with the four remaining mother–child interaction variables.

Internalizing problem behavior

See Table 5 for the results on internalizing problems. The total model explained 16% of the variance in internalizing problems ($p = 0.001$). The results showed a direct, positive effect for maternal NA on internalizing problems in the MLP group ($b = 0.45$, $p = 0.004$). This relation was not found in term-born children ($b = 0.10$, $p = 0.65$). The relationships were not significantly

TABLE 3 Correlation table.

	1	2	3	4	5	6	7	8	9
1. Maternal NA	–	0.03	−0.11	−0.00	0.06	−0.11	0.32*	0.25	0.23
2. Maternal Stimulation	0.05	–	0.37**	−0.15	0.31*	0.19	−0.10	−0.09	0.11
3. Reciprocal engagement	0.00	0.39**	–	−0.63***	0.23	0.20	−0.26	−0.03	−0.11
4. Negative Interaction	−0.20	−0.20	−0.44**	–	−0.19	−0.15	0.09	0.01	0.11
5. Emotional Support	0.00	0.27	0.34*	−0.29	–	0.00	0.02	−0.10	0.10
6. Mother-led	−0.21	0.15	0.09	−0.03	−0.06	–	−0.15	−0.08	−0.10
7. Social–emotional difficulties	0.19	−0.03	−0.36*	0.12	−0.12	−0.20	–	0.35**	0.48***
8. Internalizing problem behavior	0.11	0.07	−0.14	0.10	−0.09	−0.29	0.40**	–	0.46***
9. Externalizing problem behavior	0.10	0.03	−0.05	0.13	−0.09	−0.27	0.30	0.64***	–

Pearson correlations are presented per MLP group (upper diagonal half) and term-born group (lower diagonal half).
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

different between groups (i.e., no moderation of birth status, $p = 0.18$). For term-born children, a mediation effect was found through mother-led interaction (ab path, $b = 0.12$, 95%BootCI = 0.02 to 0.26), in which maternal NA predicted lower mother-led interaction (a path, $b = -0.04$, $p = 0.02$) which in turn predicted more internalizing problems (b path, $b = -3.00$, $p = 0.004$). This mediation effect was not found in the MLP group. No moderated mediation effects were found of birth status on this relation ($b = -0.11$, 95%BootCI = −0.28 to 0.02). No significant relationships were found with the four remaining mother–child interaction variables.

Externalizing problems

See Table 5 for the results on externalizing problems. The total model explained 13% of the variance in externalizing problems ($p = 0.05$). The results showed no direct effect for maternal NA on externalizing problems for both groups (MLP: $b = 0.28$, $p = 0.09$, term-born: $b = 0.11$, $p = 0.67$). For the term-born group, a mediation effect was found through mother-led interaction (ab path, $b = 0.13$, 95%BootCI = 0.01 to 0.29) in which higher levels of maternal NA predicted less mother-led interaction (a path, $b = -0.04$, $p = 0.02$), which in turn predicted more externalizing problems (b path, $b = -3.09$, $p = 0.008$). This mediation effect was not found in the MLP group. No significant moderated mediation effects were found of birth status for this relationship ($b = -0.11$, 95% BootCI = −0.26 to 0.01). No significant relationships were found with the four remaining mother–child interaction variables.

Discussion

The current study examined whether maternal NA was related to psychosocial difficulties in MLP and term-born toddlers, and if this was mediated by quality of mother–child interaction. Additionally, it was studied if these relationships were different for MLP children compared to term-born children (i.e., moderation effect of birth status). Our results showed that mothers with higher levels of maternal NA, which is reflected by the tendency to experience negative thoughts, feelings and emotions, reported more psychosocial difficulties in their toddlers. For MLP children, a direct relationship between maternal NA and psychosocial outcomes was found, which was not mediated by mother–child interaction. For term-born children, maternal NA was indirectly associated with psychosocial child outcomes, through levels of mother-led interaction. Birth status did not moderate these relationships, indicating that the associations found within the groups were not clearly different from each other. However, the within group findings are discussed here as well, as these may be important for future studies.

In term-born children, mother-led interaction – one of the five observed mother–child interactions–formed a mediating factor. Higher levels of maternal NA were related to lower levels of mother-led interaction, which subsequently predicted more internalizing and externalizing problems in term-born children. This is in line with previous research showing that maternal depressive symptoms are related to more passive and withdrawn maternal behaviors (Stein et al., 2012; Esposito et al., 2017) – i.e. lower levels of mother-led interaction – which negatively affect children's psychosocial functioning (Easterbrooks et al., 2012).

In addition to this mediation effect of mother-led interaction, we found non-mediating associations of mother–child interaction within the group of term-born children. Higher levels of reciprocal engagement were related to less social–emotional difficulties of the children, which also is in line with previous research (Feldman et al., 2013). Surprisingly, higher levels of maternal NA were linked to lower levels of negative interaction within the term-born group, whereas we expected to find the opposite. To interpret this finding, it is important to keep in mind that in the current study negative interaction was mainly based on the child's behavior (e.g., negative emotionality or labile affect). It might be that term-born children respond adaptively towards higher levels of maternal NA by avoiding tension and problems, resulting in lower scores on negative interaction. Future studies are needed to confirm these hypotheses.

In MLP children, maternal NA was directly related to psychosocial problems. Contrary to our expectations, no mediation effects nor associations were found for mother–child interaction, indicating that mother–child interaction was not

TABLE 4 Mother–child interaction (mediator variables) as outcomes, representing the a paths of the moderated mediation model.

	Negative interaction			Reciprocal engagement			Maternal stimulation			Emotional support			Mother-led interaction		
	b (SE)	***t***	**LL-UL**	**b (SE)**	***t***	**LL-UL**	**b (SE)**	***t***	**LL-UL**	**b (SE)**	***t***	**LL-UL**	**b (SE)**	***t***	**LL-UL**
Constant	0.17 (0.25)	0.69	−0.31;0.66	0.07 (0.30)	0.22	−0.53;0.66	0.11 (0.32)	0.35	−0.52;0.74	−0.28 (0.26)	−1.08	−0.80;0.23	0.23 (0.41)	0.56	−0.57;1.03
NA	−0.02 (<0.01)*	−2.40	**−0.04;<−0.01**	<0.01 (0.02)	0.04	−0.03;0.03	<0.01 (0.02)	0.48	−0.03;0.04	<0.01 (<0.01)	0.18	−0.01;0.01	−0.04 (0.02)*	−2.23	**−0.07;<−0.01**
Birth status	0.02 (0.07)	0.26	−0.13;0.17	−0.16 (0.10)	−1.63	−0.36;0.03	−0.16 (0.12)	−1.34	−0.40;0.08	−0.02 (0.06)	−0.41	−0.13;0.09	−0.17 (0.13)	−1.33	−0.42;0.08
NA*birth status	0.02 (0.01)	1.42	−0.01;0.05	−0.01 (0.02)	−0.59	−0.05;0.03	<−0.01 (0.02)	−0.07	−0.05;0.05	0.01 (0.01)	0.58	−0.01;0.02	0.02 (0.02)	0.87	−0.03;0.07
Gender child	0.04 (0.07)	0.54	−0.12;0.19	−0.05 (0.10)	−0.50	−0.24;0.14	−0.05 (0.12)	−0.38	−0.28;0.19	0.01 (0.06)	0.17	−0.11;0.13	0.06 (0.12)	0.50	−0.18;0.31
Education medium	−0.15 (0.23)	−0.68	−0.62;0.30	−0.16 (0.29)	−0.55	−0.74;0.42	−0.09 (0.33)	−0.27	−0.73;0.56	0.28 (0.25)	1.14	−0.21;0.78	−0.07 (0.40)	−0.16	−0.86;0.73
Education high	−0.22 (0.23)	−0.99	−0.68;0.22	0.11 (0.29)	0.40	−0.45;0.68	0.02 (0.31)	0.07	−0.59;0.63	0.31 (0.25)	1.26	−0.18;0.80	−0.21 (0.39)	−0.53	−0.99;0.57
	Conditional effect of NA on negative interaction (a path)			Conditional effect of NA on reciprocal engagement (a path)			Conditional effect of NA on maternal stimulation (a path)			Conditional effect of NA on emotional support (a path)			Conditional effect of NA on Mother-led interaction (a path)		
MLP group	<−0.01 (0.01)	−0.28	−0.02;0.02	−0.01 (0.01)	−0.82	−0.04;0.02	0.01 (0.02)	0.38	−0.03;0.04	0.01 (0.01)	0.97	−0.01;0.02	−0.02 (0.02)	−1.08	−0.05; 0.02
Term-born group	−0.02 (0.01)*	−2.40	**−0.04;<−0.01**	<0.01 (0.02)	0.04	−0.03;0.03	0.01 (0.02)	0.48	−0.03;0.04	<0.01 (0.01)	0.18	−0.01;0.01	−0.04 (0.02)*	−2.23	**−0.07;<−0.01**
R^2	0.03			0.07			0.02			0.03			0.04		
F	1.98			2.06			0.58			0.44			1.44		

LL, lower limit for the 95% confidence intervals; UL, upper limit for the 95% confidence intervals; NA, negative affectivity; MLP, moderate to late preterm born children. Bold confidence intervals represent significant findings. Birth status is coded with 0 = term-born and 1 = moderate to late preterm born.

$^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

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TABLE 5 Moderated-mediation model, representing the b, c', and ab paths as well as the index of moderated mediation.

	Social–emotional difficulties[a]			Internalizing problems[b]			Externalizing problems[b]		
	b (SE)	t	LL-UL	b (SE)	t	LL-UL	b (SE)	t	LL-UL
Constant	25.24 (5.76)***	4.38	**13.88;36.60**	36.85 (4.22)***	8.72	**28.51;45.18**	47.49 (3.47)***	13.68	**40.64;54.34**
Negative affectivity	0.34 (0.34)	1.03	−0.32;1.01	−0.10 (0.21)	0.45	−0.33;0.52	0.11 (0.25)	0.43	−0.38;0.60
Negative interaction	−0.29 (3.04)	−0.10	−6.30;5.71	1.36 (2.03)	0.67	−2.63;5.36	2.65 (2.46)	1.07	−2.21;7.51
Reciprocal engagement	−7.84 (2.56)**	−3.07	**−12.88; −2.80**	−1.76 (1.59)	−1.11	−4.90;1.37	0.52 (1.93)	0.27	−3.29;4.33
Maternal stimulation	2.11 (1.72)	1.23	−1.20;5.51	2.17 (1.15)	1.88	−0.10;4.43	1.18 (1.28)	0.92	−1.35;3.71
Emotional support	−1.41 (2.97)	−0.47	−7.27;4.46	−2.16 (2.60)	−0.83	−7.29;2.98	−2.21 (2.57)	−0.86	−7.29;2.87
Mother-led interaction	−2.50 (1.38)	−1.82	−5.22;0.21	−3.00 (1.04)**	−2.89	**−5.04;−0.95**	−3.09 (1.15)**	−2.69	**−5.37;-0.82**
Birth status	−0.22 (1.74)	−0.13	−3.65;3.20	3.18 (1.26)*	−2.51	**0.69;5.67**	1.49 (1.33)	1.12	−1.13;4.11
NA*Birth status	0.23 (0.42)	0.54	−0.60-;1.05	0.35 (0.26)	1.35	−0.16;0.87	0.17 (0.30)	0.58	−0.41;0.76
Neg Int*Birth status	−1.52 (4.57)	−0.33	−10.53;7.50	−0.75 (3.46)	−0.22	−7.57;6.07	−1.57 (3.33)	−0.47	−8.15;5.01
Rec Eng*Birth status	3.63 (3.53)	1.03	−3.34;10.61	3.29 (2.42)	1.36	−1.49;8.07	−1.35 (2.51)	−0.54	−6.31;3.60
Maternal Stim*Birth status	−2.31 (2.39)	−0.97	−7.02;2.41	−2.91 (1.66)	−1.75	−6.19;0.37	0.34 (1.67)	0.20	−2.95;3.64
Emo Sup*Birth status	3.95 (5.50)	0.72	−6.90;14.80	−0.62 (3.49)	−0.18	−7.50;6.26	3.84 (3.33)	1.16	−2.72;10.40
Mother-led*Birth status	1.03 (1.98)	0.52	−2.88;4.93	2.46 (1.46)	1.69	−0.42;5.34	2.26 (1.47)	1.54	−0.63;5.16
Gender child	−1.30 (1.71)	−0.76	−4.67;2.07	0.63 (1.27)	0.50	−1.86;3.13	0.71 (1.26)	0.56	−1.77;3.19
Education medium	−4.69 (5.54)	−0.85	−15.62;6.25	5.92 (4.31)	1.38	−2.57;14.42	0.92 (3.20)	0.29	−5.39;7.23
Education high	−8.72 (5.37)	−1.62	−19.32;1.87	4.14 (4.15)	1.00	−4.05;12.33	−1.23 (3.23)	−0.38	−7.59;5.14
R^2	0.22***			0.16**			0.13		
F	3.24			2.56			1.69		
Conditional effect of Neg int on psychosocial outcome (b path)									
MLP group	−1.81 (3.37)	−0.54	−8.47;4.85	0.61 (2.81)	0.22	−4.93;6.16	1.08 (2.27)	0.47	−3.41;5.56
Term-born group	−0.29 (3.04)	−0.10	−6.30;5.71	1.36 (2.03)	0.67	−2.63;5.26	2.65 (2.46)	1.07	−2.21;7.51
Conditional effect of Rec Eng on psychosocial outcome (b path)									
MLP group	−4.21 (2.50)	−1.68	−9.15;0.73	1.53 (1.81)	0.84	−2.05;5.11	−0.84 (1.63)	−0.51	−4.05;2.38
Term-born group	−7.84 (2.56)**	−3.07	**−12.88;−2.80**	−1.76 (1.59)	−1.11	−4.90;1.37	0.52 (1.93)	0.27	−3.29;4.33
Conditional effect of Matenernal Stim on psychosocial outcome (b path)									
MLP group	−0.19 (1.68)	−0.12	−3.50;3.12	−0.74 (1.91)	−0.62	−3.10;1.61	1.52 (1.08)	1.41	−0.60;3.65
Term-born group	2.11 (1.72)	1.23	−1.29;5.51	2.17 (1.15)	1.88	−0.11;4.43	1.18 (1.28)	0.92	−1.35;3.71
Conditional effect of Emo Sup on psychosocial outcome (b path)									
MLP group	2.54 (4.76)	0.53	−6.85;11.93	−2.78 (2.30)	−1.21	−7.32;1.76	1.63 (2.06)	0.79	−2.43;5.69
Term-born group	−1.41 (2.97)	−0.47	−7.28;4.46	−2.16 (2.60)	−0.83	−7.29;2.98	−2.21 (2.57)	−0.86	−7.29;2.87
Conditional effect of Mother-led on psychosocial outcome (b path)									
MLP group	−1.48 (1.40)	−1.05	−4.24;1.29	−0.53 (1.03)	−0.51	−2.57;1.50	−0.83 (0.93)	−0.90	−2.65;1.00
Term-born group	−2.50 (1.38)	−1.82	−5.22;0.21	−3.00 (1.04)**	−2.89	**−5.04;−0.95**	−3.09 (1.15)**	−2.69	**−5.37;−0.82**

(Continued)

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TABLE 5 (Continued)

	Social–emotional difficulties[a]			Internalizing problems[b]			Externalizing problems[b]		
	b (SE)	t	LL-UL	b (SE)	t	LL-UL	b (SE)	t	LL-UL
Conditional direct effect NA on psychosocial outcome (c' path)									
MLP group	0.57 (0.25)*	2.28	**0.08;1.06**	0.45 (0.15)**	2.91	**0.14;0.76**	0.28 (0.16)	1.72	−0.04;0.60
Term-born group	0.34 (0.34)	1.03	−0.32;1.01	0.10 (0.21)	0.45	−0.33;0.52	0.11 (0.25)	0.43	−0.38;0.60
Conditional indirect effect of negative interaction (ab path)									
MLP group	0.01 (0.03)		−0.05;0.08	<−0.01 (0.02)		−0.05;0.06	<−0.01 (0.02)		−0.05;0.06
Term-born	0.01 (0.06)		−0.11;0.14	−0.03 (0.04)		−0.13;0.04	−0.06 (0.06)		−0.19;0.03
Index of moderated mediation									
	<−0.01 (0.07)		−0.15;0.13	0.03 (0.05)		−0.06;0.14	0.05 (0.06)		−0.04;0.20
Conditional indirect effect of reciprocal engagement (ab path)									
MLP group	0.05 (0.07)		−0.06;0.22	−0.02 (0.04)		−0.10;0.05	0.01 (0.03)		−0.05;0.08
Term-born	−0.01 (0.12)		−0.28;0.22	<−0.01 (0.04)		−0.10;0.06	<0.01 (0.03)		−0.07;0.05
Index of moderated mediation									
	0.05 (0.14)		−0.20;0.37	−0.02 (0.05)		−0.11;0.10	0.01 (0.04)		−0.06;0.11
Conditional indirect effect of maternal stimulation (ab path)									
MLP group	<−0.01 (0.03)		−0.08;0.05	<−0.01 (0.02)		−0.05;0.04	0.01 (0.03)		−0.06;0.07
Term-born	0.02 (0.05)		−0.07;0.12	0.02 (0.04)		−0.07;0.10	0.01 (0.03)		−0.05;0.08
Index of moderated mediation									
	−0.02 (0.06)		−0.14;0.08	−0.02 (0.05)		−0.12;0.08	<−0.01 (0.04)		−0.10;0.08
Conditional indirect effect of emotional support (ab path)									
MLP group	0.02 (0.04)		−0.08;0.08	−0.02 (0.03)		−0.08;0.02	0.01 (0.02)		−0.03;0.06
Term-born	<−0.01 (0.02)		−0.05;0.03	<−0.01 (0.02)		−0.05;0.03	<−0.01 (0.02)		−0.04;0.04
Index of moderated mediation									
	−0.02 (0.05)		−0.08;0.10	−0.01 (0.03)		−0.08;0.05	0.01 (0.03)		−0.04;0.07
Conditional indirect effect of mother-led interaction (ab path)									
MLP group	0.02 (0.04)		−0.03;0.14	0.01 (0.03)		−0.04;0.07	0.02 (0.03)		−0.03;0.08
Term-born	0.10 (0.07)		−0.01;0.26	0.12 (0.06)		**0.02;0.26**	0.13 (0.07)		**0.01;0.29**
Index of moderated mediation									
	−0.07 (0.08)		−0.24;0.08	−0.11 (0.07)		−0.26;0.01	−0.11 (0.08)		−0.28;0.02

LL, lower limit for the 95% confidence intervals; UL, upper limit for the 95% confidence intervals. NA, negative Affectivity; Rec Eng, reciprocal engagement; Maternal Stim, maternal Stimulation; Emo Sup, emotional support; Motherled, mother-led interaction. Birth status is coded with 0 = term-born and 1 = moderate to late preterm born. Bootstrapped results are shown for the indirect effects. No *t* values are provided for bootstrapped results. Bold confidence intervals represent significant findings.

[a]Data of 1 MLP participant was missing, $n = 199$.

[b]Data of 2 term-born children and 1 MLP child were missing, $n = 197$.

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

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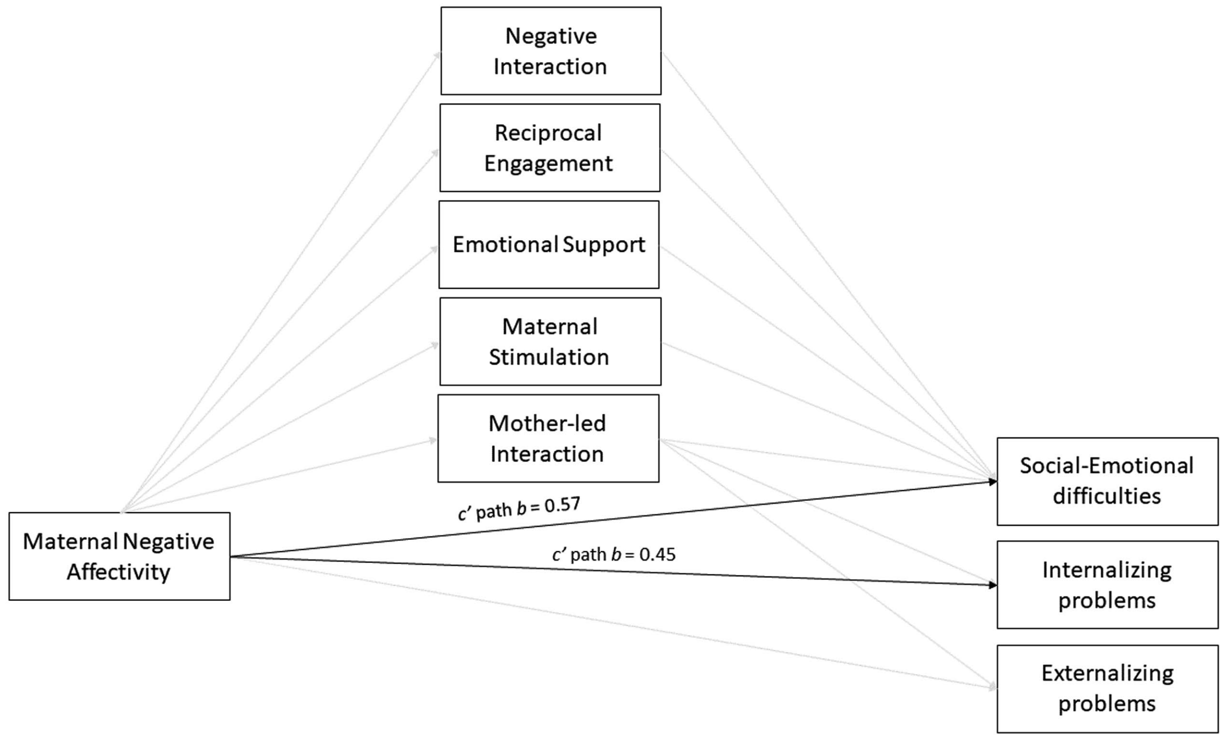

FIGURE 2
This figure shows the results of the three outcome models of the MLP sample (n=108). Bold lines represent significant paths and display unstandardized coefficients.

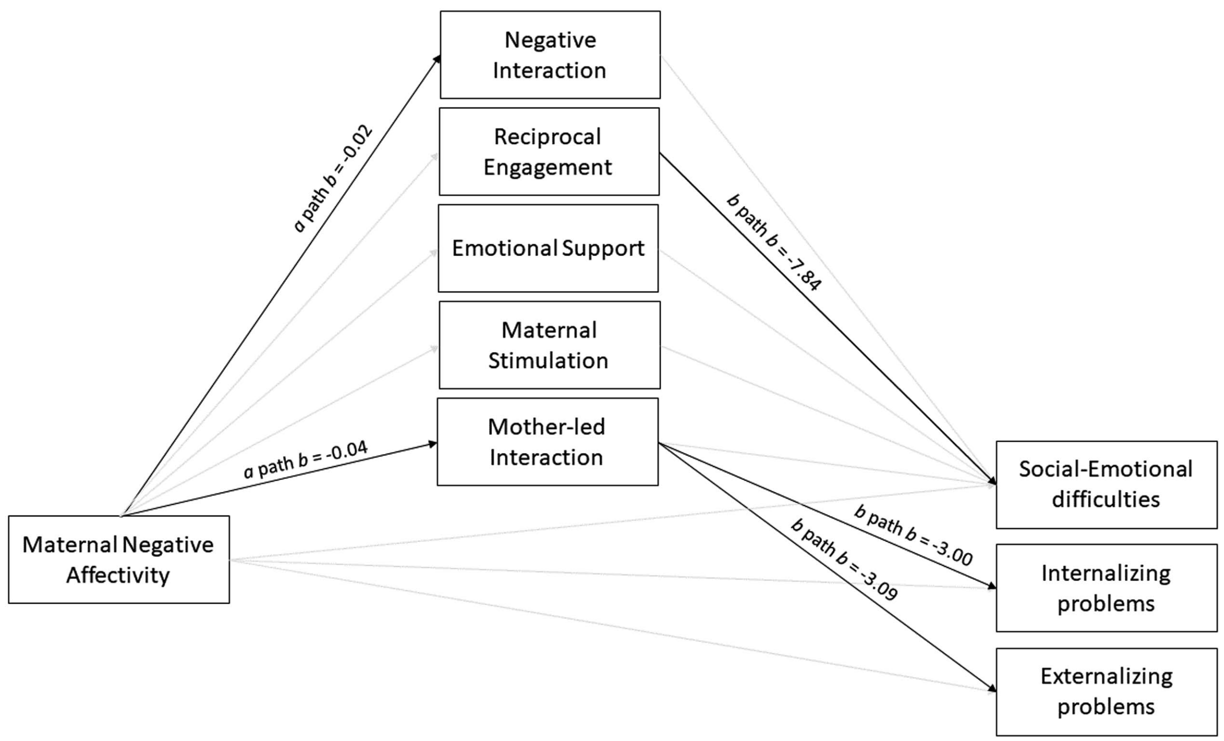

FIGURE 3
This figure shows the results of the three outcome models of the term-born children (n=92). Bold lines represent significant paths and display unstandardized coefficients. The indirect effect through mother-led interaction (ab path) was significant for internalizing and externalizing problems.

related to maternal NA and psychosocial outcomes for MLP toddlers. The absence of these associations could be due to lower neurodevelopmental functioning of MLP children compared to term-born children, which may have hindered their potential to develop through mother–child interaction. Previous research found that preterm children showed more withdrawn behavior, lower self-regulation skills, less alertness and less clear cues for the mother to interpret (White-Traut et al., 2002; Feldman and Eidelman, 2006; Pickler et al., 2010; Moe et al., 2016). We also found that the MLP group showed more internalizing problems – which includes withdrawn behaviors – and scored lower on reciprocal engagement – which includes aspects of attentional and regulation skills such as joint attention and on task persistence. Moreover, previous research on the current sample showed that the MLP group indeed had lower neurodevelopmental outcomes, as shown by lower scores on cognitive-, motor- and language/communication skills than term-born children at 24 months of age. After correcting age for prematurity, still a delay in receptive communication skills was found (De Jong et al., 2015). Difficulties in receptive communication skills can hinder the child in understanding the parent's communication. This can make it more challenging for the MLP child to engage in the interaction – which is in line with our finding of lower scores on reciprocal engagement in the MLP group – and benefit from it. We speculate that MLP children may be somewhat less active, focused and engaged during interactions. This might complicate the opportunities to learn and develop through mother–child interaction. We hypothesize that MLP children need more guidance and active behaviors from the mother than was found in the interaction observed for the current study, in order to be engaged in the interaction and to have them benefit in terms of their psychosocial development. Future studies could investigate whether an increase in active and leading behaviors of the mother would evoke more active behaviors of preterm born children.

Another explanation for the non-significant relations between mother–child interaction and the other studied variables in the MLP group could be due to our operationalization of the interaction. A 10 minutes structured task consisting of reading a book and making a puzzle together may not have given a complete representation of all (subtle) mother–child characteristics. It could be that different and perhaps more subtle mechanisms play a role in MLP mother–child dyads. Interestingly, only reciprocal engagement was lower in the MLP group compared to the term-born group, but the remaining four mother–child interaction characteristics were not of different quality. Future research is needed to investigate mother–child interaction in greater detail. We suggest an approach in which consistency across patterns can be observed and a wider variety of characteristics of mother–child interactions are elicited. This could be reached by including a greater variety of tasks than reading a book and making a puzzle, and observing for multiple days in a row or over a longer period of time, so that subtle patterns within the mother–child dyad may become clearer.

When interpreting the findings of the current study, it is important to keep in mind that – although our results suggest different patterns of relations in term-born versus MLP children– the differences in these patterns (e.g., moderation effects) did not reach statistical significance. Therefore, more research focusing on moderated-mediation analyses using larger sample sizes is advised to confirm if such different patterns exist. Other limitations of our study are that we assessed maternal NA once and are therefore unaware of the stability of this trait throughout the study. However, previous research showed that the outcomes of the DS14, which was used to assess NA, are relatively stable over time (Kupper et al., 2013). Nonetheless, for future research it is advised to measure maternal NA at multiple time points throughout the study as some variation in scores over time may occur. Another limitation is that mothers filled out the questionnaires for maternal NA as well as for psychosocial difficulties of their child, which could have elicited a response bias. However, we found no significant correlation between maternal NA and psychosocial outcomes for the term-born group, indicating that a response bias is unlikely. Lastly, the internal consistency of the ASQ-SE for the current sample was relatively low (i.e., $\alpha = 0.45$), indicating that not one single underlying construct has been measured. This is not surprising due to the broad domain of social–emotional development that the ASQ-SE measures, but it is important to keep in mind that the current results of the ASQ-SE give information about the *overall* social–emotional difficulties. Further research using instruments targeting specific dimensions of social–emotional development may provide more insight into which dimensions are most affected by maternal NA and/or mother–child interaction.

Despite its limitations, the current study contains several strenghts. In addition to its prospective longitudinal design, the fact that both self-report and observational measures were used decreases the chance of response bias. Furthermore, the preterm group consisted of relatively low-risk MLP children, a group that is studied less often than extreme and very preterm children, though MLP children form a large proportion of all children born preterm. Our results indicated that this group was not at a very high risk for problems, as we found that externalizing problems and social–emotional difficulties were comparable to the term-born group, just as four out of the five observed characteristics of mother–child interactions. Nevertheless, internalizing problems were higher and reciprocal engagement was lower in the MLP children.

For clinical practice it is advised to pay attention to levels of NA in mothers, regardless of birth status of the child. Mothers scoring high on NA could be offered additional support. Furthermore, for mothers of term-born children, the focus could be directed towards quality of mother–child interaction– specifically in stimulating mothers to show leading, active and engaged behaviors as these seem to be predictive of the term-born child's psychosocial outcomes. For MLP children, future research should clarify whether increasing levels of leading and active behaviors of the mother is beneficial for MLP children.

To conclude, higher levels of maternal NA are associated with more psychosocial problems in toddlers, directly for MLP children and indirectly for term-born children through levels of mother-led interaction.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: The data analyzed in this study can be shared upon reasonable request. Requests to access these datasets should be directed to LK, l.j.g.krijnen@uu.nl.

Ethics statement

The studies involving human participants were reviewed and approved by Utrecht Medical Center Ethics Committee, identification code NL34143.041.10. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

LK: conceptualization, methodology, formal analysis, and writing—original draft. MV: conceptualization, writing—review and editing, and supervision. AB: conceptualization, writing—review and editing, supervision. All authors contributed to the article and approved the submitted version.

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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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Children's social networks in developmental psychology: A network approach to capture and describe early social environments

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Psychologists are interested in understanding how early social environments impact children's behavior and cognition. Early social environments are comprised of social relationships; however, there have been relatively few tools available to quantify the depth and breadth of children's social relationships. We harnessed the power of social networks to demonstrate that networks can be used to describe children's early social environments. Descriptive data from American children aged 6months–5years (n=280; 47% female, 56% White) demonstrates that network properties can be used to provide a quantitative analysis of children's early social environments and highlights how these environments vary across development. Social network methodology will provide researchers with a comprehensive picture of children's early social experiences and improve studies exploring individual differences.

KEYWORDS

social network analysis, social networks, social cognition, social relationships, cognitive development

Introduction

Developmental psychologists who are interested children's early social cognition have a keen interest in understanding how children's early social experiences shape their behavior, thoughts, and mind. Children are born into a world that is rich with social information – they are a part of varied social groups and cultures and children must learn to navigate these social organizations with different rules and customs. While children certainly learn about the world through their own action (Piaget and Inhelder, 1969), children come to learn about the social world through their social relationships; they gain social cognitive capacities by interacting with their social relationships and they learn about social conventions and rules by interacting and observing their social relationships (Vygotsky, 1978; Gaskins and Paradise, 2010).

Sociocultural theories have been the leading theories to understand how social interactions affect the developing child – these theories emphasize the cultural context in which children learn and develop and how social interaction is the engine of learning and development (Vygotsky, 1962, 1978; Tomasello, 2001, 2009). The focus of these theories is how social interactions shape children's knowledge construction and that social interactions take place in different cultural contexts. Sociocultural theories highlight how important social interactions are for development. In addition to the focus on the child as a social learner, these theories explore how children's experience can vary across culture.

Sociocultural theories do an excellent job to highlight how variation at the level of culture impacts children's learning; however, there is growing interest in the field to further explore how variations in children's regular social contact and early social experience impact social cognitive development (see Fan et al., 2015 for an example). Interestingly, this dimension of early social experience – the people a child has regular social contact with – has largely been understudied in prior developmental work. A fundamental aspect of social experience is the day-to-day interactions that children have with other people. A number of studies have investigated aspects of these social relationships, for example the effects of contact with people from different racial groups on prejudice (Rutland et al., 2005; Weisman et al., 2015), the effects of multilingual social environments on social cognition and social learning (Byers-Heinlein and Werker, 2009; Barac and Bialystok, 2012; Howard et al., 2014; Yow and Markman, 2015), and the effects of siblings on social cognition (for examples see Perner et al., 1994; Jenkins and Astington, 1996; Kennedy et al., 2015).

In a typical week, young children interact with a range of social partners. Young children engage with their family members in the home, they see neighbors on the weekends, they visit their local community center, they go to library story hour and see the librarian and other kids, and they might attend daycare or preschool and interact with teachers and fellow classmates. Young children's early social relationships provide data to them about how the social world is structured and how it functions. Observing and interacting with different social relationships likely affects the skills children come to develop in social interactions, as well as inform their early attitudes and thoughts about different social groups (Vygotsky, 1978; Gaskins and Paradise, 2010).

Although this dimension of early social experience provides rich data to children about the structure and function of their early social world, there are relatively few tools and frameworks available that can describe the breadth and depth of children's early social relationships. We argue that social networks are a powerful tool and framework that developmental psychologists can use to inform our study of early social cognition. Psychologists often have research questions that ask about an individual's attitudes, cognition, or behavior, but to understand an individual's cognition or behavior, it is necessary to consider how the individual is embedded in a broader social context. Bronfenbrenner's ecological systems theory is the leading developmental theory to explore how a child is embedded in a broader social context. He argues that children's social environment can be thought about in terms of different layers – everything from the macrosystem that describes the broader culture that children live in to the microsystem, which describes the interpersonal relationships children have with family members and peers (Bronfenbrenner, 1977). We argue that a social network perspective provides an excellent methodological tool and perspective to complement this framework; social networks can consider a broad range of social partners, as well as provide metrics that allow researchers to be clear and specific about what aspects of the early social environment they are capturing and describing.

A social network perspective can inform the study of early social cognition in two important ways. First, social networks can capture and describe important aspects of children's early social experience and provide a novel way to explore children's complex and embedded early social environments. Second, a social network framework will generate questions and hypotheses not previously asked to better understand how early social experience affects social cognition.

The complicated answer to "What is a social network?"

Before we outline the benefits to be gained by using a social network perspective, it is important to establish an operational definition of a social network. An operational definition of a social network is no small task because the term "social network" refers to several different literatures with several different meanings; social networks are a powerful, flexible tool that can be used to describe and study network structure across several different disciplines.

Simply put, a network is a set of objects or actors and the connections between them (Wasserman and Faust, 1994; Perry et al., 2018). Network science shares a theoretical focus on ties between objects; however, there is a wide breadth of questions that can be asked using a network perspective (Perry et al., 2018). A social network perspective can be used to study a variety of groups – adults, adolescents, animals – and it is used to ask several different kinds of research questions at multiple levels of analysis. A social network could detail the connections between individuals at the level of the social system; for example, social networks have been used to ask about how romantic relationships in a particular high school related to the spread of sexually transmitted diseases among students (Bearman et al., 2004). This kind of network can also be explored in animals; a study of endangered killer whales discovered that in years of high food availability, there was more interconnectedness in the social network of whales (Foster et al., 2012). These networks are called sociocentric networks or whole networks (Perry et al., 2018). A social network perspective could also be used to explore how population-level characteristics relate to individual behavior; for example, a study with cowhead birds showed that birds in dynamic social networks, where individuals were replaced over time, had more reproductive success than birds in a static social network (White et al., 2010; Gersick et al., 2012). A social network could also delineate the people emotionally close to or immediately surrounding an individual; these are called egocentric networks (Robins, 2015; Perry et al., 2018). A social network perspective can be used to ask how the personal social network of an individual affects their mental and physical health (Haines and Hurlbert, 1992; Smith and Christakis, 2008), whether the presence of a smoker in an adolescent's peer network will influence whether they become a smoker (Alexander et al., 2001), if social network size is related to brain size in adults (Bickart et al., 2011), or even if the language diversity of adults' social networks relate to their theory of mind skills (Navarro et al., 2022; Tiv et al., 2022).

These examples demonstrate that a social network perspective is powerful and flexible because it can be used to study social phenomenon at several different levels of analysis and across several different populations. Because a social network perspective can be used to study network structure across several different disciplines there has been an explosion of network research in the past several decades (Borgatti and Halgin, 2011). This explosion of research is seen within the psychological sciences as well, with substantial increases of network research in education (McPherson et al., 2001), social psychology (Clifton and Webster, 2017) and even in developmental psychology (Neal, 2020). Network theorists argue that we have seen this explosion of research because networks can be studied at multiple levels and a social network perspective can generate a lot of rich data – both qualitative and quantitative – that make it an excellent tool for studying social phenomenon.

Yet, despite this increase of network research in psychological sciences, and in developmental psychology in particular, very little work has explored the personal social networks of young children (Neal, 2020). Social networks have been used in developmental psychology for the past several decades, but they have been used either in adolescent samples or answer questions at the level of the social system (see Neal, 2020 for review). Developmentalists have used network methodology to study bullying in adolescent peer networks (Neal and Veenstra, 2021; Veenstra and Huitsing, 2021), how peer networks can influence children's reading skills (Cooc and Kim, 2017) and early academic skills (Hanish et al., 2007) in the classroom, and they have even used networks to map and describe the racial composition of classrooms (Rodkin et al., 2007). If you put in the search term "social networks" on the APA PsycArticles database from 1990 to early 2022 and search for developmental samples (birth to 12-years-old) there are only 51 articles. Most of the 51 articles are looking at sociocentric social networks or networks that are bounded by the classroom or school. Young children's egocentric social networks have largely been ignored by prior work – we know very little about the composition of these networks or how aspects of networks might influence social cognition.

This vacuum of research is striking given the longstanding interest in children's early social context among developmental psychologists. It is important to understand the composition of social networks for infants and young children because a child's social network captures most of their early social experience. Infants come to learn about the social world through their social relationships; they gain social cognitive capacities by interacting with their social relationships and they learn about social conventions and rules by interacting and observing their social relationships (Vygotsky, 1978; Gaskins and Paradise, 2010).

Although there is substantial interest in understanding how variation in early social environments impacts social cognitive development, there is no unified framework to think about how social experience might affect children's social cognitive development. Prior developmental work has been limited in scope because it has only focused on single aspects of experience and how that relates to social cognition; for example, how does the number of siblings a child have relate to their theory of mind ability? When early social experience is only conceptualized as isolated components, it is impossible to consider how various aspects of early social experience relate to each other. As stated above, there is evidence to suggest that exposure to multiple languages is associated with gains in social cognitive abilities; however, it is possible that multilingual environments covary with other aspects of experience that might be important for social cognitive development, such as interacting with more people outside the immediate family or interacting with a larger number of people on a regular basis. Another limitation of prior developmental work is that the methods used to quantify experience have been varied – everything from in-lab questionnaires, school demographics, or neighborhoods demographics to quantify "typical" experience or exposure. While none of these methods are incorrect, they conflate close personal relationships with more distal properties of the social environment, which makes it difficult to tease apart which kinds of experiences contribute to children's social cognitive development.

To better understand the nature and breadth of early social relationships, we developed a network questionnaire to extract infants' and children's early social networks, which will be referred to as *The Child Social Network Questionnaire (CSNQ)* for the rest of this paper. As described in more detail below, a child's social network will refer to the people they interact with on a regular basis. The *CSNQ* will extract the following information for each child: (1) Network Size, or the number of people a child interacts with on a regular basis, (2) The diversity of social partners present in the network, measured with Entropy and EI Index (see Methods), and (3) Network Structure, or how the social relationships are patterned and connected in the social network (measured with Components, see Methods). Social networks provide a novel, innovative tool to operationalize early social experience for infants and young children. These properties can then be used to explore how experience relates to social cognitive development.

The present study

The goals for this paper are twofold. First, we describe the *CSNQ* and the kinds of metrics that can be calculated for each

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child. We developed the *CSNQ* to collect social network data from children in infancy through early childhood. We collected data from the parents of children living in the US, predominantly in and around a large city. The *CSNQ* certainly is not exhaustive of all the network metrics that could be calculated for children; however, this paper focuses on the network metrics that map onto dimensions of early social experience that developmental psychologists typically care about.

Second, we provide a test case about how this questionnaire, and network methodology more broadly, can be used in developmental samples. In addition to providing descriptive information about children's network variables and how they relate to each other, we will also ask the following questions: How do social networks vary with age? How is diversity assessed in the social network? How does network diversity vary with age and neighborhood demographics? The analysis presented below sheds light on the ways in which children's social networks may vary across early development as well as how to contend with diversity in early social environments. We recruited 280 infants and children and provide a set of descriptive analyses, and we have made the dataset and analytic tools available on The Open Science Framework.[1]

Materials and methods

Participants

The participants were recruited in two places. The first group of participants ($n = 209$; $M_{age} = 24.9$ months; range: 6.4–59.1 months) were tested in a developmental laboratory in Chicago, IL; these were families from the city of Chicago and the surrounding suburbs who volunteered to be in a database for those interested in participating in early childhood research. The second group of participants was recruited at a paid to enter science museum in Chicago, IL ($n = 108$, $M_{age} = 48.1$ months; range: 36–59.4 months). A total of 37 subjects were excluded from the final data analysis due to experimenter error in conducting the interview ($n = 30$) or parents not being able to provide complete data during the parent interview ($n = 7$) for a final sample of 280 children ($M_{age} = 33.3$ months, range: 6.4–59.4 months). The museum is a tourist destination, so while 75% of our participants were from Chicago, IL and its surrounding suburbs, 25% were from other areas in the United States. Parents reported their children were 56.0% White or European-American, 15.2% Black or African-American, 7.1% Asian or Asian-American, 9.9% Hispanic or Latino/a-American, 19.9% mixed or biracial, and 3.2% as Other. For the laboratory-tested subjects, we recorded maternal education. 74.3% of those children had college-educated mothers.

1 https://osf.io/3hc7n/?view_only=49848537a6c543d7807020537d5da0b0

The child social network questionnaire

The *CSNQ* is administered in two parts: (1) a parent interview to collect information about children's typical week of activities and (2) a form to collect demographic information for each person the child sees on a regular basis; this form is used to calculate the network measures described below. In network terminology, the parent interview is the "name generator" – this is the method used to elicit each of the people that should be included in the social network. The people in the social network are called "nodes" or "alters" (Robins, 2015). The demographic information is the "name interpreter" and this is the method used to collect the basic demographic information or other attributes of the alters (Perry et al., 2018).

Parent interview

Parents were asked to consider their child's "typical week" of activities. The interview was explained as follows: "First, we will do an interview where I will ask you to describe [CHILD's] typical week. We want to understand the different people [CHILD] sees in a typical week and what kinds of activities he/she does with those people. I am going to ask you about times [CHILD] wakes up, goes to sleep, and takes a nap so we can get a rough measure of the amount of time they spend with different people. After the interview, I will create a form for each of the people you mentioned to collect basic demographic information and also questions about how close you think your child is to that person. Starting with Monday, what time does your child wake up and what happens after that?" After parents described their child's schedule, the experimenter asked, "Is there anyone else that you think is worth mentioning that your child sees on a regular basis?" Parents' description of their child's typical schedule served as a memory prompt and allowed the experimenter to make sure all the individuals a child regularly interacted with were accounted for (see Appendix A for details about the parent interview). This method of recall has been used to maximize the chances that respondents will fully report social contacts, and not omit the weaker ties in the social network (Small, 2017). After the parent interview, parents completed a demographic survey for each of the people in their child's social network. Parents completed the demographic form in-person ($n = 249$) or in a follow-up, online form ($n = 31$).

Demographic form

There were two different versions of the demographic form for laboratory testing and public museum testing. Laboratory testing allowed for longer questionnaires to be administered to families. To accommodate the need for briefer sessions in the museum setting, the demographic form was shortened so the entire session only took 5–10 min to complete. For both laboratory and museum testing, the form asked for the following basic demographic information for each person: gender, age, race, and languages the person speaks. For laboratory testing only, the form collected information about the intensity of the individual's relationship with the child (see Appendix B). For museum testing, we added questions about the different contexts or settings each person interacts with the child. This allowed us to infer relationships among the alters and compute the density, or how interconnected the network is, for each child (see Appendix C).

Network variables

Network size

Network Size was defined as the total number of unique individuals and groups a child saw on a weekly basis. A parent had to report that the child knew the person as an individual for that person to be their own node. For example, if the parent reported that the child was in daycare or preschool, the experimenter would ask, "Are there any kids in the class that stand out as friends?" In addition to the individual named friend nodes, there would also be a node for "daycare/preschool class," which is a node that includes multiple people. This distinction was made in order to capture the network of people that the child "knows" as individuals and about whom parents were likely to be able to report demographic data. For adults, the social network of an individual is a hierarchy that can be conceptualized as concentric circles (e.g., Hill and Dunbar, 2003); this method allowed us to capture the inner most circle for children. In the network science literature, the research question determines the boundaries of the network (Borgatti and Halgin, 2011). Social networks are most useful for developmental psychologists if they capture children's recurring social contact; therefore, the network space we were interested in is who the child knows and has regular contact with.

High and low intense relationships

For the laboratory-based subjects ($n = 161$), there were three measures to assess the intensity of each relationship: the number of activities the person does with the child, how emotionally close parents reported their child feels toward the person, and the proportion of waking hours the person spends with the child (see Appendix B). A z-score was calculated across all 1122 relationships for each of the three measures and an average z-score was computed for each relationship. A median split of the average z-score then classified each relationship as either "low" or "high" intensity (see Supplementary Figure 4 for the distribution of z-scores for all the social relationships).

Proportion of kin and adult relationships

Each relationship was also classified as being kin or not kin. Kin is any relationship in the immediate and extended family (including grandparents, aunts, uncles, cousins, etc.). The proportion of kin relationships was calculated for each child's social network: number of kin relationships/total Network Size. Each relationship was also classified as either being an "adult" or "child" relationship (child was anyone under the age of 13). The proportion of adult relationships was calculated as follows: number of adult relationships/total Network Size.

Network structure

Density

The most basic structural measure of a social network is density. Density is a measure of the degree of connectedness of alters (i.e., who interacts with whom) in the network and was calculated as follows where T is the number of ties: Density $= 2T/N(N-1)$ (Perry et al., 2018). A network where all the individuals know each other would have a density score of 1. A value <1 means that not all the alters know each other – the lower the number, the less connected the network. For the museum sample only ($n = 101$; $M_{age} = 48.1$ months; range: 36–59.4 months), we could calculate density because the *CSNQ* included a question asking about the different contexts that the individuals interacts in with the child. Example network graphs are presented below to understand what the density values represent visually (Figure 1).

Number of components

Another way to describe the structure of the network is the number of components. A component emerges in the network when all the alters are connected to each other in some way (Perry et al., 2018). Components are used in network science to assess how fragmented or spread out the network is in space. In an egocentric network, a component emerges when all the alters are connected even when the child is removed from the network. For example, imagine a child in a family who has a Mother, Father, and Sister. If you remove the child, the Mother, Father, and Sister all still interact with each other, which makes those relationships a single component. In Figure 1, the child on the left has four components and the child on the right has one component. In the adult literature, this is typically assessed by asking a person to report on all the pairwise relationships of who knows whom (Perry et al., 2018). Adding those questions to the *CSNQ* would have made the survey considerably longer and therefore more time consuming to administer in the laboratory along with child assessments. To assess the components in a child's network, we asked about the different activities the child did throughout the week. The different activities were the components – for the activities, all the people at that activity would know each other. Every child has at least one component. Children with just one component only interacted with family members. Children with more than one component had a family and some other activity such as daycare, school, library story time, gym daycare center, ninja class, neighborhood potlucks, Sunday School, Chinese class, art class, or playgroup, just to name a few.

Component ratio

Finally, a social network can be described by how fragmented the network is in space. In Figure 1, the network on the left is more fragmented and spread out than the network on the right. The measure to describe how fragmented a network is called the Component Ratio. Larger networks tend to have more components, so to account for network size the Component Ratio is calculated as follows: (Components – 1)/(Network Size – 1) (Perry et al., 2018).

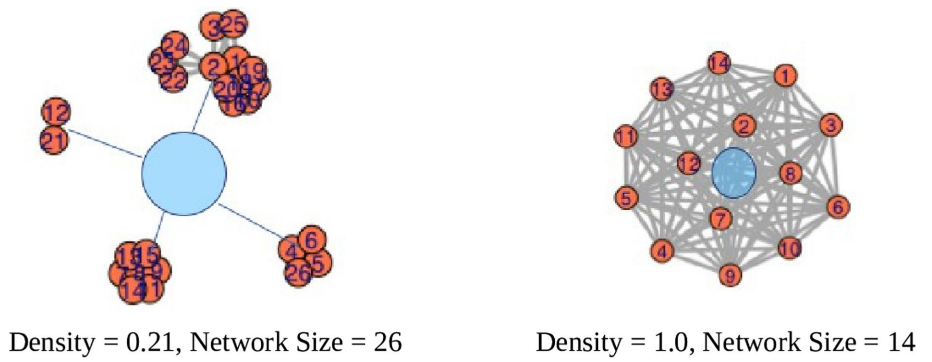

FIGURE 1
Example network graphs. The blue circles represent a child or "ego." The lower the value, the less connected the social network.

Larger values of the component ratio indicate that the network is more fragmented. In Figure 1, the network on the left (Component Ratio = (4 − 1)/(26 − 1) = 0.12) is more fragmented than the network on the right (Component Ratio = (1 − 1)/(14 − 1) = 0).

Network diversity measures

In network science, there are two conceptually distinct ways to describe network diversity. The first measure describes the representation of different social categories present in the network, which is called entropy (Perry et al., 2018). The second measures indicates how diverse the network is relative to the child, which is called the EI Index (Krackhardt and Stern, 1988). Both entropy and the EI Index were calculated using the egor package in R (Krenz et al., 2020) and they were used to describe the diversity of two relevant social groups for American children – race and language.

Entropy

For network science, entropy indicates the relative presence of different social categories among the alters in a network and is calculated as follows for a given probability vector of $P(X)$: $H(X) = -\sum P(X) * \log2(P(X))$ (Drost, 2018). The probability vector is the proportional representation of different social categories. For example, if half the alters in the network were Black and half the alters were White, then the probability vector would be $X = (0.5, 0.5)$. If half the alters in the network were White, 25% were Black, and 25% were Asian, then the probability vector would be $X = (0.5, 0.25, 0.25)$. An entropy score of 0 indicates that there is no diversity of categories; all the alters share the same attribute (e.g., all the alters are the same race). A higher entropy scores indicates a greater representation of different categories and the more categories present (i.e., the more racial groups present in the network) the higher the entropy score. For the example networks given above, the network where half the alters were White and half were Black, would get an entropy score of 1. For the network with White, Black, and Asian alters, the entropy would be 1.5. The more groups or categories represented, the higher the entropy.

Network racial entropy

To calculate racial entropy, each alter was classified by a discrete racial category. The racial categories that were used to calculate entropy were the following: African or Black-American, Asian or Asian-American, European or White-American, Hispanic or Latino-American, Native American, Mixed/Biracial, or Other. For the Mixed/Biracial category, parents could indicate that the alter was biracial by selecting "Mixed/Biracial" or by selecting more than one race. For some alters, we have detailed information (for example, if the alter was a Black/White biracial or Asian/White biracial), but for some alters we only know that they are biracial. As such, all biracial alters were categorized as "Mixed/Biracial." This is imperfect as biracial individuals are not a monolith; however, this method of categorization allowed us to retain all the racial information about the alters. See Supplementary Figure 5 for visual representations of different racial entropy scores.

Network language entropy

Similar to the racial entropy, each alter was categorized to fit into a discrete language category to calculate language entropy. This is a primarily English-speaking sample; all the children were recruited to participate in studies in English and required that English be spoken at home at least 50% of the time. The most dominant language category was monolingual English speakers (66.3% of all alters), followed by English bilingual speakers (22.5% of all alters), preverbal infants (1.7% of all alters), and non-English monolingual speakers (1.0% of all alters). Language data was missing for 8.5% of the alters and they were excluded from analysis.

EI index

The EI Index is a measure of homophily the child shares with the network and is calculated as follows: (Number of Different Alters − Number of Same Alters)/Network Size (Krackhardt and Stern, 1988). The EI Index ranges from −1 to 1; a score of −1 indicates the entire network is the same as the child on some attribute and a score of 1 indicates that the entire network is

TABLE 1 Table of the social network variables.

	Mean (SD)	Range
Network size	11.0 (5.0)	3–27
Raw number of low intense relationships	3.9 (3.2)	0–15
Raw number of high intense relationships	3.8 (2.0)	1–12
Proportion of high intense relationships	0.54 (0.23)	0.13–1.0
Proportion of kin relationships	0.52 (0.24)	0.05–1.0
Proportion of adult relationships	0.65 (0.18)	0.05–1.0
Network structure		
Density	0.56 (0.21)	0.21–1.0
Number of components	2.5 (1.2)	1–7
Component ratio	0.15 (0.12)	0–0.67
Diversity measures		
Racial entropy	0.91 (0.62)	0–2.4
Racial EI index	−0.51 (0.45)	−1–0.8
Language entropy	0.69 (0.44)	0–1.8
Language EI index	−0.76 (0.29)	−1–0.2

different from the child on some attribute. For example, if a White child had a network where all the alters were White, they would have a score of −1; see Supplementary Figure 6 for visual representations of the EI Index.

Racial EI index

To calculate the racial EI Index, each alter was classified as either same-race or different-race compared to the child. For monoracial children, this was simple – any alter that was not the same race as the child was coded as different-race (i.e., for a White child, any alter that was not also White was coded as different-race). For biracial children (19% of our sample; $n=51$), the alter was classified as same-race if they were of either races of the child. For example, for a Black/White biracial child, any alter that was White or Black would be coded as same-race. All other alters would be coded as different-race. For biracial children, parents either provided detailed information for their child or we deduced the races of the child by examining the races the parents reported for themselves.

Linguistic EI index

For the Linguistic EI Index, each alter was coded as same-speaker or different-speaker. For monolingual English children, this meant anyone who spoke a language other than English was coded as different-speaker. For bilingual and multi-lingual children, an alter was coded as different-speaker if that person spoke a language the child did not speak. For example, imagine an English/Spanish bilingual child with a network where 2 people spoke English, 1 spoke English and Spanish, and one spoke English and Dutch. The only alter that is a different-speaker is the English/Dutch bilingual because the child does not speak Dutch and would therefore have a Linguistic EI Index of −0.5 ([1−3]/4).

Neighborhood demographics

In addition to completing the *CSNQ*, parents also provided their zip code. Using data from the US Census (US Census Bureau, 2018), we extracted Neighborhood Racial Entropy and Neighborhood Linguistic Entropy for each child (Hwang, 2018). 65% of the sample lived in an urban setting with a median income of $68,770 (range: $28,965–$196,964).

Results

The results presented below will accomplish the following aims. First, we present the descriptive information about the network variables and how they related to each other, which will highlight the ways in which children's social worlds vary by the size of the network. Next, we will answer the following questions: How do social networks vary with age? How is diversity assessed in the social network? How does network diversity vary with age and neighborhood demographics? Social network data tends to be skewed and colinear, given the nature of social phenomenon (Perry et al., 2018); therefore, we used non-parametric analyses for network variables that were not normally distributed.

Social network variables

Table 1 shows the mean, standard deviation, and range for the following network variables of interest: Network Size, Raw Number of Low and High Intense Relationships, Proportion of High Intense Relationships, Proportion of Kin Relationships, Proportion of Adult Relationships, Density, Number of Components, Component Ratio, Racial Entropy, Racial EI Index,

TABLE 2 Table of correlations between network size, age, and other network variables.

	Network size	Child age
	Spearman rho	Spearman rho
Network size	–	**0.61*****
Child age	**0.61*****	–
Prop high intense relationships	**−0.41*****	−0.03
Proportion of kin relationships	**−0.56*****	**−0.41*****
Proportion of adult relationships	**−0.38*****	**−0.42*****
Density	**−0.52*****	−0.19
Number of components	**0.63*****	**0.63*****
Component ratio	−0.01	0.04
Racial entropy	**0.35*****	**0.25****
Racial EI index	**0.24*****	**0.16***
Language entropy	−0.01	−0.07
Language EI index	**0.24*****	0.09

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

Language Entropy, Language EI Index. For visual examples of the network structure values, refer to Figure 1.

How do the network variables correlate with network size?

The most fundamental part of a social network is social network size (Perry et al., 2018). As network size increases, other aspects of the network tend to covary as well. Network structure measures are inherently linked to network size – as network size increases the number of components typically increases while the density of the network decreases (Perry et al., 2018). Table 2 presents FDR-corrected correlations between Network Size and the other network properties. Consistent with the adult social network literature, network size covaried with network structure – as the network size increased, the number of components increased ($rho = 0.63$, $p < 0.001$) and the density of the network decreased ($rho = -0.52$, $p < 0.001$). As network size grew, children had more contexts that they interacted in and the connectedness of the network decreased. The content of the network also covaried with size. As network size increased, the proportion of high intense relationships ($rho = -0.41$, $p < 0.001$), the proportion of kin relationships ($rho = -0.56$, $p < 0.001$), and the proportion of adult relationships ($rho = -0.38$, $p < 0.001$) all decreased. As network size grew, children interacted with more low intense relationships, more children, and more people outside of their family. Finally, the diversity measures also covaried with network size. As network size increased, the racial entropy ($rho = 0.35$, $p < 0.001$), racial EI Index (0.24, $p < 0.001$), and linguistic EI Index (0.24, $p < 0.001$) increased as well. As network size increased, so did the various measures of diversity.

This correlational analysis demonstrates that social environments and social phenomenon are complex and embedded. While several of these dimensions of early social experience are conceptually distinct, this analysis shows they can also be empirically related. When using social network analysis and theory as a framework to understand how social experience relates to development, it is necessary to understand which aspects of experience covary to be precise about which aspects of experience relate to social cognitive outcomes. If developmentalists only focus on one dimension of experience without measuring other aspects of experience, it is impossible to know what precisely contributes to development.

How do social networks vary with age?

Descriptive social network data collected over a wide developmental age range can answer the question: How do early social environments vary with age? The analysis presented below demonstrates how network properties, which describe early social environments, vary across developmental time. The analysis presented below used FDR correction for multiple comparisons and we present the correlations in Table 2 (for scatterplots with all the network variables and child age, see Supplementary material).

Network size and age

Network Size was correlated with children's age to explore how the number of people a child interacted with on a regular basis varied across the first few years of life. Network Size was square root +0.5 transformed because Network Size is a small count variable (Kirk, 2013). The results showed a significant, positive correlation between Network Size and age; as children got older their Network Size increased ($rho = 0.61$, $p < 0.001$; Figure 2). At a time when children are experiencing rapid changes to their social cognitive development, they are also experiencing drastic changes to their early social environments. The number of close, reoccurring social relationships children had increased over the first few years of life.

This growth in network size cannot be entirely be explained by children entering school. A linear regression was conducted to

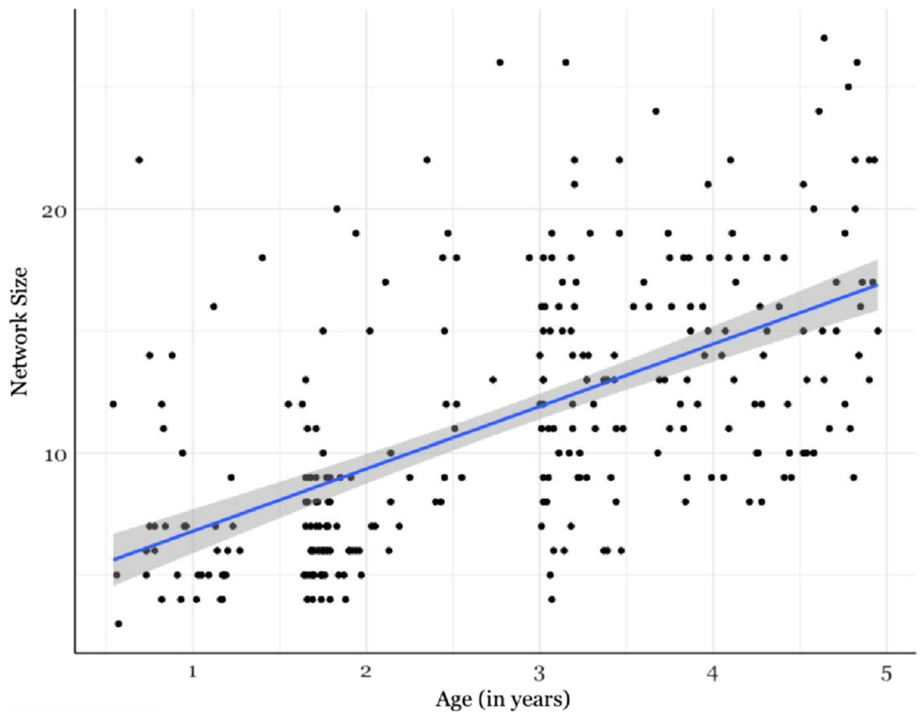

FIGURE 2
There was a significant, positive correlation between Network Size and child age; as children got older their Network Size increased (*rho*=0.61, *p*<0.001). Shaded area indicates the 95% confidence interval.

test the effects of child age, out-of-home childcare, and their interaction on Network Size; the regression was significant ($R^2 = 0.39$, $F(3, 275) = 61.3$, $p < 0.001$). There was a main effect of age ($\beta = 0.02$, $p < 0.001$), no main effect of childcare experience ($\beta = 0.10$, $p = 0.62$), and no significant interaction ($\beta = 0.006$, $p = 0.28$; see Supplementary material). Although it is true that children in out-of-home childcare had larger social networks than children without out-of-home childcare ($M_{OutofHomeChildcare} = 13$ people (5), $M_{NoOutofHomeChildcare} = 9$ people (5); $W = 5{,}031$, $p < 0.001$), when controlling for the effect of out-of-home childcare on Network Size, child age was a significant predictor. Post-hoc, Bonferroni corrected correlations were performed to explore if the age trend is present for both children with and without out-of-home childcare and there was a significant, positive correlation with age for both groups of children (Out-of-home childcare: $r = 0.61$, $p < 0.001$; No Out-of-home childcare: $r = 0.41$, $p < 0.001$). Regardless of childcare experience, as children got older their networks grew.

In addition to the tremendous growth in size during the first few years of development, there was also substantial variation at any given time point. This variability was present in infancy and continued throughout early childhood. Taken together, this raises two interesting possibilities. First, at a time when children see a rapid expansion in the number of social relationships they interact with on a regular basis, they are also experiencing rapid changes to their social cognition. Their social cognitive skills start to emerge and mature during the first few years of life, which raises questions about how the growth in network size relates to the emergence and development of these skills. Second, while there is steady growth in network size, there is also substantial variability at any given age during this developmental window. This variability opens up questions about how variation in network size relates to variation in social cognitive skill development – these are questions that can be asked in infancy and throughout early childhood. As networks grow, this creates the possibility for changes in other aspects of network structure. The next analysis evaluated age-related variation in network composition and structure.

Network composition and age

The next set of analyses explored how network composition varied with child age. Network composition refers to the make-up of the social network – the high and low intensity relationships, the kin relationships, and the age of relationships. Before exploring how network composition varied with child age, we explored the nature of kin relationships and whether these were also the high intensity relationships. Across all participants, there were a total of 1,122 social relationships that could be classified as either kin or not kin ($n_{kin} = 683$, $n_{notkin} = 439$) and high or low intensity ($n_{highintensity} = 561$, $n_{lowintensity} = 561$). On average, approximately half of children's relationships were high intense and half the relationships were kin (Table 1); however, not all kin relationships were necessarily high intense. 31% of the kin relationships were low intensity relationships ($n = 212$) and 20% of the not kin relationships were high intensity relationships ($n = 90$).

Children had some non-kin relationships that were high intense relationships, such as daycare teachers, and they had kin relationships that were low intense, such as extended family members. We also looked to see if the Proportion of Kin relationships was correlated with the Proportion of High Intense relationships. Networks with a larger proportion of kin relationships were also networks that had a larger proportion of high intense relationships ($rho = 0.42$, $p < 0.001$).

We next explored how the proportion of high and low intensity relationships, kin relationships, and adult relationships varied with child age. The FDR-corrected correlations are reported below and displayed in Table 2. The high intensity relationships ($rho = -0.03$, $p = 0.72$) and the proportion of low intensity relationships ($rho = 0.03$, $p = 0.72$) were not correlated with age. Both proportion of kin relationships ($rho = -0.41$, $p < 0.001$) and proportion of adult relationships ($rho = -0.42$, $p < 0.001$) were negatively correlated with age.

While there was a relation between child age and proportion of kin relationships and adult relationships, there was no evidence that the proportion of high intense relationships was related to child age. This is surprising because the proportion of kin relationships was positively correlated with the proportion of high intense relationships. Taken together, this suggests that kin relationships were not the only source of high intense relationships in early childhood. As children got older, they started to interact with more people outside their family, but these people could still be high intense relationships, such as a teacher or a close friend. It was also true that as children got older, they started to interact with more children and similarly-aged peers. These analyses suggest that as children get older, the composition of their social world undergoes significant changes, which opens up questions about how changes in the nature of social interaction impact cognitive development.

Network structure and age

We next explored how network structure varied with child age. This analysis focused on density, components, and component ratio. Density is the most basic structural aspect of a network and describes the extent that people in the network are connected to each other. Components describe the different contexts that children interact in and Component Ratio describes how fragmented in space the network is.

Density and age

There was no significant correlation between density and child age; there was no evidence to suggest that as children got older their networks become less connected ($rho = -0.19$, $p = 0.12$; Table 2). Importantly, density could only be calculated for data collected at the museum ($n = 101$), which reflected a smaller age range than the rest of our sample. It is possible the null result is due to the constricted age range.

Components, component ratio, and age

To explore how network structure related to age, we next looked to see how the number of components and the Component Ratio correlated with age. The number of components was positively correlated with age – as children got older, the number of components in their network increased ($rho = 0.63$, $p < 0.001$; Table 2). Interestingly, the Component Ratio was not correlated with age; there was no evidence that the fragmentation of children's networks varied with age ($rho = 0.04$, $p = 0.59$; Table 2). It is possible the Component Ratio stayed relatively flat throughout the first few years of development because while it was true that the number of components increased over developmental time, so did network size. The Component Ratio was calculated with Network Size in the denominator (Number of Components − 1/ Network Size − 1), which explains why the relative fragmentation stayed consistent throughout the first few years of life when both the components and network size were rapidly growing. See Supplementary Figures 13, 14 for the scatterplots for Network Structure and child age.

Summary of age findings

Our results showed compelling evidence that as children got older, their network size, or the number of people they interacted on a weekly basis, increased. At a time when children's social cognitive skills are rapidly emerging and developing, they are also experiencing drastic changes to their social world. In addition to an increase in the number of people children saw on a weekly basis, there was a decrease in the proportion of kin and proportion of adult relationships. As children got older, they interacted with more people outside of their immediate family and started to interact with more children and peers. Not only did the number of people who children interacted with changed as they got older, the kinds of people they interacted with changed as well. This raises interesting questions about the role that non-kin and other similar-aged peers play in children's development. Prior developmental work has emphasized the role of parent–child interactions for early development; however, the results presented here showed that children have relationships with a broader network. It is fruitful to consider the value of these other relationships for children's cognitive development.

Diversity in social networks

The final set of analyses explored the ways that diversity can be measured in social networks in early childhood, how network diversity varies across the first few years of life, and how network diversity relates to broader neighborhood demographics. Although network measures can be used to describe the diversity of any attribute that can be measured about a person, this paper focused on two social categories relevant to American children – race and language. Both racial and linguistic diversity were assessed using entropy, which describes the representation of different social groups, and EI Index, which describes how diverse the network is relative to the child.

Before exploring how network diversity varied by age or by neighborhood demographics, the entropy and EI Index measures were correlated with each other using Spearman

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correlations. Both measures of racial diversity were correlated with each other ($rho = 0.72$, $p < 0.001$) as were both measures of linguistic diversity ($rho = 0.50$, $p < 0.001$). Although these are conceptually distinct ways to operationalize diversity in a social network, in early childhood, these measures are highly correlated with each other.

Network diversity and age

There was a significant positive correlation with age for Network Racial Entropy ($rho = 0.25$, $p < 0.001$) and for Network Racial EI Index ($rho = 0.16$, $p = 0.01$; Table 2). As children got older, the representation of different racial groups in their network increased, as did the amount of racial outgroup members. There was no significant correlation between Network Language Entropy and child age ($rho = -0.07$, $p = 0.29$) nor between Network Linguistic EI Index and child age ($rho = 0.09$, $p = 0.28$; Table 2). Unlike Network Racial Diversity, there was no evidence that Network Language Diversity changed as children got older.

In addition to increased network size with child age, there was also evidence that network racial diversity increased with age. The representation of different racial groups in their network and how diverse the network was relative to the child's own race, increased with child age. Interestingly, there was no evidence that network language diversity was related to age; neither language entropy nor the linguistic EI index were correlated with child age. These set of findings have implications for how developmental psychologists should consider the effects of diversity on children's emerging social cognitive abilities. Data from US children suggest that as children get older, they are exposed to more racial groups, but they are not necessarily exposed to more different-language speakers.

How does network diversity interact with structural network properties?

The benefit of social network analysis is that it can be used to describe how network variables are related to each other. For instance, the network racial diversity can be described by using the two measures outlined above – racial entropy and racial EI Index. These measures perfectly describe the racial diversity of children's reoccurring social contacts. Social network analysis can take this one step further to ask: How are different racial group members patterned in the social network? Is children's contact with racial outgroup members interconnected or more dispersed in the social network?

Using the data collected at the museum ($n = 101$; $M_{age} = 48.1$ months; range: 36–59.4 months), we calculated not only the racial entropy of the network, but also the racial entropy of each of the components. Children ranged in the number of components they had – from 1 to 7 – and for each child, we could calculate the proportion of their components that had 0 entropy. A component that had 0 entropy meant that all the people in that component were the same race. A child with a proportion of 1 would mean all the components in their network had a racial entropy score of 0, which would indicate no network diversity. Although it would be theoretically possible for someone to have two 0 entropy components of different races and an overall network racial entropy >0 (i.e., a child has one component with all White members and one component with all Black members and therefore both components have 0 entropy), that did not occur in this dataset. Children that had a proportion of 1 were children in no diversity networks. A child with a proportion of 0 would mean that all the components had a racial entropy >0 – all the components had people of different races. The average proportion of 0 entropy components per child was 0.31 (SD = 0.30, range: 0–1).

Once the racial entropy of each component was calculated, it was then possible to identify different patterns of diversity that emerged. Table 3 highlights examples where subjects had identical overall Network Racial Entropy, but the racial diversity was patterned differently in the network. For example, Subject1 and Subject2 had the same overall Network Racial Entropy; however, Subject1 had a network where the racial diversity was not evenly distributed. Their family did not provide any racial diversity, but they had fairly high racial diversity at school. On the other hand, Subject2 had high levels of racial diversity across all their components; their social network was more racially integrated. Table 3 highlights that the Network Racial Entropy glosses over complexity present in children's social relationships. Not only can the network be described by the composition of different social groups, but networks can also be used to explore how the pattern of those relationships might matter and impact social cognitive development. How racial outgroup exposure is patterned in their network is data to children about how the social world operates and likely informs their early intergroup cognition.

TABLE 3 Example social network information.

	Network size	Network racial entropy	# of components	Family component	School component	Other component 1	Other component 2
Subject ID							
Sub1	9	1.22	2	0.00	1.5	–	–
Sub2	18	1.22	4	1.25	1.22	1.52	1.56
Sub3	14	1.52	4	1.49	0.81	1.49	0.81
Sub4	10	1.52	2	0.00	1.41	–	–
Sub5	9	0.50	3	0.00	0.92	0.00	–
Sub6	9	0.50	2	0.00	0.65	–	–
Sub7	9	0.50	2	0.00	0.72	–	–

Children's networks could further be characterized by how the racial diversity was distributed in the network – did children experience racial diversity in an integrated network, where there was non-zero entropy in each component, or did children experience racial diversity in a segregated way, where some components had no racial diversity and other components did? Each child's network could be described as either integrated, segregated, or no-diversity networks. Integrated networks meant that the overall network racial entropy was greater than zero and each component in the network also had network racial entropy greater than zero. A segregated network was when the overall network racial entropy was greater than zero and the proportion of zero entropy components in the network was greater than or equal to 0.5, but <1 (see Supplementary material for visual examples). A no-diversity network meant that the overall network racial entropy was 0 – all the people in the child's network were the same race and therefore each component also had 0 racial entropy. For this sample, 40% of the children had an integrated network, 54% had a segregated network, and 6% had no-diversity networks. This sample of children demonstrated that racial diversity can be patterned in several different ways. This raises the interesting question about whether *how* racial outgroup members are patterned in the social network matters for children's emerging intergroup cognition.

How do network and neighborhood diversity relate to each other?

The final set of analyses explored how network and neighborhood diversity measures, specifically racial and linguistic diversity, related to each other. Prior developmental work has used neighborhood demographics to approximate experience (Weisman et al., 2015; Mandalaywala et al., 2019), but only one study has used neighborhood demographics to test how distal social experience affects cognition (Howard et al., 2014). It remains an open question whether neighborhood demographics have a differential impact on children's cognition than the demographics of children's reoccurring social contact. It is not well understood whether the neighborhood demographics provide different information to children than the demographics of their recurring social contact. Using children's social network data and the US Census data, we can explore this possibility. Participants provided their zip code and their neighborhood racial and language entropy was calculated using the American Community Census Survey from 2018.

Network and neighborhood racial diversity

The FDR-corrected correlation between Network Racial Diversity and Neighborhood Racial Diversity was positive and significant (*rho* = 0.17, $p < 0.005$). We further explored whether this varied by the geographic location – either urban or suburban and rural areas. Using the zip code, each participant was classified as either living in an urban area or suburban or rural area according to the CDC's classification of counties (Ingram and Franco, 2014). Participants who lived in Cook county, but not in Chicago, IL, were classified as living in a suburban area. In our sample, 183 subjects lived in an urban area and 90 subjects lived in a suburban or rural area. Figure 3 shows Network and Neighborhood Racial Entropy by urban and suburban or rural areas. Spearman correlations revealed that for urban subjects only, there was a positive correlation between Network and Neighborhood Racial Diversity (*rho* = 0.24, $p = 0.002$), but there was no significant correlation for suburban or rural subjects (*rho* = 0.02, $p = 0.89$).

Network and neighborhood language diversity

Similar to the Racial Diversity findings, Network and Neighborhood Language Entropy were positively correlated with each other (*rho* = 0.22, $p = 0.004$). The geographic analysis showed the same pattern of results as the Racial Diversity findings. There was no evidence that Network and Neighborhood Language Entropy were related in suburban and rural areas (*rho* = 0.07, $p = 0.71$), but there was a positive correlation for urban areas (*rho* = 0.25, $p = 0.004$; Figure 3).

Summary of neighborhood findings

For both Racial and Language Diversity, network and neighborhood entropy were correlated with each other; however, this finding seemed to be driven by the subjects living in urban areas. For subjects living in suburban and rural areas, there was no evidence that their network and neighborhood Racial and Language Diversity were correlated. It is possible there was no evidence that network and neighborhood demographics map onto each other for suburban and rural areas because these areas are not as densely populated. Even if a suburban area has higher levels of Neighborhood Racial Entropy, that diversity could be spread out across greater areas of land than in urban areas. Most of the urban sample is from [Chicago, IL], which is a densely populated city and it is therefore reasonable that children's reoccurring relationships would match the demographics of their community. Future work can explore why network and neighborhood demographics do or do not map onto each other; it is possible this effect could be explained by parents' values about community involvement or the extent that their own social networks reflect the demographics of the communities that they live in.

Although these findings leave several open questions, this initial analysis suggests that networks and neighborhoods can supply different demographic information to young children, which raises important methodological and theoretical implications. First, this analysis shows that networks can be used to improve methodological practices in the field by better operationalizing children's early social environments. Given that networks can be used to better describe early social environments and make a distinction between children's close, reoccurring contact and their more distal social environment, we can then use this framing to generate questions about whether and how networks and neighborhoods have differential impacts on cognition.

Discussion

This paper has demonstrated that a social network perspective can be used in developmental science to measure children's early social environments. A social network perspective is not only helpful

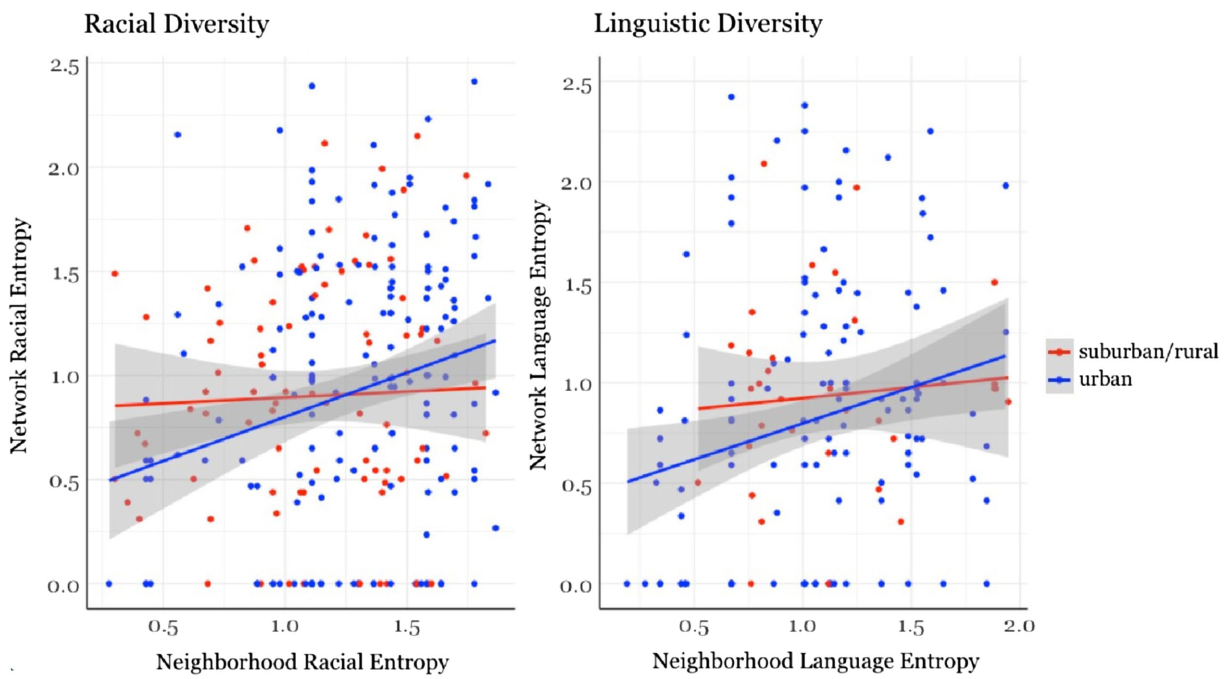

FIGURE 3
For urban subjects only, there was a positive correlation between Network and Neighborhood Racial Diversity (*rho*=0.24, *p*=0.002) and Network and Neighborhood Linguistic Diversity (*rho*=0.25, *p*=0.004). Shaded area indicates the 95% confidence interval.

to describe early social environments, but once early social experience is conceptualized as network properties, a social network perspective can be used as a framework to generate hypotheses about how early social experience impacts cognition and development. For example, researchers can ask whether the number of individuals a child interacts with on a weekly basis impact their social cognitive skills. The data presented in this paper provide an initial look at how a social network perspective can be used in developmental science and raises several interesting implications for studying and understanding children's early social environments.

Children's social network data illustrate the varied aspects of social network structure that can be identified in infancy and early childhood. As the results showed, while several of these network variables and aspects of early social environments are conceptually distinct, they might also be empirically correlated with each other. To best understand how early social environments relate to children's development, it is important to understand the aspects of early social environments that are related to each other. We presented analyses about how aspects of experience were correlated for this particular highly educated, urban sample in the US; however, it is possible, and in fact likely, that different patterns and trends would emerge for different samples of children, both cross-culturally and within the US. A social network perspective is useful for developmental science because different dimensions of networks can be used to describe social environments, but it is also useful because it provides a framework to understand the embedded and complex nature of early social environments.

Our results also highlight the ways in which children's social networks vary across infancy and early childhood. Most notably, our cross-sectional analysis showed that as child age increased, so did network size. This was true across early development, during infancy, and continuing into the preschool years. Children's networks also varied in other ways across the first few years of development. As child age increased, children interacted with more peers and less family, as well as interacted with more racial outgroup members. At a time when core aspects of social cognition are developing, children's social networks undergo significant change. This raises the obvious question of whether and how social cognitive development may be affected by changing social environments, and raises the possibility that developments that were assumed to reflect maturation may instead, or in addition, be driven by experience.

Finally, our results demonstrate the ways in which networks can be used to assess and explore diversity in early childhood. Our results showed that while diversity can be evaluated in conceptually distinct ways, they are often related to each other in early childhood. This measure of precision in capturing and describing diversity will allow developmentalists to refine theories about how outgroup exposure affects social cognitive development. In addition to using social networks to precisely describe diversity, our results show the ways that diversity varies across age and geographic location. For racial diversity only, as child age increased, so did both measures of racial diversity. As children get older, they interact with more racial outgroup members. For subjects in urban settings only, both network and neighborhood measures of diversity were related to each other. This analysis demonstrated two important points. First, given that network and neighborhood diversity measures are not necessarily correlated with each other, it is problematic to use neighborhood demographics to approximate typical experience and pushes against assumptions that characteristics of a neighborhood would be reflected in children's immediate social environments.

Second, this analysis highlighted that networks and neighborhoods can provide different information to children; this raises the possibility that proximal and distal social environments have differential effects on cognition. Future work can probe this possibility to refine theories about how experience shapes cognition.

It is important to reiterate that our sample is highly educated (over 70% of mother's have a bachelor's degree or higher), approximately half White, mostly reside in or around a large, urban city, and data was collected before the COVID-19 pandemic; it is necessary to test widely to explore whether these findings generalize across different samples. As stated above it is possible, and likely, that these patterns vary across different samples, even within the US. In particular with socioeconomic (SES) diversity, there are theories in the network literature that suggest adults from high- versus low-SES backgrounds have different functions for the high and low intensity relationships in their networks (Granovetter, 1983; McPherson et al., 2006). Indeed, there is a general trend in the US that adults with higher levels of education have less kin relationships in their social networks (McPherson et al., 2006). Future work will need to explore whether these trajectories of early social experience are the same for children from low-SES backgrounds.

Prior developmental work that has implemented network methodology has used methods of validation to quantify the networks. For example, in a study asking children about who their friends were in a classroom, researchers also surveyed the teacher to see if the reported friendships by the children were accurate (Neal et al., 2016). Our method relied on parent report, which is a commonly used method for the reported age range because infants and young children cannot reliably provide the information themselves. Parent report was chosen to elicit young children's networks because parents are the most reliable informants about who their child sees on a regular basis. Especially in infancy, someone is always watching the infant and American parents always know who that person is. It is important to note that parent report is not without limitation, especially as children get older and gain more autonomy in who they spend time with. For example, there is a reason parent report is not used to extract adolescent social network data. While children could have been observed more naturalistically, this method of recall is commonly used in the adult social network literature, so it made sense to adapt that protocol for this particular developmental sample. Further, by asking a more objective question about who the child has contact with rather than something more subjective like "name your children's friends," we can eliminate some of the bias that contributes to mismatches between who people report their friends are and who their actual friends are.

A network perspective in developmental science

Social network research can be broken down to research questions that study network variables as predictors, outcomes, or both – this produces three distinct theoretical approaches to the study of social networks (Borgatti and Halgin, 2011; Perry et al., 2018). Network variables as predictors has been the focus of this paper; however, other theoretical network approaches can be used to generate cutting-edge questions for the field of developmental science.

Studies that explore network variables as outcomes ask questions about how a non-network variable leads to the formation of the social network. For example, do parents' values about diversity relate to the racial make-up of children's network? Do parents' values about diversity have an indirect effect on children's racial bias as a result of the child's social network? How do parents' beliefs about family relate to the formation of children's networks? Rather than focusing on how network properties might relate to social cognitive development, questions under this theoretical approach can be used to ask how non-network aspects of early social experience (such as attending school) might relate to the formation of certain social networks.

Studies that explore network variables as both outcomes and predictors ask questions about how a particular network phenomenon relates to another network phenomenon. Research questions that employ longitudinal social network design would fall under this theoretical approach. Although there is obvious value in using social networks in a cross-sectional design, social networks are an exceptional tool to ask how *changes* in network properties relate to *changes* in cognition or behavior. For example, the cross-sectional analysis showed that child age was correlated with network size. Is it the case that as children get older, their network size increases? Does an increase in network size relate to changes in social cognitive abilities? The cross-sectional data suggests that children do experience growth in their networks during the first few years of life, which would allow developmentalists to test whether changes in network size relate to changes in social cognitive capacities. Prior work with adults and non-human primates suggests that this might be true – those with larger social networks have superior social cognitive skills (Stiller and Dunbar, 2007) as well as changes and increases to brain size and function (Bickart et al., 2011; Sallet et al., 2011). These questions can be explored further using the *CSNQ* in a longitudinal design.

Recommendations for developmentalists who want to use social network analysis

Developmentalists have nuanced theories about the kind of experiences that might be important for shaping children's early social cognition. However, until now, there have not been the proper tools to capture the whole picture of infants' and young children's early social interactions. Social networks are a powerful tool that can begin to address prior debates in the field as well as inform cutting age theories about social cognitive development.

To most effectively use network analysis and methods, it is necessary to be intentional about applying social network analysis to developmental questions. Social network analysis is a powerful tool and it is not a method that can be applied thoughtlessly. Social network theory will generate several hypotheses about how early social environments affect social cognition; however, it is crucial to specify which kinds of experience might matter for development. Social network theory can be used as the framework to consider how certain aspects of experience might be correlated with each other; this framework and school of thought can then lead to thoughtful experimental design to tease apart which kinds of experience might matter for development. Relatedly, it is important to not overinterpret data and to be clear about what claims can and cannot be made from social network research. Early social environments are complex and embedded, and social network research is largely correlational; it is necessary to be clear and honest about what conclusions can be drawn from the data.

The *CSNQ* used social network methods to capture and describe the people children interact with on a regular basis, but children do not have one social network. Several different kinds of networks can be extracted for an individual; the network space is determined by the research question (Borgatti and Halgin, 2011). For each of the dimensions of social networks, a researcher can make different decisions about what kind of network will be examined. For example, instead of asking about who the child interacts with during a typical week, a researcher could ask about every individual the child saw in the last month, which would cast a wider network space of people to be included. The questions that are asked about each of the alters can also vary. The *CSNQ* focused on racial and linguistic network diversity, but a researcher could ask an endless amount of questions about each of the alters: religious affiliation, political identity, education level, food preferences, or even shared beliefs. Finally, the kind of relationships that are examined could vary. The *CSNQ* focused on who the child "knew" and saw regularly, but the relationships that are examined could be affective ones (who the child "likes" or "dislikes") or even event-based interactions, such as how many times a child plays with another child (Borgatti and Halgin, 2011). We made decisions across these three dimensions to make the *CSNQ* most useful to developmentalists; however, network methods can be adjusted to extract different kinds of networks based on the desired research question.

In summary, the *CSNQ* is an excellent tool to capture and describe children's early social relationships. When early social environments are conceptualized in a unified framework, social network theory can be used to generate questions and hypotheses about how experience impacts social cognitive development. A network perspective will expand and explore these kinds of questions, which will allow researchers to produce hypotheses about the mechanisms underlying early social experience. The data presented here offers initial insight into the potential usefulness of this framework for developmental research, providing both a tool and a conceptual framework to better explore the nature of early social environments and their potential relations to social cognitive development.

Data availability statement

The original contributions presented in the study are publicly available. This data can be found at: https://osf.io/3hc7n/?view_only=49848537a6c543d7807020537d5da0b0.

Ethics statement

The studies involving human participants were reviewed and approved by University of Chicago IRB. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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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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Supplementary material

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Face-to-face contact during infancy: How the development of gaze to faces feeds into infants' vocabulary outcomes

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Infants acquire their first words through interactions with social partners. In the first year of life, infants receive a high frequency of visual and auditory input from faces, making faces a potential strong social cue in facilitating word-to-world mappings. In this position paper, we review how and when infant gaze to faces is likely to support their subsequent vocabulary outcomes. We assess the relevance of infant gaze to faces selectively, in three domains: infant gaze to different features within a face (that is, eyes and mouth); then to faces (compared to objects); and finally to more socially relevant types of faces. We argue that infant gaze to faces could scaffold vocabulary construction, but its relevance may be impacted by the developmental level of the infant and the type of task with which they are presented. Gaze to faces proves relevant to vocabulary, as gazes to eyes could inform about the communicative nature of the situation or about the labeled object, while gazes to the mouth could improve word processing, all of which are key cues to highlighting word-to-world pairings. We also discover gaps in the literature regarding how infants' gazes to faces (versus objects) or to different types of faces relate to vocabulary outcomes. An important direction for future research will be to fill these gaps to better understand the social factors that influence infant vocabulary outcomes.

KEYWORDS

faces, social development, infancy, gaze, vocabulary

Introduction

Early word learning appears a difficult task, given that an infant's environment is full of objects and sounds (Quine, 1960; Smith and Yu, 2008). Infants acquire words from the people they interact with, who repeatedly expose them to certain word-to-world combinations. The first signs of infants' word comprehension are observable as early as 6 months (Bergelson and Swingley, 2012; Tincoff and Jusczyk, 2012). This precedes the earliest observations of more complex social abilities that are first observed 9 months of age onward, such as joint attention, and which are considered instrumental for word learning (Carpenter et al., 1998; Cleveland et al., 2007). Previous literature has frequently shown that where infants attend in such social settings can have cascading effects on how their word learning progresses (Moore et al., 1999; Charman et al., 2000; Mundy et al., 2003; Slaughter and McConnell, 2003; Houston-Price et al., 2006). One such powerful cue could be how infants attend to other faces present in the interaction (from now on “gaze to faces”; Hessels, 2019), as infants start attending to faces and to features within faces very early on in life (Grossmann, 2017). The purpose of this position paper is to review studies demonstrating a link between infant gaze to faces and vocabulary outcomes. We will assess the literature on gaze to faces, because it is considered one of the pre-requisites of later developing more complex social abilities [such as following the gaze of a social partner (Reid and Striano, 2005; Gredebäck et al., 2010; Grossmann, 2017)] that are found to correlate with word learning and vocabulary outcomes. Our aims in this position paper are to find new directions for future research to improve our understanding on whether, when, and how gaze to faces feeds into vocabulary acquisition.

While the relevance of being able to attend to social partners has been acknowledged for all facets of early language development, it is likely that gaze to the faces and facial features of social partners helps to bootstrap one aspect of language acquisition in particular: vocabulary acquisition (Tomasello, 1992, 2000; Çetinçelik et al., 2021). Acquiring a vocabulary requires the mapping of auditory spoken words to their matching concepts, both of which may require some level of disambiguation. The words that infants tend to acquire early are concrete objects that are visually present in the interaction, such as “bottle” and “sock” (Kavanaugh and Jirkovsky, 1982; Bergelson and Swingley, 2012; Braginsky et al., 2019). Infants can benefit from attending to the face of their social partner, as it can provide both visual (e.g., their eyes gazing at the named object) and auditory cues (e.g., mouth speaking the word form) to guide word learning. We theorize that infant gaze to faces is important to vocabulary acquisition, not only as it is a precursor to infants' ability to utilize the cues that faces signal to word learning, but also as it scaffolds the development of those more complex social abilities instrumental in word learning (e.g., gaze following, joint attention, Reid and Striano, 2005). These more complex social abilities have been shown to relate to vocabulary outcomes; however, the relation between the precursor of these complex social abilities and vocabulary outcomes has been contemplated less (Carpenter et al., 1998; Morales et al., 2000; Slaughter and McConnell, 2003). Therefore, we examine the relevance of infant gaze to faces by zooming in on vocabulary as our chosen outcome measure. Note that vocabulary outcomes can refer to both productive and receptive vocabulary. Whenever there are mixed findings in the literature discussed below, we highlight the nature of the vocabulary outcomes (i.e., whether expressive, receptive, or both vocabulary outcomes are affected), as this distinction may help to explain mixed results.

The relevance of gaze to faces to vocabulary is not yet fully understood. One complexity stems from the gaze to faces being defined in a number of ways. For instance, we can assess it by zooming in on the relevance of specific elements of a face, or we can compare it against other objects present within the same scene, or by contrasting different kinds of faces across different interactions. Moreover, it remains unclear whether this relationship proves stable across development or whether there are any developmental trends. It could be that the relevance of gaze to faces wanes off across development, but holds especially for the youngest age group just starting to build a vocabulary but who cannot yet rely on higher social–cognitive abilities such as joint attention. It is also unclear whether the choice of experimental tasks impacts the relationship. That is, it is possible that how infants utilize and weigh cues in a face may depend on the situation at hand and their developmental stage, making it difficult to understand exactly the relationship between infant gaze to faces and vocabulary outcomes. For instance, in cases where it may be relatively difficult to hear the words correctly, infants may look more at the mouth, whereas in cases where there are multiple novel objects present, infants may benefit more from gazing at the eyes. Hence, the relevance that looking to the mouth will have to infants' word learning and subsequent vocabulary outcomes will depend on what needs to be disambiguated in the task, and whether the infant is at a developmental level where they can successfully disambiguate this information. Considering this, the developmental stage of the infant and the task they are presented with are important to consider in our review, as they may moderate which aspects of gaze to face are the most related to vocabulary outcomes.

This paper is organized as follows. We will start by presenting an overview of the existing theoretical frameworks pointing to gaze to faces as a possible facilitator to vocabulary outcomes in infancy. Then, we will review relevant literature that assesses how gaze to faces impact vocabulary outcomes, for three specific aspects of gaze to faces: first, to specific elements in the face (the eyes compared to the mouth); then, to faces versus other elements in the environment; finally, to different types of faces. Regarding vocabulary outcomes, we will assess papers look at both productive vocabulary outcomes and receptive vocabulary outcomes. Within each section, We will assess the relevance of this specific type of gaze to faces to vocabulary outcomes and describe how this relation is moderated by developmental trends and experimental tasks. In our discussion, we will evaluate the evidence for and against a relation between gaze to faces and vocabulary outcomes, based on the literature reviewed. We will then conclude by addressing the questions that are left unanswered by the existing literature, followed by recommendations for future research directions.

We therefore aim not only to collate literature showing whether, when, and why infant gaze to other persons' faces could scaffold infants' vocabulary outcomes (Locke, 1993) but also to identify gaps in the literature. Our overarching goal will be to complement and bridge existing theoretical frameworks that link social factors to early word learning (Tomasello, 2000;

Werker and Curtin, 2005; Kuhl, 2007; Çetinçelik et al., 2021; Bastianello et al., 2022).

Theoretical frameworks on infancy: Why would gaze to faces facilitate vocabulary?

Research has evidenced the crucial role that the social environment has in language acquisition in the first years of life (for a review, see e.g., Kuhl, 2007). Similarly, theoretical frameworks have attempted to outline the feedforward effects of the social environment on language acquisition (Pinker, 1979; Hollich et al., 2000; Tomasello, 2000; Werker and Curtin, 2005; Chater and Manning, 2006; Kuhl, 2007; Frank et al., 2009a; Gogate and Hollich, 2010; Johnson, 2016). This section aims to outline the theoretical frameworks that link the dynamics of the social environment to vocabulary acquisition to provide the motivation for assessing the feedforward effect that infant gaze to faces may have on their vocabulary outcomes.

The social environment is composed of many sub-parts of parental warmth and input (Madigan et al., 2019; Anderson et al., 2021). To facilitate word learning, it is beneficial to infants to detect the communicative intent from the partner to the infant, as it highlights potential situations where infants can acquire new words (Floor and Akhtar, 2006). One important source for detecting communicative intent is provided by the faces of social partners. Cues, such as direct gaze (but not averted gaze), can indicate to the infant that their social partner wishes to engage with them (Senju and Csibra, 2008). Indeed, one account on infant language development, the Social-Pragmatic account of language acquisition, holds that infants' ability to recognize communicative intent is crucial to language learning and more specifically their learning of words (Tomasello, 1992, 2000). This theory considers the detection of communicative intent critical, as it provides the foundation of more complex social behaviors (such as joint attention) that are required for language learning. Hence, since the Social-Pragmatic account holds that recognizing communicative intent mediates word learning, it follows that infants' gazes to faces as the more socially informative parts of the environment could be related to their vocabulary outcomes.

Besides detecting the cues that signal communicative intent, infants need to be able to combine and comprehend information that is presented multi-modally in order to map meaning to words. That is, infants need to map the auditory (i.e., words) information to the visual (i.e., concrete objects present in the scene) information. As is highlighted in the Intersensory Redundancy hypothesis, learning is facilitated whenever there is temporal synchrony between two modalities, because the same amodal information is highlighted above other sources of non-synchronous amodal information (Bahrick and Lickliter, 2012). While this account is not specific to word learning, it predicts that multi-modal information, as is present in dynamic faces, would facilitate word learning by linking information from two modalities through their temporal synchrony. That is, faces provide information from two modalities at the same time: The auditory information that we hear and the visual information from the movements of the eyes and mouth. Therefore, an early face preference is arguably necessary to selectively direct the attention of the infant. This then allows them to gain extensive experience with faces and thereby successfully learn to process multimodal information presented by their environment. For example, viewing a moving mouth and hearing speech involves information from the audio and visual modalities that can be linked based on their temporal synchrony to create a combined auditory and visual signal, i.e., a speaking mouth producing sounds, that benefits word recognition (Hollich et al., 2005). Infants may use this synchronous information not only to improve word processing (the mouth-word relationship) but also to facilitate the word-to-world mappings (using visual cues such as the speaker's gaze to a named object, the eyes-word relationship) (Gogate and Hollich, 2010; Bahrick and Lickliter, 2014). Therefore, how well infants can connect the auditory to visually synchronous information that they receive from faces may relate to their vocabulary outcomes.

Above, we discussed two theories that emphasized that gaze to faces could provide useful cues to guide infants' word learning. The theories posited that gaze to faces could improve awareness of communicative intent, boost auditory word processing, and guide word-object pairings, all of which are instrumental for the learning of words. In both the Social Pragmatic Account and the Intersensory Redundancy hypothesis, it was argued that infants need to be able to flexibly utilize the multiple cues that they receive from social partners to learn words (Tomasello, 2000; Bahrick and Lickliter, 2014). But will there be development when infants start utilizing these cues? There are two theoretical frameworks on infant language learning that emphasize that there is a progression in the kind of cues that infants use to guide their early word learning: the PRIMIR framework (a developmental framework for Processing Rich Information from Multi-dimensional Interactive Representations; Werker and Curtin, 2005) and the ECM-model (Emergentist Coalition Model; Hollich et al., 2000). Both accounts acknowledge that the extent to which infants will be able to utilize cues will depend on the developmental stage of the infant. PRIMIR focuses on explaining development in speech perception and word learning by progression in the developmental level of the child, next to initial biases and language-specific requirements. The ECM-model stresses more the social nature of word learning, as it explains development in word learning through the combined roles of social-pragmatic factors, cognitive constraints, and global attentional mechanisms (Hollich et al., 2000; see also Tomasello, 2000 for the social-pragmatic account). As we are interested in gaze to faces as a social cue likely to facilitate vocabulary acquisition, we examine this account more closely below.

The Emergentist Coalition model creates an important distinction between cues that are available versus utilized by infants, arguing that younger children rely on only a subset of the cues that older children are able to use. For example, whereas 7–8-month-old infants are shown to have their word recognition disrupted if a familiarized word is produced by a new voice, at 11 months infants no longer show this disruption (Houston and Jusczyk, 2003). Thus, although the social environment makes a number of cues available (such as multiple speakers repeating the same word; McRoberts et al., 2009), infants' utilization of these cues is dependent on their cognitive and social abilities. That is, attending to socially informative information present in faces will relate to word learning if (a) the infant is at a developmental stage where they are able to use the socially informative information for word learning, and (b) the information is relevant to the task at hand, and thus indeed informative. Therefore, whether gaze to faces proves relevant to vocabulary outcomes may depend on experimental parameters, such as ages tested or choice of tasks. For instance, since we know that certain social abilities, such as joint attention and gaze following (Reid and Striano, 2005), become relevant to vocabulary acquisition later in development, we can similarly imagine that the relevance of gaze to face to vocabulary acquisition also changes over development. Across development and across tasks, we may expect different relations between infant gaze to faces and vocabulary outcomes. This is why we next turn to review empirical evidence not only on whether gaze to faces feeds into vocabulary, but also to evaluate how this relation is affected by the developmental stage of the infants and tasks at hand.

How does gaze to faces relate to vocabulary outcomes?

The faces of social partners can provide infants with cues to guide their leaning of words but can be indexed in different ways. We will relate three specific aspects of gaze to faces relevant to vocabulary outcomes: first, gaze to specific facial features – to the eyes versus the mouth: then selective gaze to faces relative to other objects; and finally, selective gaze to more versus less social faces. In each of these three subsections, we will relate gaze to faces to vocabulary outcomes across infants' developmental trajectories and tasks.

How do gaze to the eyes and the mouth relate to vocabulary?

During our literature review, we found multiple studies that related infants' fixations to the eyes and mouth to vocabulary outcomes (for recent reviews, see Çetinçelik et al., 2021; Bastianello et al., 2022). In what follows next, we first zoom in on whether there is any development across infancy in how infants attend to those facial features. For each facial element, we then consider how this relation to vocabulary is moderated by development and task. Finally, we explain the observed patterns by returning to the theories discussed earlier.

When infants are exposed to faces, they usually fixate first on the eyes of a social partner (Hills et al., 2013). Additionally, they attend to the eyes longer and more frequently than to the mouth (Haith et al., 1977). Infants prefer to look at eyes, even when presented with faces missing various parts (e.g., eyes, mouth, or nose): 2-month-olds fixate equally long to complete faces as to faces with only the eyes are present, and less to faces with only the mouth or the nose present (Maurer, 1985). From 2 to 6 months of age infants fixate more to the eyes than on other features of a social partner including their mouth and body (Jones and Klin, 2013). Some studies indicate that infants maintain the highest proportion of gaze to the eyes (Hunnius and Geuze, 2004; Lewkowicz and Hansen-Tift, 2012; Morin-Lessard et al., 2019). Others find that this higher frequency of fixations to the eyes is only to be present earlier in infancy (Frank et al., 2012). Although some studies indicate infants have a robust preference to attend to eyes, the mixed findings of studies indicate that this does not necessarily hold across development or across tasks.

Although the eyes remain the primary focus of attention, the mouth also increasingly draws attention during the first year of life (Young et al., 2009; Lewkowicz and Hansen-Tift, 2012; Tenenbaum et al., 2013; Elsabbagh et al., 2014). This finding is confirmed by several studies, notably with high participant numbers, and thus with good statistical power. These studies often test infants at multiple time points throughout the first years of life, some looking at as many as four to five separate developmental time points (Lewkowicz and Hansen-Tift, 2012). Infants are observed, in a task where they are gazing at a speaking face, to look longer to the eyes at 4 months, equally to the eyes and mouth at 6 and 8 months, more to the mouth at 10 months and finally more to the eyes at 12 months (Lewkowicz and Hansen-Tift, 2012). Therefore, across different timepoints in the first year of life, infants divide their length of fixations between the eyes and the mouth differentially for the same task.

The developmental stage of the infant also impacts the frequency with which infants attend to different types of eyes and mouths. That is, infants show progression in the types of facial features they prefer to attend to. For example, although both 9- and 10-month-old infants can differentiate between open and closed eyes, it is only from 10 months onward that infants recognize that only open eyes could provide information about where a social partner is looking (Brooks and Meltzoff, 2005). Thus, infant sensitivity to open versus closed eyes is a prerequisite to being able to follow their partner's eye gaze, which is a powerful cue shown to predict subsequent productive vocabulary growth (e.g., (Brooks and Meltzoff, 2008, 2015). This indicates a developmental progression in the extent to which infants can utilize the cues provided by the eyes to direct their gaze.

There are also noticeable changes in how infants attend to different types of mouths. Infants increasingly also prefer looking at speaking mouths over other types (such as smiling mouths) from 6 to 9 months of age (Tenenbaum et al., 2013, 2015). Another example is that infant gaze to facial elements hinges on the type of speech they hear: a cross-sectional study manipulating whether infants watched speakers' producing a language that was native versus non-native to the infant showed that the looks that infants directed to the eyes and the mouth differed across the native and non-native speech conditions. While 4- to 8-month-olds increasingly devoted more gazes to the speakers' mouths irrespective of the type of speech, 12-month-olds only fixated more to the mouth when they heard a speaker producing a non-native versus native language (Lewkowicz and Hansen-Tift, 2012). This finding is observed cross-linguistically, with infants also undergoing an attentional shift to the mouth when the dominant language in their environment is Japanese (Sekiyama et al., 2021).

Another study manipulated whether or not there was synchrony between audio and visual information: at 10 months, infants' usual pattern of a preference to fixate to a mouth was absent in the desynchronized condition compared to when synchronized audio-visual information was presented (Hillairet de Boisferon et al., 2017). This finding held both when infants were presented with native or non-native speech. Similarly, looking times to the mouth were longer when infants were presented with speaking compared to silent faces – in the latter condition, looking times to the eyes were shown to be significantly longer (Tomalski et al., 2013). All these illustrations thus point to infants becoming increasingly sensitive to those situations that prove maximally informative, and this is mirrored in their differential gazes to specific facial regions.

While above we summarized studies that provide evidence of a development in how infants attend to both the eyes and the mouth, two recent review papers provide ample evidence that gaze to eyes (Çetinçelik et al., 2021) as well as a gaze to the mouth prove relevant to vocabulary outcomes (Bastianello et al., 2022). We complement their reviews by focusing on those studies that assess whether there is the developmental change in the relevance of gaze to eyes versus mouth regions.

The review by Bastianello et al. (2022) confirmed that increased gaze to (speaking) mouths around the first year of life is associated with infants' early expressive language skills across all of the reviewed studies in the paper. Yet, for slightly younger infants (5-month-olds), it is infant gaze to the eyes (over the mouth) that has been shown to predict their receptive vocabulary size at 14 months (Viktorsson et al., 2021). Similarly, in a situation where the face provides mismatched auditory and visual information, it is again longer gaze times to the eyes and shorter gaze times to the mouth that correlates positively with 6 to 9-month-old infants' later receptive and productive vocabulary outcomes (Kushnerenko et al., 2013). However, in another study presenting infants with mismatched auditory and visual information, infants are found to have increased looking times to the mouth between 6 and 9 months of age (Tomalski et al., 2013). This seemingly contradictory pattern of results can be explained by the observation that while infants increasingly attend to the mouth over the course of development, they may not directly be able to utilize all cues that the speaker's mouth provides (Hollich et al., 2000). Given that integration of multi-sensory information is underdeveloped at birth and develops over the course of the first year (Burnham and Dodd, 2004; Bahrick et al., 2013), it could be that these younger infants could not yet fully utilize the multi-modal information most saliently present in the mouth region (Nardini et al., 2010). In this case, younger infants' capacity to ignore mismatched an unreliable cues and to rely more on the cues of the eyes instead may be predictive of vocabulary outcomes (Kushnerenko et al., 2013). In comparison, older infants may be able to use multimodal (that is, auditory and visual) information more flexibly, including in situations where the modal information is mismatched. Thus, there is development in how informative facial features can be to infants and subsequently in how infants' gazes to the eyes and mouth relate to vocabulary outcomes.

While most research points to a positive link between infants' increased fixation to the mouth or eyes with vocabulary outcomes, it is important to consider that this relation may not only hold for specific ages, but also for specific tasks (Kushnerenko et al., 2013; Altvater-Mackensen and Grossmann, 2015; Ter Schure et al., 2016; Danielson et al., 2017; Bastianello et al., 2022). To illustrate the effect of the task, we compare studies that differed in the complexity of the presented scene, while also linking infant gaze to vocabulary outcomes. In visually complex scenes (live action scenes with many characters performing different activities), 7-month-olds' increased fixations to the mouth is shown to be associated with superior productive vocabulary outcomes at 36 months (Frank et al., 2012). In comparison, in simpler live-action scenes (that contain a single face displaying communicative signals), increased fixations to the mouth in contrast relate to inferior productive vocabulary (Elsabbagh et al., 2014). Why might this be? This could be because the two tasks indicate different abilities when the infants fixate to the mouth. In the simpler scenes, a speaking mouth is the most perceptually salient feature within the scene, whereas in the visually complex scenes, a speaking mouth competes with other perceptually salient elements, but is still the most cue relevant for vocabulary. It is therefore important to consider how the same behavior (e.g., gaze to the mouth) may indicate different abilities depending on the task with which the infant is presented, and which cue (within the task) happens to be the most relevant for word learning. When evaluating how infants' gazes to faces relate to vocabulary outcomes, it is therefore important to evaluate which cue is likely to be the most informative to the infants' word learning.

Having above reviewed evidence that both gaze to eyes as well as mouth prove relevant to vocabulary outcomes, we now turn to explain why this could be. Infants' fixations to the eyes could be beneficial to their word learning because the eyes of a social partner can signal their communicative intent or provide information about the referent to which a social partner is attending (Tomasello, 1992, 2000). Some studies show that infants first rely more on attentional cues, such as perceptual salience, rather than on gaze-cues from the interlocutor to guide their early word-object mappings (Brooks and Meltzoff, 2005, 2015; Pruden et al., 2006). As eyes are a perceptually salient feature of the face to which infants have a bias to attend to, then eyes may be one of the features that in early infancy draws infants to attend more to faces than to other objects (Di Giorgio et al., 2012). As an example, one study shows that infants who are able to detect when they are being gazed at and who can also subsequently follow the partner's gaze direction to an object may have a considerable advantage in determining the thoughts and intentions of their social partners (Langton et al., 2000). This is advantageous for word learning because understanding the internal state of a social partner increases the probability of an infant correctly discerning which of the many possible referents a social partner is communicating about.

While the eyes provide visual information to whom or about what the speaker is communicating, the mouth provides multimodal (visual and auditory) information about what is being said. In line with the Intersensory Redundancy Hypothesis, the combination of auditory and visual information may benefit word learning in multiple ways (Bahrick and Lickliter, 2012; Lewkowicz and Hansen-Tift, 2012). The development of increased fixations to mouths may benefit word learning because the mouth can provide a combination of auditory and visual cues that aid in the learning of words. This audio-visual information allows listeners to narrow down potential words by segmenting speech streams and locating word boundaries in continuous speech (Hollich et al., 2005; Mitchel and Weiss, 2014). Thus, the synchrony of the visual and auditory modalities (i.e., the movements of the mouth combined with the sounds it produces) makes it easier to narrow down *what* is being said (thereby facilitating infants' receptive vocabulary), *how* it is said (thereby facilitating infants' learning of expressive vocabulary), and *who* said it (highlighting communicative intent) (Bahrick and Lickliter, 2012; Lewkowicz and Hansen-Tift, 2012; Benders, 2013; Altvater-Mackensen and Grossmann, 2015). Infants who are learning words may therefore benefit from fixating to the mouth as a way to reduce several kinds of ambiguities of the visual and/or auditory information they are receiving through the combination of the two modalities.

Besides which facial elements infants selectively attend to, this review further demonstrates that the developmental stage of the infant plays a large role. We synthesized research reporting that progression in how infants attend to eyes versus mouth was relevant to their vocabulary acquisition. According to the Emergentist Coalition model, how infants develop their detection of and subsequently utilize socially more informative cues (such as speaking mouths) is critical to word learning (Hollich et al., 2000). In line with this, infants' development in the utilization of the social cues provided by the eyes is shown to correlate with later receptive and productive vocabulary (Brooks and Meltzoff, 2005, 2008). Additionally, the shift in gaze to specific types of mouths, i.e., speaking ones, is also shown to relate to vocabulary outcomes; for example, 6-month-olds who fixate more to the mother's mouth during live interaction have the superior productive vocabulary at 24 months (Young et al., 2009). This preferential fixation to speaking versus silent mouths could be beneficial to word learning by increasing the likelihood that the infants fixate to a mouth from whom they can learn words. Fixating more frequently to certain eyes and mouths may in turn facilitate word learning by increasing the likelihood of infants' fixating to a partner who is providing more communicative cues (e.g., one with direct gaze and/or a speaking mouth) and thereby increasing the opportunities for word learning.

How does gaze to faces relative to other objects relate to vocabulary?

In the examination of the literature that preceded the writing of this review, we could not find empirical evidence that assessed the impact that infants' preferential gaze to faces relative to objects had on their vocabulary outcomes. However, we theorize that infants' gazes to faces relative to other objects is a pre-requisite to more complex social abilities (such as gaze following), which have been shown to be linked to vocabulary outcomes (Carpenter et al., 1998; Morales et al., 2000; Slaughter and McConnell, 2003). We theorize this because it appears logical that before infants can follow adults' gaze correctly to labeled objects, infants first require ample experience with faces. This experience may be facilitated by the presence of a preference for faces over other objects. In this section we therefore review only the evidence of whether there are developmental changes in infant gaze to faces, and whether there are task-related changes. We then continue to speculate how this gaze to faces relative to other objects may relate to infants' vocabulary outcomes and how this relation may change across development and tasks.

Throughout infancy, infants are shown to have a preferential bias to attend to faces compared to other objects, looking longer to and orienting more frequently to face-like stimuli compared to non-face-like stimuli (Johnson et al., 1991;

Valenza et al., 1996). This is observed across a number of visual attention tasks: some studies reporting a face-preference involve infants' free viewing of clips that contain faces (e.g., video clips from the TV show Sesame Street) (Frank et al., 2009a, 2014; Franchak et al., 2016). Other studies look at preferential biases for faces by presenting images of faces together with other static objects (e.g., birds and cars) (Gliga et al., 2009; Elsabbagh et al., 2013). In the case of both paradigms, studies calculate the percentage of trials where the first fixation is directed to a certain category of object and/or calculate the average number of fixations to an area of interest. These similarities in how studies define infants' gaze to faces make it easier to cross-compare findings across studies (Hessels, 2019). In both paradigms, studies find that infants tend to direct their first gazes to faces as well as fixate more frequently to faces, compared to other stimuli on the screen (Gliga et al., 2009; Elsabbagh et al., 2013). Based on the qualities (e.g., sufficient participant numbers) and reoccurring findings of the studies, the finding that infants prefer to attend to faces (compared to other objects) appears robust.

Although all tasks show that infants primarily attend to faces, studies differ in the proportions of face preference, possibly based on differences in study parameters, such as children's age and children's opportunities to explore. To illustrate the mixed findings for the effect of age, there is a set of studies that recorded fixations to all available visual stimuli in a natural interaction for infants between 1 and 24 months of age. These studies report that across age, there is a decline in the frequency of gaze to faces, coupled with an increasing frequency of gaze to hands, meaning that age has an effect on the frequency of gazes to faces versus hands (Jayaraman et al., 2015; Fausey et al., 2016). In this paradigm, infants freely move about in their home environment while their gaze patterns are measured with head-mounted eye-trackers. Contrastingly, other studies (using different tasks) suggest that older infants fixate to faces more than younger infants do when watching video clips (6–24-month-olds; Franchak et al., 2016; 3–9-month-olds: Frank et al., 2014). The mixed findings across different tasks make it important to consider which aspects of the task or situation led to differences in infants' observed frequency of fixations to faces. Factors may include aspects of the methodology such as contrasting stimuli presented or whether the infants' movements during eye-tracking are restricted (as in Frank et al., 2014; Franchak et al., 2016) or not (as in Jayaraman et al., 2015; Fausey et al., 2016). Overall, it appears that the frequency of fixations that infants direct to faces hinges on their capacity for movement. Infants' capacity for movement depends both on their developmental stage (i.e., whether they can walk or sit up) and the task at hand (i.e., whether the procedure restricts their movements or not). Regarding developmental stage, older infants (who are more mobile) are shown to receive a more mixed visual input on faces and hands, whereas younger infants receive more input from faces. Regarding tasks, infants' preference for faces may be stronger, when their movement and visual input is restricted. When drawing conclusions on the development and ubiquity of face preferences, it is therefore important to consider how the methodological choices may impact the behaviors that infants display during the procedure.

In the preceding paragraphs, we have considered how the developmental stage and task at hand influence how infants fixate to faces. Will this type of gaze to faces (face preference) also impact their vocabulary? As we have seen in the theoretical accounts, fixating to faces can be a facilitator of word learning because the cues provided by the face allow infants discern what their partner intends to communicate about and to whom their communication is directed to, e.g., to the infant, thereby guiding the infants' learning of words. Indeed, the bias to fixate to faces (over other objects) is arguably an important prerequisite to infants' vocabularies because it directs infant gaze to the cues provided by the face (Tomasello, 1992, 2000). Yet it is likely that there are developmental patterns as we have seen that face preference changes with development. A higher proportion of fixations to faces compared to other objects could be particularly important in younger infants, who have less developed social and cognitive abilities than older infants (Hollich et al., 2000), which in turn may compromise their ability to direct and maintain their gaze to objects in their environment, and as a result make them more dependent on a social partner to guide their learning (Colombo and Cheatham, 2006; Reynolds et al., 2013). Future research could investigate whether the relevance of preferential fixation to faces to vocabulary outcomes is more substantial early in vocabulary development, but declines with age. Furthermore, future research should consider how the choice of paradigm affects the relation between preferential fixation to faces and vocabulary outcomes.

How does gaze to more social versus less social faces relate to vocabulary?

When we are considering the types of faces that might prove informative, we note that current studies have not correlated infants developing a preference for more social faces to their vocabulary outcomes. Just as in the preceding subsection, we therefore first evaluate whether there are potential meaningful changes in this type of gaze to faces before, we speculate whether this could impact infant vocabulary outcomes.

Infants gradually begin to preferentially attend to certain types of faces over others, that is, faces that contain potentially more social cues (Smith and Gasser, 2005; Frank et al., 2009b, 2014; Slater et al., 2010). From 3 months onward, infants begin to prefer natural face images to unnatural ones (Turati et al., 2005). Around this age, they are also shown to preferentially fixate to upright over inverted faces (Chien, 2011; Elsabbagh et al., 2013). By 6 months, infants direct their first gazes to upright and not to inverted faces (Gliga et al., 2009).

Additionally, infants are shown to develop a preference to fixate to speaking faces above silent dynamic faces from 2 to 8 months, such that older infants increase their looks to speaking faces and decrease their looking away rates (Bahrick et al., 2016). Thus, the development of preference for specific faces appears to be robust across tasks; infants' increased sensitivity to certain faces moves toward faces to which infants are frequently exposed in their daily environment. Infants' gazes also increase toward more communicative faces over the course of development, while their gazes to less communicative faces remain similar (Bahrick et al., 2016). This preference to specific types of faces could be an index of perceptual learning, which refers to an increased sensitivity to specific faces frequently present in the environment and decreased sensitivity to others (Maurer and Werker, 2014).

When we are considering the relevance of attending to faces that are more social than other faces, we can only speculate that preferential gaze to more social faces could relate to vocabulary outcomes. Social faces are those types of faces that provide more explicit cues indicating communicative intent directed at the child (e.g., *via* direct gaze), and which are present often in the child's environment. As is theorized in the Social Pragmatic account of word learning, the understanding of communicative intent is key to the learning of words (Tomasello, 1992, 2000). Whether infants gaze to more social faces (that contain more explicit cues) arguably increases their opportunities for word learning and subsequently relates to their vocabulary outcomes. The relation between gaze to social faces and vocabulary outcomes may hold in particular for younger infants. Whereas older infants are shown to be able to learn words by overhearing conversations, it is less clear whether younger infants have similar capacities (Akhtar et al., 2001). Younger infants may rely more on communicative intent recognized by more visual engagement with the speaker (Tomasello, 2000). Therefore, infants' capacities to attend to more socially relevant faces could relate more to vocabulary outcomes when they are younger.

There are other task-related factors which arguably influence how socially relevant certain types of faces are, and which further could impact vocabulary outcomes. For example, whether or not a person's face is physically present or whether this person is reciprocating the infants' behaviors could ultimately influence vocabulary outcomes. Whereas some studies find that infants can learn from digitally presented faces (i.e., faces that are not physically present) that direct their gaze at a target object (Houston-Price et al., 2006), others find that there is a "video-deficit," and that infants' learning is hindered when the tutor appears on video instead of being physically present (Anderson and Pempek, 2005). Findings are mixed regarding the extent to which infants can use the cues provided by physically versus digitally presented faces to guide their word learning (O'Doherty et al., 2011; Roseberry et al., 2014; Troseth et al., 2018; Tsuji et al., 2020). In part, these mixed findings may also depend on the difficulty of the word-learning task with which the infant is presented (Gogate and Madhavilatha, 2017). More difficult word-learning tasks may benefit from the faces of social partners being physically present and reciprocating. Further research is needed to clarify in which tasks infants can use the face to guide their learning of words. Additionally, further research is required as to how the difficulty of the word-learning task impacts infants' abilities to learn from faces that are not physically present and/or not reciprocating.

To summarize, based on the existing literature, it remains unclear how infants' fixation toward more socially relevant faces impacts their vocabulary outcomes. Further research is needed to elucidate how flexibly infants can learn word-world pairings from the faces of social partners and the extent to which this flexibility depends on the developmental stage of the infant, and the task at hand.

In the above three sections of this paper, we discussed how three aspects of infant gaze to faces relate to vocabulary outcomes: gaze to different elements within faces; gaze to faces relative to other objects; and gaze to different types of faces. We will now discuss our findings in the literature and make suggestions for future research.

Discussion

This position paper first aimed to assess how infant gaze to faces may feed into their vocabulary outcomes. We reviewed the literature on three aspects of infant gaze to faces: gaze to the eyes compared to the mouth; gaze to faces compared to objects; and gaze to more socially relevant faces. Several studies were found that related infant gaze to facial elements and vocabulary outcomes. Here, we observed that the relationship between infants' gaze to eyes and the mouth with their vocabulary outcomes was impacted by the developmental stage of the infant, and the task at hand. However, to the best of our knowledge, no studies explored how gaze to faces (compared to other objects) or gaze to more social (compared to less social) faces relate to vocabulary outcomes. We will now discuss how gaze to faces could influence vocabulary outcomes, pointing out how different strands of future research can tackle the further assessment of these cascading effects. We will then discuss some of the limitations of the review and point to possible future directions.

A number of studies related gaze to the eyes versus mouth to vocabulary outcomes. Studies examined both how infant gaze to the eyes (Carpenter et al., 1998; Mundy and Gomes, 1998; Morales et al., 2000; Brooks and Meltzoff, 2005, 2008) and to the mouth relates to vocabulary outcomes (Young et al., 2009; Elsabbagh et al., 2014; Tenenbaum et al., 2015), and how these relations change over development. That is, infants increasingly attend to the mouth over the course of the first year of life, and this developmental shift longitudinally predicts infants' vocabulary outcomes later in development

(Elsabbagh et al., 2014; Tenenbaum et al., 2015). Developing a capacity to switch between fixating to the eyes or mouth of a social partner is shown to have feedforward effects on vocabulary outcomes because the eyes and mouth provide meaningful yet different cues to word-object pairings in their environment. Arguably, infants who can selectively attend to the eyes and the mouth at points in time when such a facial feature is maximally socially informative will receive more cues to guide their word learning. Subsequently, these infants will have larger vocabulary outcomes compared to other infants. Yet, although there is substantial research linking gaze to the eyes or to mouth with word learning, additional clarification is needed on when and in which situations it is that infants develop an appropriate ability to socially encode information from the more relevant facial features, such that their gazes predicts and facilitates their word learning.

Whether there is a relationship between infants' preference to gaze to faces (over other objects) and their vocabulary outcome remains theoretical, with no empirical evidence looking into whether face-preference has a feedforward effect on vocabulary outcomes. Additionally, no studies have attempted to correlate how infants' preferential fixation to certain types of social faces may relate to their later vocabulary outcomes. Infant preference for faces (compared to objects) and their preference for more compared to less social faces may facilitate word learning by increasing the probability of infants attending to the relevant social cues that the face provides to guide their word learning (Tomasello, 1992, 2000).

Gaze to faces has frequently been theorized and empirically shown to have feedforward effects on vocabulary outcomes (Çetinçelik et al., 2021). Feedforward effects (also defined in the literature as cascading effects) are the cumulative consequences of the many interactions and transactions occurring in developing systems (Masten and Cicchetti, 2010; Sameroff, 2010; D'Souza and Karmiloff-Smith, 2011; Junge et al., 2020). Preferential gaze to faces is an early instance of selective attention, that may direct infants' gazes to faces and provide infants with extensive experience of face stimuli. This extensive experience with faces could be a precursor to more complex social abilities (e.g., gaze following) that have frequently been shown to relate to vocabulary outcomes (Çetinçelik et al., 2021). Subsequently, infants' early face preference could feed into word learning by feeding into infants' complex social abilities that directly relate to their word learning. Understanding these feedforward effects of preferential gaze to faces on vocabulary outcomes may guide us toward the mechanisms and constraints leading to the acquisition of words and the subsequent vocabulary outcomes (D'Souza and Filippi, 2017; Kidd and Donnelly, 2020). In light of this, studies correlating infants' early preferential gaze to faces with their vocabulary outcomes will give us insight into whether and why infants can learn their first words from the information that faces provide.

As yet, confirmative research is required to substantiate our hypotheses and further explain the nature of this feedforward effect. Regarding this nature, it is possible that gaze to faces has some direct feedforward effects on vocabulary outcomes. Alternatively, it is possible that face-preference serves as a mediator to vocabulary outcomes, as it scaffolds more sophisticated social abilities, such as joint attention (Junge et al., 2020). The strength of the relationship between infant gaze to faces and vocabulary outcomes could change as a function of the developmental stage, with face-preference facilitating word learning earlier in development more than later in development. The relation between gazes to faces and vocabulary outcomes is therefore likely to be stronger when assessing younger infants, because older infants have access to a larger range of social mechanisms, e.g., joint attention, that are made up of multiple smaller social domains. Therefore, we recommend that future research explores the relationship between the three domains that are addressed in this review (gazes to eyes and mouth; gazes to faces versus objects; and gazes to specific face types) and vocabulary outcomes in younger infant groups, who have fewer social capabilities at their disposal for word learning.

Additionally, the task given to the infant is also likely to affect the feedforward effect. When examining how infants attend to faces it is therefore important to consider both how the developmental stage and task given to the infant influence their processing of a face that they could attend to and how this processing may subsequently impact infants' vocabulary outcomes.

Limitations

This review has some limitations. First, as outlined above, the links made between some aspects of infant gaze to faces and vocabulary outcomes in this review remain theoretical and require more empirical evidence. Although we did not systematically review experimental findings, it appears there is insufficient research to draw clearer conclusions about how specific aspects of infant gaze to faces feed into vocabulary outcomes. Additional research is needed to confirm these links, including large-scale longitudinal studies, experimental studies with different paradigms, and intervention studies to illuminate whether, how, and when infant gaze to (aspects of) faces impacts vocabulary outcomes (Masten and Cicchetti, 2010).

Second, it is also important to take into account that the research from which we draw our theoretical links involve primarily (if not completely) samples of infants and parents from societies that are Western, educated, industrialized, rich, and democratic (that is, WEIRD societies: Henrich et al., 2010). The beliefs, traditions, and day-to-day lives of individuals from non-WEIRD societies may differ from WEIRD societies to the extent whereby the links observed in one society may not be comparable to the other. For example, whereas in

Boston, MA, America (a WEIRD society) mothers are shown to frequently visually engage with their infants, in Gusii, Kenya (a non-WEIRD society) mothers engage more frequently through holding and touching instead of direct gazing at their infant (Akhtar and Gernsbacher, 2007). Our hypothesis that gaze to faces proves relevant in a number of ways should therefore not be interpreted as the most significant or only successful facilitators of word learning.

Our aim was to disentangle how an early developing social cue (infants' attending to faces) related to vocabulary outcomes. Of course, this does not mean that gaze to faces is the only potential cue that relates to vocabulary outcomes. The literature documents a myriad of factors that impacts early word learning, ranging from the infant level to familial risks, to the environment (Kidd and Donnelly, 2020). For instance, at the infant level there exist many possible predictors: infants' non-verbal cognitive skills (Colombo et al., 2008; Rose et al., 2009), general auditory abilities (Benasich and Tallal, 2002), and speech perception abilities (Fernald and Marchman, 2012; Cristia et al., 2014; Ference and Curtin, 2015; Wang et al., 2021). Moreover, we note that there are several other perceptual processes developing during infancy that contribute to more complex forms of social processing, such as joint attention (Lewkowicz and Ghazanfar, 2006; Scherf and Scott, 2012; Hadley et al., 2014; Happé and Frith, 2014; Pascalis et al., 2014). In this review, we have chosen to restrict the scope to fixation to faces as a proxy of early social behavior observable in infants from birth onward. It remains to be seen how all these potential factors hold together when explaining individual variations in early vocabulary.

Future research directions

Based on the research findings and hypotheses compiled in this review, there are a number of gaps in the literature and subsequent directions that future research can take to further elucidate the role of infants attending to faces in being relevant to vocabulary outcomes. One line of studies could use repeated multiple measurements to investigate how and when across development gaze to faces (over objects) or gaze to more (compared to less) socially informative types of faces are indeed related to vocabulary outcomes. This could shed light on the developmental processes that gaze to faces comprises. For example, how infants attend to faces (compared to objects) may be more predictive of vocabulary outcomes earlier in development and become less predictive when infants start utilizing additional cues (such as direct and averted gaze) to guide their learning. Similarly, gaze to social faces may (or may not) become less predictive of vocabulary outcomes as infants start to direct more of their gaze to the surrounding environment or to other social stimuli, e.g., the hands (Smith and Yu, 2013; Deák et al., 2014; Jayaraman et al., 2015; Fausey et al., 2016).

Another line of research should focus on explaining the individual variation in early vocabulary (Bates et al., 1994; Frank et al., 2017). Understanding the sources of individual variation ultimately informs both theory-forming as well as practitioners aiming to maximize children's word-learning potential (Kidd and Donnelly, 2020). To assess whether variation in early gaze to faces predicts word learning, as we hypothesize here, we need more empirical evidence testifying that there is such a link, and why such a link would exist. For example, it could well be that infants who look more at their partners may in turn receive more social responses from their partners that prolong the length of the interaction. Lengthening the interaction may increase the time window in which word learning can occur and improve the quality of the interaction may increase the probability of correct word-object pairings being made. Short-term, this could lead to more word learning opportunities when the infant is engaged in communication with a partner and long-term it could lead to observable differences in the vocabulary size and content of the infant. Subsequent studies could then use intervention-designs focusing on fostering infants' fixation to faces to promote early vocabulary.

Finally, research could focus on well-controlled laboratory studies to carefully examine how the task within which the infant is engaged could impact the extent to which gaze to faces is predictive of vocabulary outcomes. For example, it has been shown that in some experimental settings, 1-year-olds hardly look at the faces of their social partner, but instead coordinate joint attention between themselves and a social partner by attending to objects held by themselves or their partner (Smith and Yu, 2013). In situations where the infant and the partner are handling the objects instead of looking to a faraway/out-of-reach object, there may be a lower ambiguity of the word-referent pairing, and thus less reliance on facial cues, than when an object being referred to is not in direct reach of the infant or social partner (Deák et al., 2014). Taking into account the interaction contexts (or tasks) in which infants learn words will expand our understanding of how and why visual social cues, such as those present in the faces of their social partners, affect word learning.

Future research could thus take into account how developmental, task-related and individual differences in infants attending to faces have feedforward effects on vocabulary outcomes. There are ample opportunities and directions for future research.

Conclusion

Overall, infant gaze to faces could have an important effect on early word learning through the constrictions that facial cues provide on the natural variability of environments. A face-preference appears to be an initial bias that aids infants' gazes to social stimuli early in development, when they have less attentional control. It may also feed into later developing, more complex social abilities, such as gaze following, that have been found to relate to word learning and vocabulary outcomes. Gazes to specific features of the face, on the other hand, develop over time and may constrict information relating to words, referents, and word-object pairings. Infants' gazes to the eyes may aid in their discerning of communicative intent and in determining where in the environment the gaze of a social partner lies. Gaze to mouth movements provide multi-modal information to aid the processing of speech and learning of words, as well as reinforcing child-directed speech. Combined, these processes provide numerous cues to facilitate the creation of word-object pairings. There are a number of studies that have shown how infants gazes to the eyes and mouth relate to vocabulary outcomes. However, whether infant gaze to faces (compared to objects) as well as to more socially relevant types of faces relate to vocabulary outcomes remains speculative and could depend on an infant's developmental level, which affects their ability to correctly discern and use such cues to guide their learning. Developmental level, as well as the task (i.e., situational factors), is therefore important to consider when evaluating correlations between infant gaze to faces and their vocabulary outcomes. Although this review hypothesizes that infant gaze to faces relates to their vocabulary outcomes, and finds some evidence in favor of our hypothesis, future empirical studies could examine the feedforward effects on vocabulary outcomes more directly.

Author contributions

ZB, CB, and CJ: conceptualization, investigation, writing—original draft, and writing—review and editing. CB and CJ: funding acquisition and supervision. ZB: project administration. All authors contributed to the article and approved the submitted version.

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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.

Publisher's note

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Case report: Improving quality of care in Kazakhstan institutions

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This project is a community case study implemented by local professionals and caregivers to improve the quality of caregiving in two Kazakhstan institutions for infants and toddlers. Local professionals first received comprehensive training by an international team experienced in relevant research-based practices, and then the locals trained institutional staff. Over nearly 2 years, one institution progressively implemented changes in three wards and the other institution in one ward. The changes attempted to make the institution more family-like (e.g., smaller groups and fewer and more consistent caregivers) and caregivers behave more parent-like (e.g., more warm, sensitive, responsive interactions and relationships) without changing nutrition or medical care. Of the 45 children given some exposure to the emerging new wards, 11 experienced the fully revised wards for at least 4 months during their first 2 years of life. They displayed substantial increases in their physical growth, especially those entering in their first year of life, in contrast to the unchanging developmental patterns of 165 children who were reared in the two institutions before the ward changes were made. Physical growth is a commonly used standard of developmental well-being in institutions. Research shows it is sensitive to infants' psychosocial environment, and improvements in physical growth are related to children's cognitive and social-emotional development. Although this pilot community case study had only a few infants fully exposed to the complete ward changes and lacked characteristics of a research experiment, these results are consistent with children's developmental improvements reported in larger scientific studies of similar interventions. This project is an example of how some research-based practices are likely to be implemented in communities in the future. Specifically, it shows that local communities can successfully improve the rearing conditions within institutions, which improve the children's development, and may contribute to the success of their subsequent foster placement and adoption.

KEYWORDS

community case study, improve caregiving, institutions, infants, development, Kazakhstan

Introduction

Extensive research shows that infants and young children reared in traditional institutions in Russia, Eastern Europe, Latin America, and Asia are drastically delayed in their physical, cognitive, and social-emotional development (i.e., more than a standard deviation below average; Dozier et al., 2012; Berens and Nelson, 2015; McCall and Groark, 2015). Assuming normal distributions for physical growth and behavioral scales, essentially 9 out of 10 children reared in families would be more advanced in their development than the typical resident of these institutions.

Further, extensive research shows that children adopted or fostered from these institutions display higher rates of physical, mental, cognitive, social-emotional, and behavior problems even years after having been placed in these families (Dozier et al., 2012; Berens and Nelson, 2015). Studies also indicate that it is primarily the social-behavioral rearing environment in these institutions that produces these deficiencies, not the genetics, prenatal, and birth circumstances of the children or the medical care and nutrition provided them in the institutions, although these factors have some effect.

Specifically, this conclusion is supported primarily by two studies, among others. In one study, institutionalized children were randomly assigned to professionally-supported foster care vs. remaining in the institution, which controls for a variety of potential selection variables (Nelson et al., 2014). In the other study, all children in an institution experienced fewer and more consistent caregivers who behaved in a more sensitive and responsive manner, which controlled for nutrition, medical care, and other environmental variables (St. Petersburg–USA Orphanage Research Team., 2008). The specially treated children in both studies displayed substantially improved development relative to non-treated comparison children.

For example, the traditional institutional environment typically consists of large wards of homogeneously aged children, separate groups of children with disabilities, with many and changing caregivers who interact with children in a perfunctory, business-like manner. But when this institutional environment is made more family-like and caregiving more parent-like children's physical, cognitive, and social-emotional development improves substantially and some of their long-term problems are reduced (St. Petersburg–USA Orphanage Research Team., 2008; Hermenau et al., 2016; Julian et al., 2019).

Context

The developmental status of institutionalized infants and toddlers in Kazakhstan in particular is similar to that reported for other countries. A study conducted in 2009–10 under the supervision of the Kazakhstan Academy of Nutrition found that children in 10 institutions for infants and toddlers in the cities of Astana, Almaty, and Karaganda were comparably underdeveloped (Hearst et al., 2014).

In light of this previous research, the Ana Yui Foundation of Kazakhstan started on a path toward welfare reform for vulnerable children in Kazakhstan. An important early step was to demonstrate that local professionals and caregivers could improve the caregiving in two institutions for infants and toddlers. To begin with, Kazakh professionals received comprehensive training by a University of Pittsburgh (USA) and St. Petersburg State University (Russian Federation) team of professionals experienced in research-based practices to improve caregiving in institutions (St. Petersburg–USA Orphanage Research Team., 2008). Then these local professionals trained institutional staff and caregivers, and the institutions implemented aspects of the training according to their own policies, practices, and schedule.

This report is not a traditional research study, but it is a report of the application of research. Specifically, it represents a community-based clinical case study using the train-the-trainer approach (Center for Disease Control Prevention., 2022) to improving children's development and potentially minimizing longer-term problems after adoption or fostering. It is likely that in the future some research-based practices will be implemented in communities using general processes similar to those reported here.

Below we provide brief descriptions of the changes that local professionals made as well as physical growth assessments of children before the changes and of children who experienced the revised environments. This project was considered by the University of Pittsburgh Review Board not to be research but rather an attempt by service agencies to modify their services. Therefore, it was not reviewed.

Program intervention

International training

The USA-St. Petersburg team provided initial training that took place on three occasions over 6 months. A total of 25 Kazakh professionals from Astana, Shymkent, and other cities participated. All had some prior training in relevant topics, experience with institutions, and the intention to support children, caregivers, and families in the future.

Sixteen topics were taught covering children of all ages including developmental milestones, developmental risks, responsive caregiving, attachment, parenting, the effects of trauma, mental health, behavioral and psychiatric problems and how to respond to them, coaching and supervision, and changing an institution (based upon the authors' experience reported in St. Petersburg–USA Orphanage Research Team., 2008). A prepared curriculum was used that consisted of written modules, exercises, and discussion topics supplemented by power points, handouts, videos, and instructions on how to train other professionals and caregivers.

Local training

After the international training, professionals and caregiving staff from each institution were trained. Four participants from the international training trained in seven to eight sessions for a total of 22–29 h ~150 local professionals and caregivers from the two institutions. They selected the topics of mental health, attachment, child development, risk signs, and more respectful caregiver-child interactions.

Ward changes

Over a span of nearly 2 years, one institution progressively implemented changes in three wards and the other institution did so in one ward. Although the implementation details differed between institutions because of staff resignations (including the director in one institution), renovations required by the city, and other local circumstances, the changes in both institutions similarly emphasized reducing group size, mixing children of different ages within a group, integrating children with and without disabilities in the same group, discontinuing periodic graduations of children to new groups, assigning fewer caregivers per group and having them work more consistently across days, and encouraging caregivers to interact with children in a warm, sensitive, and responsive manner. In short, the changes were an attempt to make the institution more family-like and caregivers behave more parent-like.

Specifically, instead of 9–12 different caregivers serving approximately 12 children and usually different caregivers every day, the revised schedule had six to seven children in a group, ranging in age from 1 month to 4 years of age, including one or two children with disabilities. Children were selected to enter the special wards to create and maintain the diversity of age and disability in the group. Preference was also given to children who were more likely to remain in the institution (i.e., did not have a family likely to take the child back soon).

Children were served by four caregivers during the day and three at night. Although their precise hours changed slightly over time, there were two "primary" daytime caregivers who worked 9–10 h alone on 2 days and then both worked 6 h in non-overlapping shifts on 3 days with 2 days off per week. They were assisted by two nurses, who worked 14 h on two consecutive days and then were off for 2 days, plus two night caregivers. Therefore, children saw one or both "primary" caregivers and two or three of these four daytime caregivers every day. Caregivers were encouraged to interact with children in an engaged, warm, sensitive, and responsive manner. No changes were made in medical care or nutrition. Which specific changes and how and when they were implemented were totally under the control of the institutional administrators, professionals, and caregivers.

Outcomes

Children's physical growth in the institutions

The well-being of children within such institutions is typically indexed by the children's physical growth (e.g., height and weight), which is assessed routinely by the institution's pediatricians. Research has demonstrated that children's physical growth is retarded when they are reared in poor psychosocial environments, such as is typically provided by traditional institutions (Hearst et al., 2014), regardless of nutrition and medical care (i.e., the "psychosocial short stature hypothesis;" Skuse et al., 1996). Further, improvements in the psychosocial environment alone have been demonstrated to improve children's physical growth, which in turn is related to improvements in their mental functioning and social-emotional behavior (St. Petersburg–USA Orphanage Research Team., 2008; Johnson et al., 2010). Therefore, physical growth was selected as an index of the potential benefit of these social-behavioral rearing changes for children's development.

Baseline physical growth before environmental changes

Samples of all children arriving in the two institutions during a specific calendar period of time before any changes were made provided a baseline of 3,795 height and weight measurements over age from 165 different resident children. The measurements were converted to standardized *z* scores according to the WHO Child Growth Standards (2017) which are based on non-institutionalized children. Non-institutionalized children would have a mean *z* score equal to 0.0 with a standard deviation of 1.00.

These measurements of height (left) and weight (right) are plotted in Figure 1 across age separately for children with (bottom) and without (top) profound disabilities as determined by the institution's pediatricians. Although these data are not strictly longitudinal, it is not likely that selective attrition influenced the developmental trends until the older ages.

These data show that, relative to non-institutionalized family-reared children, institutional residents as a group generally did not improve or decline much in mean relative standing over age. Instead, their growth profiles of standardized height and weight were predominately horizontal straight lines, increasing or decreasing only slightly over age.

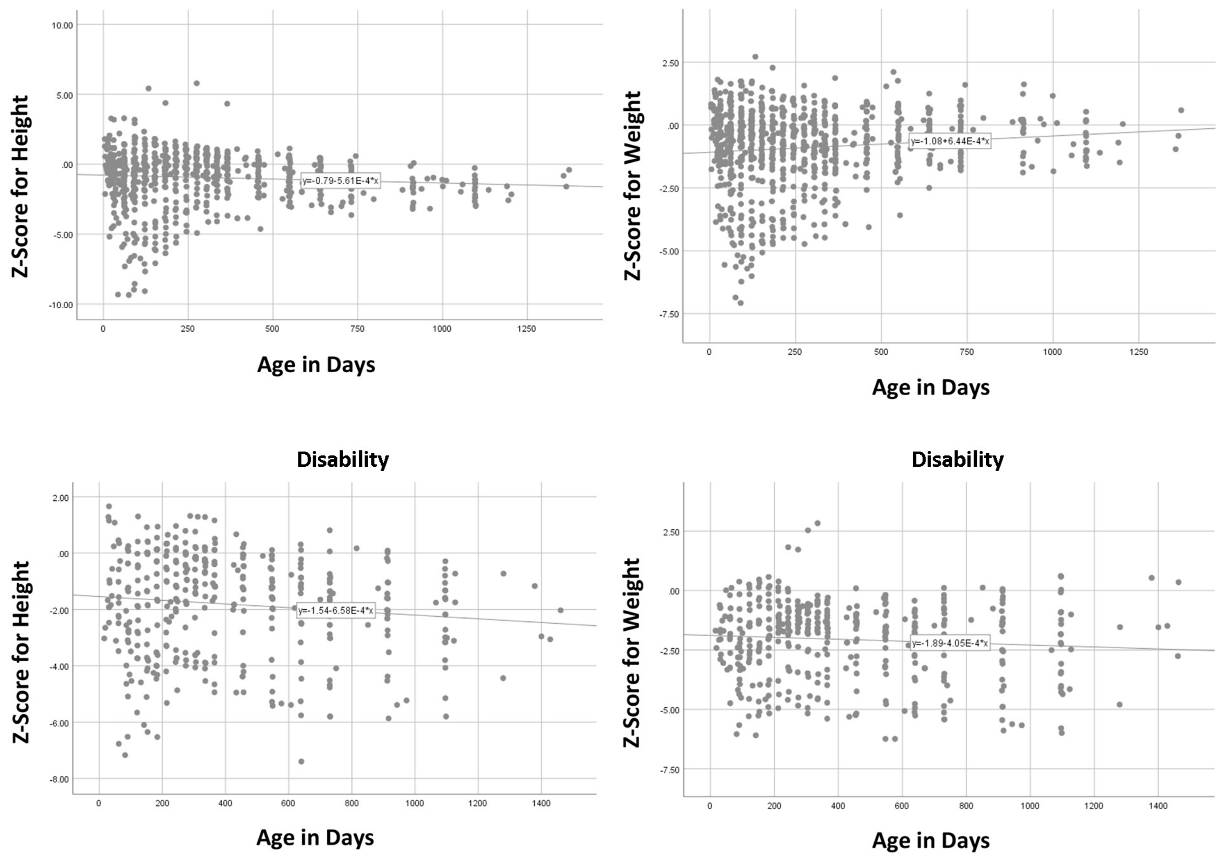

FIGURE 1
Plots of baseline height **(left)** and weight **(right)** *z* scores across age for typical **(top)** and children with disabilities **(bottom)** before interventions.

Similar to the previous study of institutional children in Kazakhstan (Hearst et al., 2014), the average level of physical growth was approximately one standard deviation below the average ($z = -1.00$) for non-institutional children, lower for children with disabilities. This means that ∼84% of non-institutionalized family-reared children would be taller and weigh more than the average institutional child of the same age and gender. As can be seen in the graphs, variability of measures was quite high at young ages, reflecting vast differences in children's personal and environmental circumstances prior to intake, but then children tended toward the institutional mean as they aged.

The effects of the ward changes on children's physical growth

Forty-five children experienced some form of the intervention. They did not differ from no-treatment baseline children in age, height, and weight *z* scores at intake to the institutions. Because some changes were implemented early and others not until later, of the 45 children in the two institutions who were ever assigned to intervention wards, only 11 experienced the full set of changes for at least 4 months within their first 2 years of life, a period when the effects of the intervention on physical growth have been shown to be most likely because physical growth typically occurs rapidly during this age period (Johnson et al., 2010). Again, although there are few cases, these 11 children were not obviously different from the non-intervention children or the 45 intervention children in terms of age, height, and weight at intake to the institution.

Figure 2 presents the growth profiles for six of the 11 infants who entered the newly completed wards within their first 12 months of life and stayed at least 4 months, when the effects of the intervention would be most profound. Assessments made before entering these special wards appear to the left of the doted vertical line, assessments between the dotted and dashed vertical lines were made before the intervention was completed, while those to the right of the dashed vertical line were made after the intervention was completely implemented. The abscissa represents days in residence in the institution.

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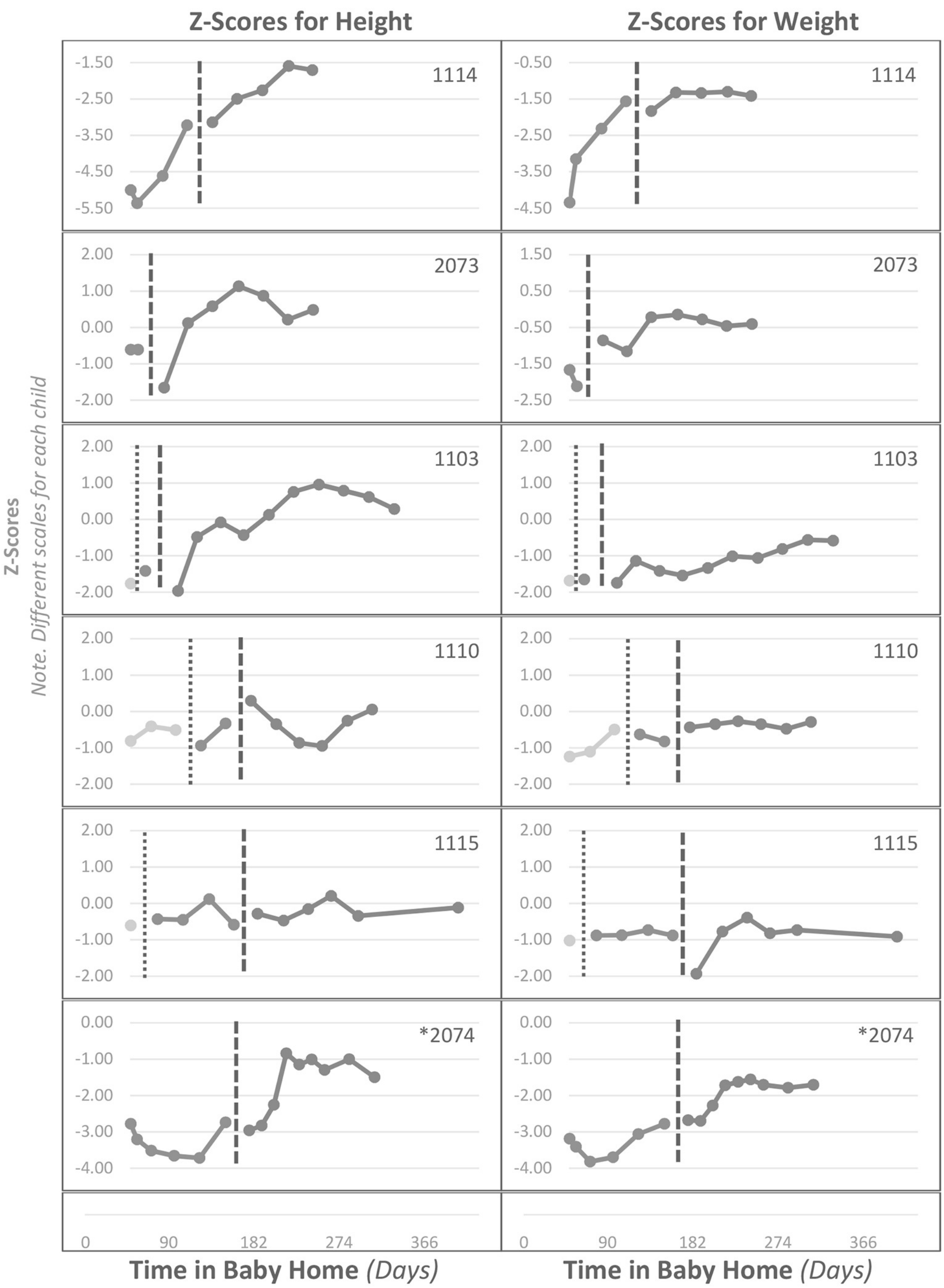

FIGURE 2
Individual infants' *z* scores across time in the institution (Baby Homes) for height **(left)** and weight **(right)** for infants entering the intervention before 12 months of age and remaining at least 4 months. Data to the left of the vertical dotted line are before entering the intervention, data between the dotted and dashed vertical lines are during an incomplete intervention, and data to the right of the dashed line are during the completed intervention.

These children entered the institution and began the completed intervention at different ages: #1103 (13, 43 days respectively); #1110 (67,184); #1114 (57, 122), #1115 (89, 256); #2073 (50, 78); #2074 (37,161). Child number *2074 had a disability. Figure 2 shows that the height and weight *z* scores for these six children at the start of the completed intervention were quite varied but were generally within the range of non-intervention children in Figure 2.

Four of the six infants, including one with a disability, showed substantial improvements of 1.5 to 2.0 standard deviations in height and approximately 1 standard deviation in weight. All four of these children entered the completed ward with "stunted" heights or nearly so ($z =< -2.00$), but none ended in stunted condition. One of the other two children irregularly reached new highs in height and regularly in weight, while the other child did not display an increasing profile. Of the six children entering the new wards in their first year of life, four ended with heights at or greater than the average of non-institutionalized family-reared children.

Two of these six children (#1114, #2074) displayed some increase in physical growth before entering the intervention. However, note in Figure 2 that these two children entered the institution extremely underdeveloped (z scores between -3.00 and -5.00). As illustrated in Figure 1, such children tend to progressively improve in growth up to the institution average with no special intervention; presumably the traditional institutional environment is better than their pre-intake environment.

Of the five children who entered the completely revised wards after 12 months of age, two showed clear gains, one as much as 2 standard deviations in height and 0.5 in weight. Two other children displayed modest reversals in pre-intervention declines, and one did not show systematic improvement.

Discussion

Most of children who were sufficiently exposed to the fully revised wards in their early months of life showed substantial increases in their physical growth, including one child with disabilities. Improvements were positive but less profound for children who entered the intervention in their second year of life. Although this case study had only a few infants fully exposed to the ward changes, these results are consistent with larger scientific studies of similar interventions (St. Petersburg–USA Orphanage Research Team., 2008), and they stand in contrast to the generally unchanging growth trends among a large group of untreated residents of these institutions.

Moreover, this result demonstrates that a strictly behavioral change in the caregiving environment can produce improvements in physical growth (St. Petersburg–USA Orphanage Research Team., 2008), and research shows that these improvements in physical growth are accompanied by increases in cognitive and social-emotional measures (St. Petersburg–USA Orphanage Research Team., 2008; Johnson et al., 2010), but these data were not available in this case.

As a community case study, this project lacked numerous procedural and other controls and descriptive details that would characterize a proper scientific demonstration of the intervention's effectiveness. The implementation of changes was left entirely to the discretion of the institutional directors and staff. For example, we do not know the details of how children and caregivers were selected to participate in the intervention (i.e., no random assignment), and we certainly would have liked a larger sample. We had no control over the age of infants when they entered or how long they remained in the revised wards. We know that the wards housed six to seven children ages 1 month to 4 years old most of the time, and that two primary caregivers shared duties during waking hours across the week and one of them was available every day (they were assisted by two other daytime caregivers and two night caregivers). But we have no measurements of caregivers' behavior with the children. Could these and other extraneous factors have contributed to the results?

Of course... Nevertheless, although the two institutions implemented the ward changes somewhat differently and each faced unique challenges and irregularities in their implementation, both created wards with fewer children who were of mixed ages and disability status, fewer and more consistently available caregivers, and more warm, sensitive, and responsive caregiver-child interactions. Further, children who were assigned to the special wards were not obviously different from children who did not experience these wards with respect to their age, height, and weight at intake to the institutions or to the completed intervention. Moreover, the effects on their physical growth occurred over their time in residence, not as a function of their initial values, diminishing concerns about selective sampling. Finally, these basic ward changes and the results on children's growth that we observed were similar to the outcomes of proper and comprehensive scientific studies in which these and other factors were controlled (St. Petersburg–USA Orphanage Research Team., 2008).

Conclusion

This community-led project illustrates that, with some outside training, local professionals and caregivers can implement changes in institutions' structure, employment patterns, and caregiver behavior that are associated with improvements in children's physical growth, especially in children entering the improved wards in their first year of life. Such improvements have been shown to be related to corresponding improvements in children's mental and social-emotional behavior while residents of the institutions (St. Petersburg–USA Orphanage Research Team., 2008) and years later after placement into families (Julian et al., 2019).

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: the physical growth data on residents of institutions are considered private and access to the data is not permitted by institutions. Inquiries regarding the datasets should be directed to RBM, mccall2@pitt.edu.

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

RBM, CG, AJ, and LM contributed to the design of the project. AJ organized, obtained, and interpreted the data. RJM, CG, and AJ contributed to the drafting and editing of the report. RBM, CG, RJM, OP, and BH contributed to the design and presentation of the training workshops. RBM, AC, and CS contributed to the design and interpretation of the data analysis. All authors contributed to the article and approved the submitted version.

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Conflict of interest

LM was employed by company International Assistance Group.

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.

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Investigating the effect of synchronized movement on toddlers' word learning

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The effect of interpersonal behavioral synchrony on children's behavior is an emerging field rich with research potential. While studies demonstrate its effect on affiliative and prosocial outcomes, the role of synchronized movement on children's specific learning outcomes has not yet been investigated experimentally. One possibility is that synchrony, as a coordinated social activity, encourages perceived social bonds, leading to heightened attention, and better information retention. Equally likely is that physiological, rather than social learning, mechanisms mediate the effect, given the previously demonstrated role of autonomic arousal in attentional fluctuations, cognitive engagement, problem solving, exploration, and curiosity. The present study investigated the behavioral and physiological effects of synchrony conceptualized as induced, interpersonal, behavioral, movement-based interaction, on word learning in 2.5-year-old children. In a laboratory experiment, toddlers engaged in either a synchronous or an asynchronous movement-based interaction with an adult experimenter while listening to an upbeat children's song. After the (a)synchronous movement episode, the same experimenter engaged children in a word learning task. During the (a)synchrony and learning phases, children's physiological arousal was continuously recorded, resulting in heart rate and skin conductance response measures. Following a caregiver-child free play break, children were tested on their novel word retention. The results indicated that children learned novel labels at equal rates during the learning phase in both conditions, and their retention at test did not differ between conditions: although above chance retention of novel labels was found only following the synchronous, but not the asynchronous episode, the cross-episode comparisons did not reach statistical significance. Physiological arousal indices following the (a)synchrony episode did not differ between conditions and did not predict better word learning, although skin conductance response was higher during the learning than the movement episode. This study contributes to our understanding of the underlying cognitive and physiological mechanisms of interpersonal behavioral synchrony in the knowledge acquisition domain and paves the way to future investigations.

KEYWORDS

toddlers, word learning, interpersonal synchrony, skin conductance, heart rate, behavioral synchronization

Introduction

The focus of social cognition investigations has recently undergone a dramatic shift from isolated intra-personal responses to stimuli to inter-personal dynamic interactions (Davis et al., 2018; Hoehl et al., 2021). One main result of this research has been that synchronized activities lead to increased cooperative and prosocial behaviors. For instance, synchronized behavior with a stable pattern (i.e., engaging in joint actions such as drumming, finger tapping, clapping, jumping, or rocking) both in adults and young children is strongly associated with prosocial outcomes such as cooperation, helping, affiliation, bonding, interaction quality, rapport, likeability, and attachment (Hove and Risen, 2009; Miles et al., 2009; Valdesolo et al., 2010; Cirelli et al., 2014; Pearce et al., 2015; Rabinowitch and Knafo-Noam, 2015; Tunçgenç et al., 2015; Nguyen et al., 2020). However, this rapidly growing research field has not so far shed light on the role of interpersonal behavioral synchrony on cognitive rather than social outcomes. In the current study, we ask whether synchrony facilitates learning that occurs in social contexts but pertains specifically to the knowledge acquisition domain. We thus tested the effect of induced interpersonal synchronized movement on novel word learning in toddlers.

Studies with infants and children have reliably demonstrated the effects of synchrony on prosocial outcomes (Cirelli, 2018). One seminal study with 14-month-olds explored the effects of interpersonal movement synchrony on children's prosocial behavior (Cirelli et al., 2014). To experimentally induce a state of (a)synchrony, infants were put in a front baby carrier and bounced either synchronously (in-phase and contingently) or asynchronously with an adult who stood in front of them while the infant listened to music. After the synchronous movement episode, infants were more likely to spontaneously help the experimenter in a prosocial task than after the asynchronous bouncing. In another study (Tunçgenç et al., 2015), 12-month-olds were rocked in a chair as they viewed a video of a toy (either a social one – a teddy bear that also established communication with the child, or a non-social one – a colorful box that produced sounds and lights) that was also positioned in a chair which rocked either synchronously or asynchronously with the child's chair movement. When later given the opportunity to select one of them, infants preferred to reach to or crawl towards the toys that moved in synchrony with them only in the social, but not in the non-social condition. The prosocial effects of interpersonal movement synchrony also transfer to infants' inferences and behavior towards adults uninvolved in the synchronous episode based on their social affiliations (Cirelli et al., 2016; Fawcett and Tunçgenç, 2017). Studies with preschoolers also showed that similarly induced synchrony enhanced children's peer cooperation, imitation of, perceived similarity and closeness towards each other (Rabinowitch and Knafo-Noam, 2015; Rabinowitch and Meltzoff, 2017; O'Sullivan et al., 2018). In addition, the literature has documented the effect of synchrony on norm learning and ritualistic behavior (e.g., Herrmann et al., 2013), highlighting its importance for effective cumulative cultural knowledge transmission (Watson-Jones et al., 2021).

Extending and enriching these behavioral findings, a new generation of studies using hyperscanning approaches shows that behavioral synchrony leads to inter-brain synchrony through brain coupling (Dumas et al., 2010; Hasson et al., 2012; Hu et al., 2017). Early childhood studies using dual EEG and fNIRS approaches have reported that adults' brains predictively synchronize to infants' neural responses during social interaction (Leong et al., 2017; Wass et al., 2018) and support the conclusions that synchronized movements effect a range of interpersonal prosocial outcomes (Markova et al., 2019; Miller et al., 2019; Hoehl et al., 2021).

Unlike with prosocial outcomes, research into the effects of synchrony on specific learning outcomes so far is scarce and has produced inconclusive results. In a study with adults engaged in teaching and learning novel labels from each other following either a synchronous or asynchronous activity, synchrony did not lead to better word learning, although it had led to an increase in teacher-learner rapport (prosocial outcome) and inter-brain synchronization (Nozawa et al., 2019), in line with other hyperscanning studies with adults reporting associations between the brain activities of learners and teachers (Holper et al., 2013; Takeuchi et al., 2017). However, in another adult study, in addition to finding that teachers' brains synchronized with learners', the teaching outcome (here, numerical reasoning) was predicted by the interpersonal neural synchrony when the brain activity of the teacher preceded that of the learner (Zheng et al., 2018). Further, synchrony led to greater memory for details about people with whom participants were synchronized, but not greater generalized memory capacity (Miles et al., 2010). Overall, research with adults to date suggests a positive predictive role of the learner-teacher synchrony on learners' engagement and attention during the explicit pedagogical process (Cheng et al., 2021), although this interim conclusion needs to be treated with caution due to mixed results and methodological inconsistencies (Hu et al., 2022).

Longitudinal studies with children showed that synchrony, broadly defined as responsive attunement, in infant-mother interaction predicted children's subsequent school adjustment (Harrist et al., 1994) and verbal IQ (Feldman, 2007). Relatedly, though not measuring synchrony as such, specific learning outcomes such as vocabulary and math scores have been shown to benefit from teacher-child bonding (Lowenstein et al., 2015; Spilt et al., 2015; Roorda et al., 2017). Of crucial note, however, is substantial variability in the definition and conceptualization of synchrony in the developmental literature dealing with synchrony-related constructs (Harrist and Waugh, 2002). Broadly, one approach emphasizes contextual, cultural, and relational factors focusing on both inter-individual variability and intra-individual dynamics of behaviors (Jaffe et al., 2001; Feldman, 2006, 2012) and approaching synchronization as a complex dynamic system in development (Thelen and Smith, 1998; Mayo and Gordon, 2020).

For example, when working together to solve a puzzle task, child-caregiver neural synchrony predicted coordinated problem-solving success in preschool children (Nguyen et al., 2020). On the other hand, there is also an extensive literature where synchrony in a dyad is conceptualized as temporal coordination, e.g., naming objects in synchrony with moving them in front of the child (Matatyaho and Gogate, 2008), with the effects of such turn-taking, intermodal, temporal synchrony on language development well documented (Rohlfing and Nomikou, 2014; Nomikou et al., 2016). For example, naturally occurring adult (both mother and stranger)-infant vocal rhythmic coupling at age 4 months predicted not only attachment, but also higher cognition scores on the Bayley Scales, at age 12 months (Jaffe et al., 2001). Nevertheless, while acknowledging these distinct and rich traditions in the study of synchrony, these only indirectly point to the hypothesized effect of interpersonal behavioral synchrony on learning in a specific knowledge acquisition sense. In sum, while interpersonal synchrony includes positive effects on children's emotional and social experience (Leclère et al., 2014), its direct effects on specific memory and learning outcomes remain under-studied.

One of the greatest challenges facing researchers in this domain is identifying the underlying mechanisms behind the link between interpersonal synchrony and its outcomes (for reviews, see Cirelli, 2018; Davis et al., 2018; Hu et al., 2022). Broadly, two groups of mechanisms have been proposed: a higher-level socio-cognitive, and a lower-level neuro-physiological mechanism. The socio-cognitive, top-down process proposes that synchrony arises as a result of higher-level social perceptions or cognitive appraisals of the synchronous social situation (e.g., Baimel et al., 2015). Synchrony thus motivates prosocial behavior through forming domain-specific social representations. Another explanation, a bottom-up process, suggests that synchrony arises from neurobiological rhythms due to detecting perceptual contingency in mutual movement, gaze, and action such as finger tapping, or engaging in joint musical activity. In turn, this entrainment to social rhythms activates domain-general attention mechanisms in the social context and stimulates prosocial interactions (e.g., Markova et al., 2019). The two mechanisms may be complementary rather than alternative to each other, explaining the same phenomenon at different levels. Indeed, the evidence for these mechanisms is so far mixed and suggests that both processes might be at play at the same time. Moreover, as the investigated outcomes primarily related to prosociality and cooperation, the hypothesized mechanisms might be limited to these accumulated empirical findings.

Along with the effect of synchrony on prosocial outcomes, as part of the same mechanism there may be also an effect on specific learning outcomes in a social context. It is possible that synchrony also leads to heightened learning readiness or better encoding of information that was acquired while in the state of synchrony with the social partner. Within the top-down socio-cognitive framework this would be expected if higher-level affiliative judgements and perceived similarity due to enhanced and enriched social interaction during synchrony transfer to the learning domain. This stronger affiliation to the learning partner could then affect, for example, how learners evaluate information provided by others or their desire to live up to the expectations arising in direct pedagogical context, and lead to a higher chance of encoding new information. At the same time, bottom-up, biological synchronization may drive attention mechanisms, in that teachers who are in sync with learners may provide them with necessary attention modulation to keep them focused on learning, and such attention, as a lower-level attribute, may lead to better learning, and information retention.

Study motivation

As detailed above, the effect of interpersonal synchrony on children's behavior is a rapidly expanding field rich with research potential. Studies have shown that experiencing interpersonal synchrony encourages affiliative and prosocial behavior in children. However, the role of directly experienced behavioral synchrony on specific learning outcomes in early childhood has not yet been directly investigated experimentally. If such a relationship exists, there may be several possible cognitive mechanisms underlying it. One possibility is that synchrony, as a coordinated social activity, encourages perceived social bonds between the child and the adult, which leads to heightened attention and better information retention. Equally likely, the physiological, rather than social learning, mechanisms could be responsible for the hypothesized relationship. The proposed study aims to investigate if the effects of synchrony extend to learning, and if there are psychophysiological markers of it. Importantly, it was not designed to tease apart which of the two mechanisms is at play, but rather capture the effect of synchrony at both behavioral and physiological levels. Whichever causal mechanism is in place, it is plausible to expect that the increased physiological arousal associated with synchrony leads to higher rates of learning.

The current study

For the purposes of this study, we conceptualized synchrony as a rhythmic movement to music occurring without the child's active intention, but randomly assigned and controlled by others, which leads to achieving interpersonal synchrony with a stranger in a momentary interaction. This allowed us to isolate the process of synchronization in an experimental, highly controlled setting, and was in line with prior seminal experimental lab-based research with infants and young children, where synchrony was induced by a rocking chair, swing-set apparatus, or another person's movement (Cirelli et al., 2014; Tunçgenç et al., 2015; Rabinowitch and Meltzoff, 2017).

We induced the experience of interpersonal (a)synchrony between 2.5-year-old children and the experimenter in a laboratory setting. Children sat on their caregiver's lap. Both caregiver and experimenter wore headphones through which a song was played, either synchronized or not. The experimenter moved, and the caregiver rocked the child from side to side, according to the beat of the song they were listening to, resulting in either a synchronous or asynchronous movement between the child-caregiver dyad and the experimenter. Following this phase, children engaged in a novel word learning task facilitated by the same experimenter (Horst and Samuelson, 2008). During the synchrony and the learning episodes, we also measured children's physiological arousal (measured by heart rate and skin conductance response signals derived from a wearable wristband device, Empatica E4) conceptualized as an index of heightened attention and interest.

We predicted that interpersonal behavioral synchrony would differentially affect children's learning, in that following a synchrony episode, children would successfully retain more new words than following an asynchrony episode (Hypothesis 1). We further expected that physiological arousal level would be higher during synchrony (Hypothesis 2) and that at an individual level, heightened arousal would predict higher rates of successful word retention (Hypothesis 3).

Materials and methods

Participants

Participants were typically developing 2.5-3-year-old children ($N = 40$; 17 males, 23 females; $M_{age} = 32.08$ months, $SD_{age} = 1.53$ months; range 28–34 months) and their primary caregivers, recruited from a database of families in the Northwest of England who had voluntarily expressed interest in participating in infant studies. Participating families were reimbursed for travel expenses and children received a book as a gift, in accordance with standard laboratory practices. The study received university ethics committee approval and caregivers provided informed written consent. The experimental protocol was preregistered on April 15, 2019, prior to the start of the data collection and is available at[1]. Data collection took place between April 2019 and August 2019.

The sample size was determined *a priori* using the G*Power analysis software (Faul et al., 2007), which indicated that a sample size of $N = 18$ would be sufficient to produce a large effect size (with a power of 0.80 and alpha of 0.05) based on the main statistical analysis. We collected data from 40 children randomly assigned to two conditions (synchronous and asynchronous) with 20 children in each. Additional 7 participants were tested but their data excluded for the following reasons: child fussiness or refusal to take part in the procedure at any phase of the experimental design resulting in an incomplete dataset ($n = 6$) and technical error (missing video recording, $n = 1$).

1 https://osf.io/qa5gc

Experimental procedure and materials

Upon arriving to the laboratory, caregivers received instructions during the consenting procedure. The child, upon their verbal assent, was fitted with an Empatica E4 wearable wristband device to measure physiological arousal (heart rate and electrodermal activity)[2] (Empatica Inc., 2015; a wearable research device validated in adults; van Lier et al., 2020) and successfully used in developmental and atypical populations (Mehr et al., 2017; Bainbridge et al., 2021). The band was positioned on the child's leg as close to the foot as possible on either calf or ancle, depending on the size of the child, which was in line with other studies using the same research device and the manufacturer's recommendations (Bainbridge et al., 2021). As an incentive to attaching the band, an attractive sticker of the child's choice was placed on the band and the child was told that when they were all done, they would be allowed to keep the sticker.

The experimental flow is presented in Figure 1. The procedure consisted of an interpersonal movement episode, followed by a warm-up and novel label learning phase, a play break, and concluded with the test phase to assess novel label retention. Children were randomly assigned to either a synchronous or an asynchronous condition using a between-subject design. The experiment was recorded using a single video camera and lasted approximately 15 min.

The interpersonal movement synchrony between the experimenter and the children was manipulated by asking the caregiver to playfully rock their child to a 2 min children's song (the "Happy Song" by Imogen Heap[3]) played out loud with a constant beat of 84 bpm. Children sat on their caregiver's lap on the floor, facing the experimenter who sat across from them on the floor at a distance of approximately 1 m (Figure 2).

Half of the sample ($n = 20$) experienced a synchronous movement episode with the experimenter. Specifically, their caregiver rocked the child side to side to the beat of the song (as heard through the programmed headphones) and the experimenter mirrored this, rocking side to side, to produce a synchronous movement episode. The other half of the sample ($n = 20$) was also rocked by their caregiver side to side to the beat of the song, however, the experimenter in this case rocked asynchronously – with beats either 33% faster or slower than the caregiver rocking the child to the song's beat (adapted from Cirelli et al., 2014 design). In both conditions, both the parent and the experimenter wore headphones that played metronome beats to which they rocked side to side, but not the music. Children instead heard the song played out loud through the speakers, but not the metronome beats. The song's rhythm and the caregiver's rocking were always congruent to each other, while the experimenter's

2 The experimenter's physiological response was also recorded using the wristband, as pre-registered, however, these data are not being reported here.

3 http://imogenheap.com/thehappysong

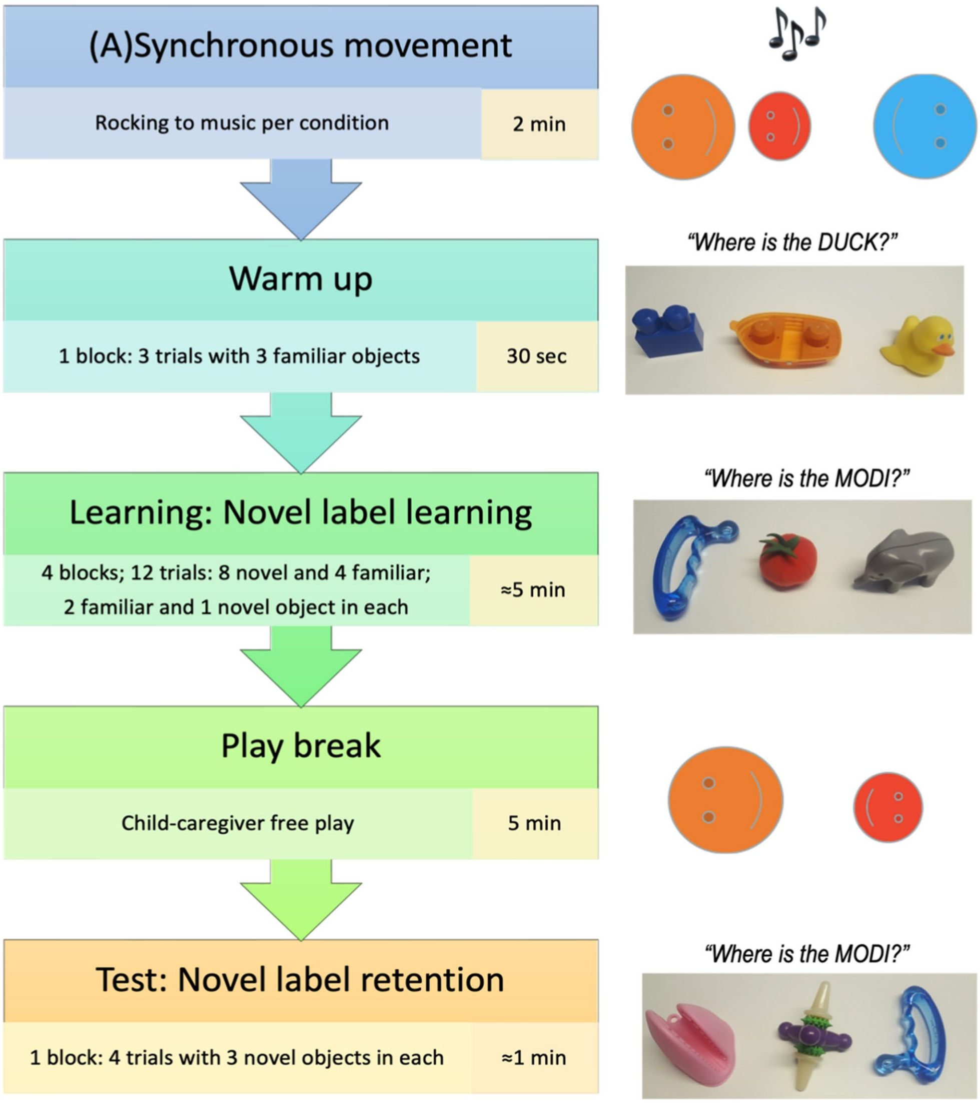

FIGURE 1
Experimental flow.

rocking varied according to condition. The caregivers sat cross-legged with their child on their lap and created the sideways rocking motion by lifting either leg up slightly in alternating order. Caregivers were instructed to refrain from otherwise actively interacting with their child throughout the study, aside from completing the rocking motion and encouraging their child to engage with the experimenter if the child lost attention at any point. This episode lasted 2 min.

Following the (a)synchrony episode, children engaged in the word learning task with the same experimenter. They independently sat at a table across from the experimenter with the caregiver sitting behind and to the side of them (Figure 2), and the experimenter presented the tray with objects and labels.

The word learning task consisted of two phases: learning and retention test. The learning phase was a referent selection task (based on Horst and Samuelson, 2008), in which the child had an opportunity to learn 4 pseudo words (*koba, modi, blicket, and toma*) for 4 novel objects in trials where at each trial, two familiar objects were paired with one novel object and the novel label was introduced. Objects were presented by the experimenter on a tray with three sections next to each other. The warm-up block consisting of three trials familiarized the child to the referent selection procedure with three familiar objects, proceeding to the word learning task. On each learning trial the experimenter presented the tray with three objects, two familiar and one novel, and asked the child to choose a novel object labeled with the pseudo word ("I see a [familiar/novel object]! Can you see a [familiar/novel object]? Can you pass me the [familiar/novel object]?"). The experimenter made eye contact with the child upon presenting the tray and maintained the gaze on the child, not the tray, until the child made a selection (by pointing at it, touching it, reaching for it, or handing it over), and provided

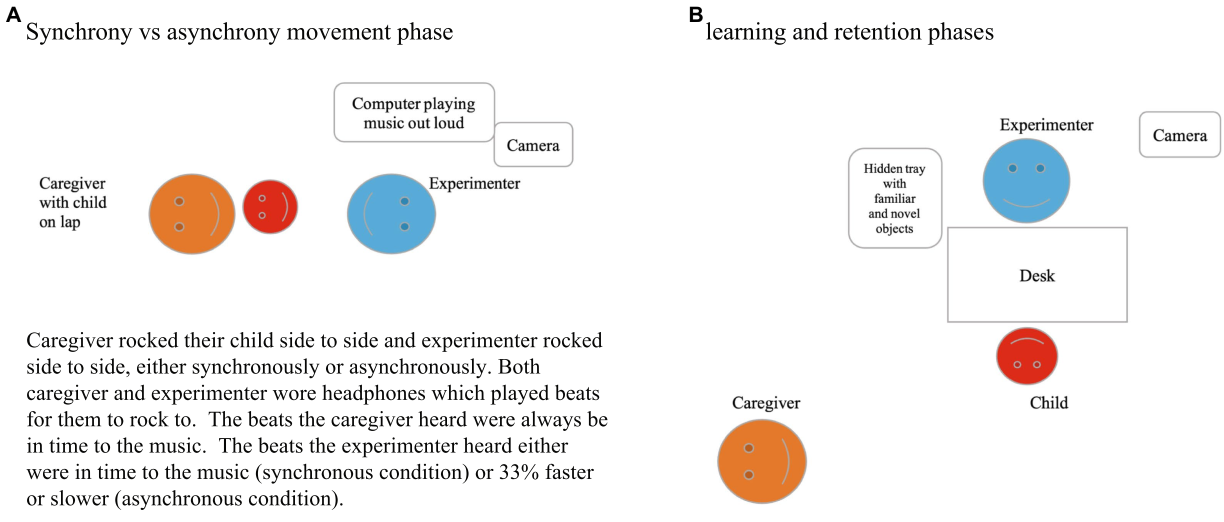

FIGURE 2
Experimental setup.

positive reinforcement to the child regardless of the selection. In total, children received four familiar and eight novel referent selection trials (2 for each novel object). The experimenter asked for the novel objects during the first two trials, and for the familiar objects during the last trial of each block, and repeated this process for each of the three novel object-label pairs in a pseudo-randomized order.

Familiar objects selected for the task (Figure 3) were in line with the CDI norms data (Frank et al., 2016). The objects were selected from two categories – food items and animals – and grouped so that one object from each category was presented with the novel object during each trial of the referent selection phase.

Following this referent selection phase and prior to the retention phase was a free-play 5 minute episode during which the experimenter left the room, and the child could play with a range of toys on the floor of the testing room. Caregivers were explicitly asked to ensure that children did not approach the objects' tray.

For the retention phase the experimenter returned to the room and the child again sat at the table across from the experimenter as during the learning phase. In the test phase, children's retention of the learned referents was assessed. On each of the four test trials, the experimenter presented the tray containing three of the previously seen four novel objects, in a pseudo-randomized order, and asked for one of them ("I see a [pseudo word]! Can you see a [pseudo word]? Can you pass me the [pseudo word]?") such that each novel object was asked for once. After choosing an object (by pointing at it, touching it, reaching for it, or handing it over) the child was thanked; no feedback on the correctness of the choice was given.

The physiological response was measured using the wristband continuously throughout the (a)synchronous episode and the word learning task, with the first event marker signifying the start of the (a)synchronous episode and the second event marker signifying the start of the word learning task. The experimenter removed the band before leaving the room for the free play break preceding the word recall phase.

Measures and coding

Manipulation check and *post hoc* behavioral control coding

To ensure the synchronous and asynchronous conditions were reliably achieved, we coded the degree of synchrony during the movement episode. First, two blind coders (with second coder coding 20% of the participants, $n = 8$) made a judgment of the condition based on the observed synchrony in the movement of the caregiver with the child and the experimenter. Second, the coders rated the level of synchronization in the dyads during the movement episode using a Likert-type scale (1 – absolutely non-synchronous, 4 – sometimes synchronous, sometimes non-synchronous, and 7 – absolutely synchronous). The raters' agreement was very high, indicating that blind coders could reliably guess the condition (Kappa = 1 for condition guess and Cronbach's alpha = 0.991 on ratings of synchronization). Confirming the successful manipulation check, the level of synchronization was significantly higher in the synchronous ($M = 6.6$, $SD = 0.6$) as compared to the asynchronous condition ($M = 1.68$, $SD = 0.75$), as demonstrated by an independent-samples t-test $(38) = 22.7$, $p < 0.001$].

Further, to check whether the experimenter displayed equal levels of positive affect (operationalized as the rate of smiling while making eye contact with the child) during the movement phase in both conditions, the coders assessed it using a Likert-type scale (frequency of smiling: 1 – very rarely; 2 – rarely; 3 –

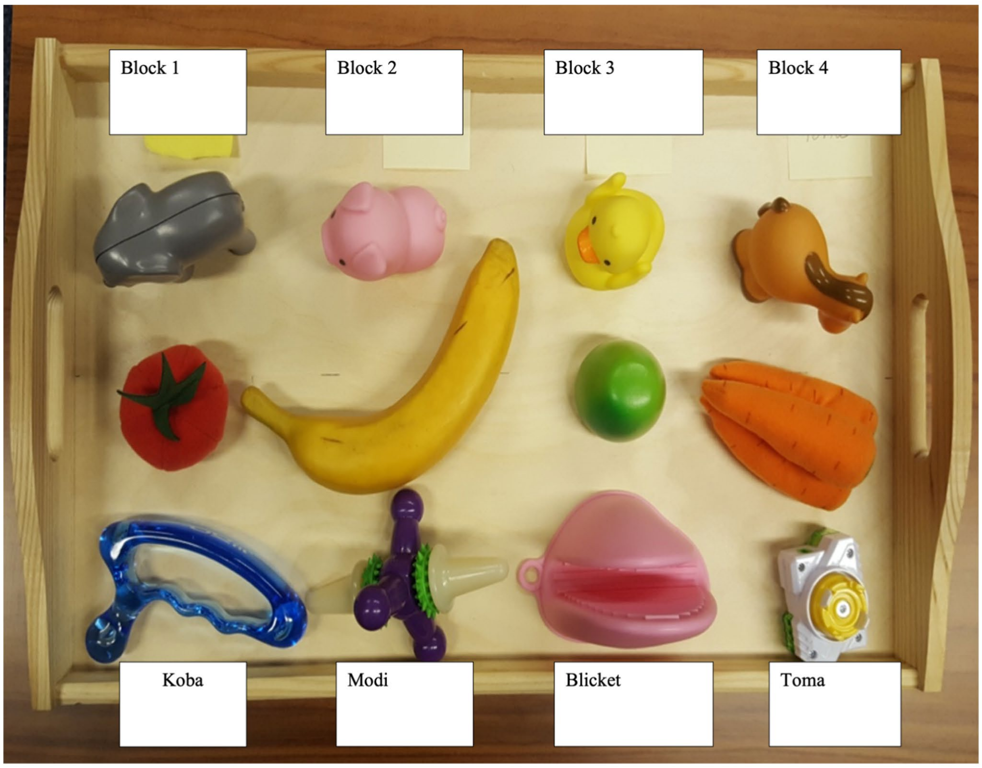

FIGURE 3
Learning phase: Novel label learning task objects.

sometimes, 4 – often, and 5 – very often). The child's positive affect was also coded in the same manner. The inter-rater reliability was very high (Cronbach's alpha = 0.991 on both ratings). The results of the independent-samples *t*-test support the assumption that the experimenter's positive affect was consistent between conditions, $t(37) = 1.54$, $p = 0.066$ ($M_{sync} = 5.0$, $SD = 0.0$; $M_{async} = 4.89$, $SD = 0.32$), and the children also displayed similar levels of smiling during both conditions, $t(32) = -0.837$, $p = 0.204$ ($M_{sync} = 2.06$, $SD = 1.4$; $M_{async} = 2.5$, $SD = 1.63$), confirming that the movement (a)synchronization was indeed the distinguishing feature of the condition assignment.

Finally, the free-play episode was also coded *post hoc* to ensure there was no mention of the preceding learning phase by the caregivers or children, which may have influenced the retention of the word-object pairs as measured at test. The coders noted the number of times the parent mentioned novel objects or words learned in Learning phase. The coders' agreement was 100% and no caregiver in this sample mentioned the stimuli during this break.

Behavioral measures

During the word learning task, children received four familiar and eight novel referent selection trials and four retention trials. The following three variables were computed: (1) The number of familiar objects correctly selected during the referent selection phase; (2) The number of novel target objects successfully selected during the referent selection phase; (3) The number of novel words successfully retained at test. The referent selection and object choices were coded offline from the video recordings, indicating whether the child selected the correct object (e.g., a novel object referred to as *koba* on the tray that presented it along with two familiar objects; see Figure 1) by pointing at it, touching it, reaching for it, or handing it over to the experimenter. The main coder coded 100% of the videos and the second coder coded 20% of the videos ($n = 8$; 4 from each condition), reaching perfect reliability (Cohen's Kappa = 1). Both coders were blind to the analyzed condition (synchronous or asynchronous). For each of these outcome variables, the proportion of correct choices was calculated by dividing the number of correct responses by the total possible (i.e., 4 for familiar trials, 8 for novel trials, and 4 for retention trials).

Physiological measures

The physiological response data acquired during both phases (synchrony and word learning) were averaged to produce the heart rate and skin conductance level indices during the (a) synchrony and the word learning phases. Each sensor's sample rate was embedded in the output provided by the manufacturer

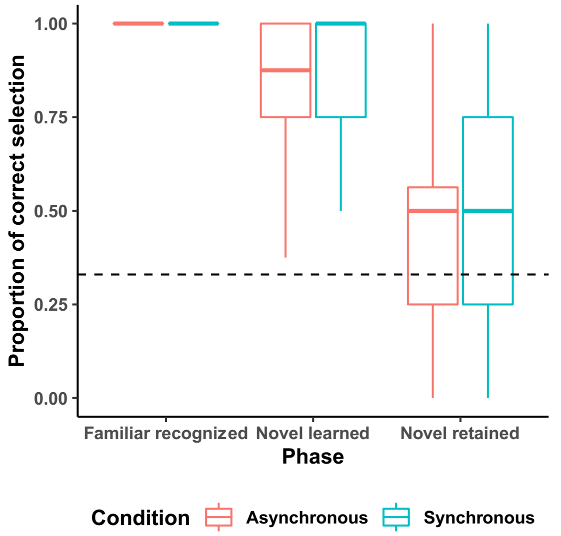

FIGURE 4
Proportion of retained words at test across word learning task phases. Boxplot of the proportion of the correctly selected objects in each of the three phases of the word learning task, with the dotted line indicating the chance level (0.33) and the solid lines indicating the median values.

and optimized to capture the frequency content of relevant signals (Empatica Inc., 2015).[4]

The heart rate data from Empatica E4 is indexed as blood volume pulse (BVP; sampled at 64 Hz) with data from photoplethysmograph (PPG) and inter beat intervals (IBI; intermittent output with 1/64 s resolution). We used inter-beat intervals as our primary measure; these were computed by Empatica's proprietary algorithm, which automatically imputes missing data from the photoplethysmograph signal and corrects for motion artifacts; with some segments in time devoid of IBI data (refer to Empatica E4 wristband User's Manual). We first identified the data points that corresponded in time to each of the two experimental phases (movement episode and word learning phase), as signified by two event markers recorded through the manual presses on the physiology band by the experimenter. To make the IBI data correspond to the EDA data on a time scale, we extrapolated the IBI data to 4 samples per second by computing duplicate values if needed. We selected a baseline period of 30 s immediately before the start of the movement phase. We then averaged z-scored values for each experimental phase and computed a difference score between averaged values and baseline values to control for individual differences.

The data from the electrodermal activity sensor (EDA, sampled at 4 Hz in μS, i.e., four samples per second) was indexed as the basal tonic skin conductance level (SCL), which is relatively stable and associated with gradual changes in skin conductance. We subtracted the skin conductance response amplitudes from the tonic signal to establish a better representation of SCL. The Ledalab[5] software based on MATLAB (The MathWorks, Inc., Natick, MA, and United States) was used for raw signal processing as recommended by the wristband manufacturer. Signal processing submits raw data for decomposition analysis and feature extraction of the EDA signal. Extracted SCL data were visually inspected for movement artifacts (atypically large spikes or drops in the amplitude) and low signal quality which were excluded from the cumulative measures. We exported z-scored values from Ledalab, averaged z-scored values for each child's SCL for each of the two experimental phases and computed the baseline-corrected difference score.

Results

> *Hypothesis 1*. Effect of synchrony on word learning.

All children correctly identified the familiar object-referent pairs. The proportions of correctly selected novel objects during the word learning task were as follows: novel objects selection at learning: Synchrony condition: $M = 0.89$, $SD = 0.16$; Asynchrony condition: $M = 0.82$, $SD = 0.2$; novel objects retention at test: Synchrony condition: $M = 0.49$, $SD = 0.31$; Asynchrony condition: $M = 0.44$, $SD = 0.31$ (Figure 4).

We pre-registered to conduct a 2 (condition: synchronous or asynchronous) × 3 (trial type: familiar recognized vs. novel learned vs. novel retained) mixed analysis of variance. As the assumptions for the parametric analysis were not met, we instead conducted the non-parametric equivalents and performed the Mann–Whitney tests on novel learned and novel retained phases. There were no significant differences between conditions in either phase; novel learned phase: Synchrony ($Mdn = 1$), Asynchrony ($Mdn = 0.88$), $U = 153$, $p = 0.17$; novel retained phase: both $Mdn = 0.5$, $U = 184.5$, $p = 0.68$, indicating that children learned and retained novel labels at equal rates in both synchronous and asynchronous movement conditions.

Next, we conducted one-sample *t*-tests to calculate if children retained the novel referents at proportions above chance, with the chance level set at 0.33 for all reported tests. Further, a Bayes Factor analysis was performed to obtain support for either the alternative or the null hypothesis for each of the main analyses with a half normal distribution (implying a maximum possible effect size of 0.707). For the Bayes Factor analyses, we used the system proposed by Jeffreys, (1961) to interpret the size of a BF: $BF_{01} < 3$ is considered moderate support for the null hypothesis, $BF_{10} > 3$ is considered moderate support for the alternative hypothesis. These analyses revealed the above-chance retention of novel labels only in the synchronous [$t(19) = 2.28$, $p = 0.03$;

4 https://www.empatica.com/en-gb/manuals/

5 http://www.ledalab.de

$BF_{10} = 2.65$, $M = 0.49$, $SD = 0.31$], but not the asynchronous condition [t (19) = 1.54, $p = 0.14$; $BF_{01} = 1.14$, $M = 0.44$, $SD = 0.31$]. Nevertheless, the Bayes Factors indicated insufficient support for either hypothesis.

We therefore conclude that we could not reject the null for our hypothesis 1.

> *Hypothesis 2.* Effect of synchrony on physiological arousal.

We pre-registered to conduct a 2 (condition: synchronous or asynchronous) × 2 (phase: (a)synchrony movement vs. learning) mixed analysis of variance (ANOVA) on each of the physiological arousal indices. Due to fussiness and/or technical issues, 13 participants had missing or incomplete Inter-Beat-Interval (IBI) data, resulting in a reduced sample size of 27 children ($n_{\text{Async}} = 14$, $n_{\text{Sync}} = 13$) in this analysis. Similarly, due to fussiness and/or technical issues, 3 participants had missing or incomplete Tonic Skin Conductance Level (SCL) data, resulting in a reduced sample size of 37 children ($n_{Async} = 19$, $n_{Sync} = 18$) in this analysis. As this relatively small sample size may reduce the power of ANOVA, we instead ran independent sample *t*-tests for arousal indices in two conditions, and pairwise *t*-tests for arousal indices in the movement and learning phases, both to look at the effect of the condition and the effect of the phase (Figure 5). Further, due to the SCL data not being normally distributed, we used the non-parametric alternatives: Mann–Whitney test for SCL between conditions, and Wilcoxon signed-rank test for SCL between phases.

For IBI data, no significant result was found between conditions [$M_{Sync} = 0.19$, $SD = 0.69$, $M_{Async} = 0.19$, $SD = 0.73$, $t(52) = 0.002$, $p = 0.998$] and phases ($M_{movement} = 0.13$, $SD = 0.69$, $M_{learning} = 0.25$, $SD = 0.72$, $p = 0.53$).

For SCL data, no significant result was found between conditions ($Mdn_{Sync} = 1.31$, $Mdn_{Async} = 1.07$, $U = 665$, $p = 0.84$). However, we found SCL during the learning phase ($Mdn = 2.20$) significantly higher than during movement phase ($Mdn = 0.53$), $V = 73$, $p < 0.001$.

Overall, despite finding higher SCL arousal in learning as compared to the synchronized movement phase (but not higher IBI), we did not find different levels of arousal between conditions, in contrast to our hypothesis 2.

> *Hypothesis 3.* Effect of synchrony and arousal on word learning.

We fitted a multiple linear regression as pre-registered to investigate the role of the hypothesized predictors for novel label retention. Due to data loss caused by fussiness and/or technical issues for both IBI and SCL, this regression was conducted with a sample size of 26 participants out of 40 ($n_{Async} = 13$, $n_{Sync} = 13$). We used the proportion of retained labels as the dependent variable, and age, gender, the proportions of the novel learned words or the familiar words recognized, the group (synchronous or asynchronous), and the IBI and SCL as independent variables. The model yielded no significant results (*p*s > 0.27), suggesting that neither IBI nor SCL, nor any other factors in our model, predicted label retention.

Furthermore, as our main question was whether physiological arousal levels in different condition groups predicted the learning outcome, the pre-registered regression model may not be able to answer this question fully. Therefore, we conducted additional linear regressions separately for IBI and SCL to look at whether the interaction of condition and arousal levels predicted the learning outcome. For each model, we submitted the word retention proportion as a dependent variable, interaction of condition and arousal (IBI or SCL), as well as IBI or SCL as a predictor, along with age and gender. Results revealed a main effect of SCL on the word retention proportion (ß = − 0.17, $p = 0.050$), suggesting increased SCL predicted poorer performance during word retention regardless of condition. Neither main effect of IBI, nor any of the interaction effects, age or gender predictors revealed significance, *p*s > 0.062.

Exploratory analyses

Given the null results, we conducted two exploratory analyses we did not pre-register to investigate the label retention at the trial level and to look at the individual differences in the physiological arousal indices.

First, instead of the proportion, we used the raw accuracy scores from each of the four trials of the retention test phase (assigning a score of 1 for a correct and 0 for an incorrect response). A generalized linear mixed effects model (GLMM) was fitted with the raw accuracy as a dependent variable, condition (synchronous vs. asynchronous) and the word learning task trial type (novel vs. retained labels selection), as well as their interactions, as fixed effects, and with participant as a random effect. Results revealed a significant main effect of the phase, $X^2(2, 40) = 131.71$, $p < 0.001$. No other significant results were shown (*p*s > 0.281). This additional test is consistent with the results of the pre-registered analyses.

Our second step stemmed from the main analysis showing that the IBI did not significantly differ between conditions or phases, motivating us to further investigate the relationship between heart rate change and novel word retention at the trial level. We computed the Pearson's correlation between the IBI data and the movement and the learning phases. The results showed a medium positive correlation between IBI across the two phases ($r = 0.58$, $p = 0.004$), suggesting presence of individual differences (see Figure 6).

Next, to clarify whether the individual differences in the IBI changes were influenced by condition, a GLMM was fitted with the IBI difference score as the dependent variable, condition as a fixed effect, and participant as a random effect. Here we calculated the changes in the IBI by using absolute IBI values between the movement and learning phases for each individual. This analysis yielded no significant results,

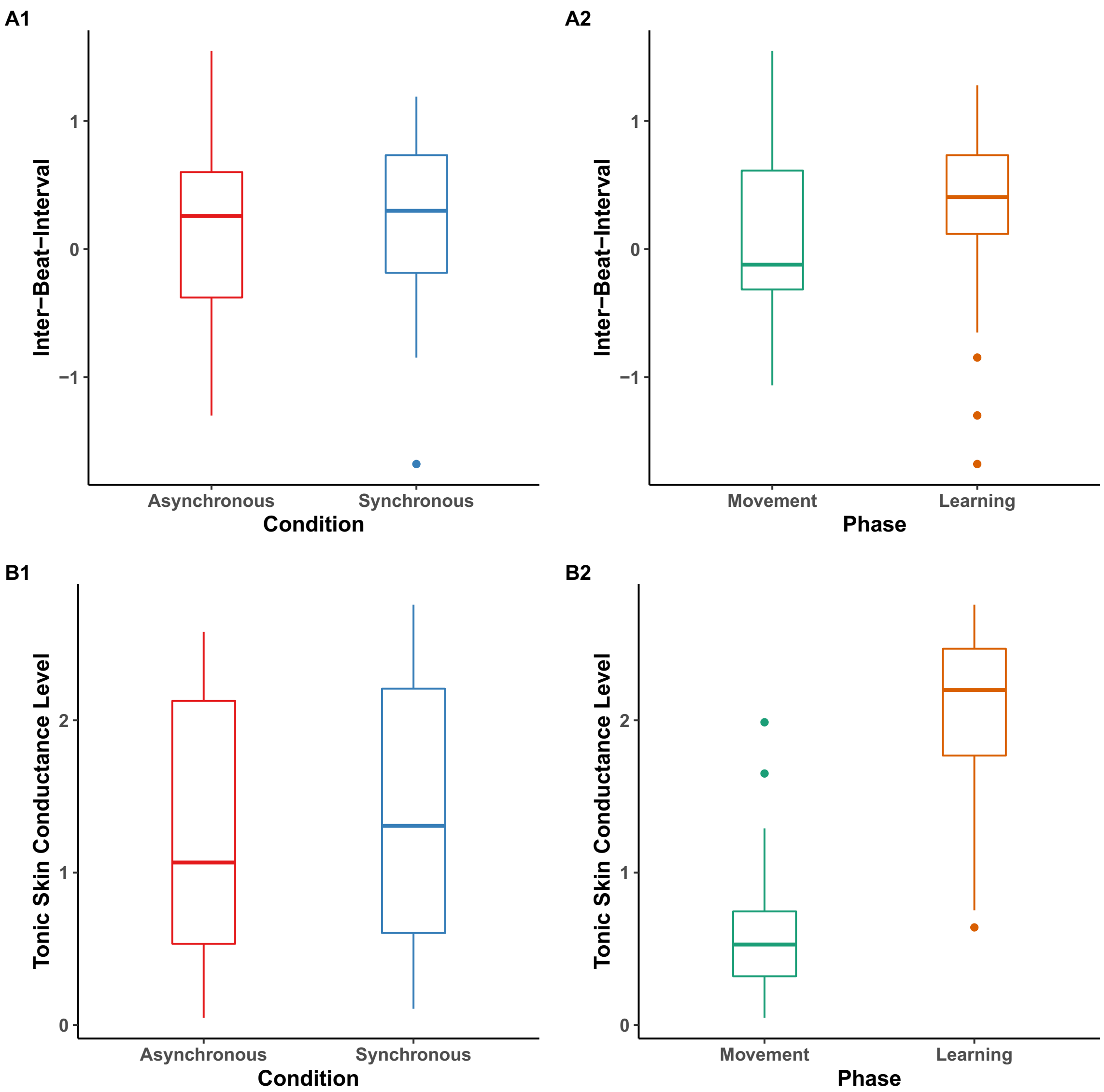

FIGURE 5
Inter-Beat-Interval (IBI) and Tonic Skin Conductance Level (SCL) baseline-corrected difference scores in z values across phases and conditions. Box plot of IBI (A1, A2) and SCL (B1, B2) across phases and conditions. The midline in the box represents the median values of each condition/phase, outliers are shown as circles, and the error bars represent the 95% CI.

ps > 0.22, confirming that the individual differences visually present in changes in the IBI (Figure 6) are not statistically different between conditions.

Finally, to investigate whether label retention was influenced by these individual differences, we split the participants into two groups based on whether the change in their IBI increased or decreased between the movement and the learning phases. A GLMM was fitted with the raw accuracy as the dependent variable, the group assignment based on the direction of the IBI change (increased or decreased) as fixed, and participant as random effect. No significant result was found, $p = 0.72$, indicating that IBI change did not predict children's performance during test.

Discussion

Our primary research question was to investigate whether interpersonal behavioral synchrony facilitates young children's novel word learning. Specifically, our paradigm was designed to test if engaging in a behaviorally synchronous interactive movement with an adult improves toddlers' novel word retention in a subsequent word learning task with the same adult. We expected that following a synchronous episode, children would successfully retain more novel words than following an asynchronous episode. However, our main results revealed that children's retention rate did not differ between conditions: although we observed the above-chance retention

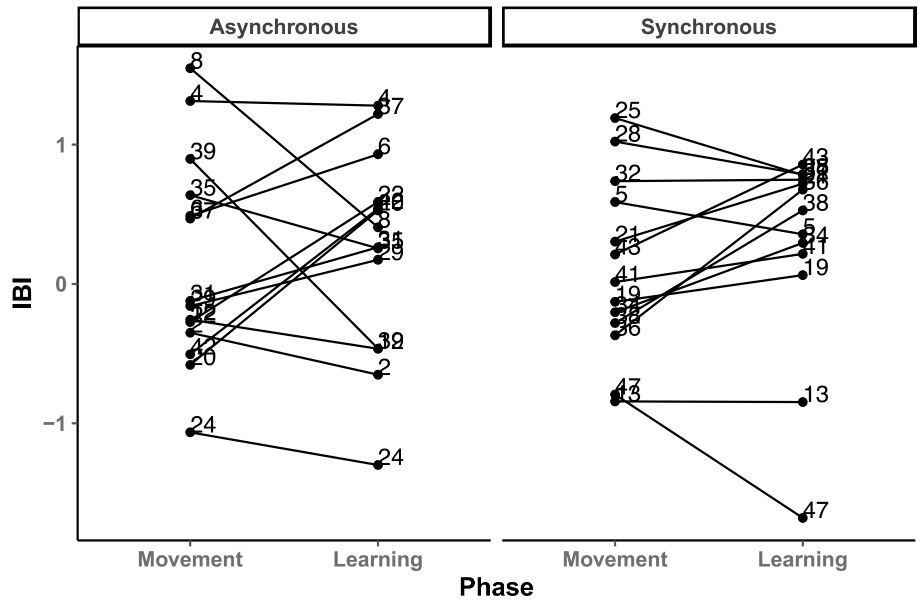

FIGURE 6
Change in individual participants' IBI levels across (a)synchronous movement and learning phases, separated by asynchronous and synchronous conditions.

of novel labels only following the synchronous, but not the asynchronous episode, the comparison between conditions did not reach significance. Second, our goal was to assess if synchronized movement episode affected children's physiological arousal (namely, the heart rate and skin conductance response), and, thirdly, if physiological indices associated with synchrony would accompany higher rates of successful novel word learning, compared to asynchrony. The results showed that heart rate and skin conductance response did not differ between conditions and did not impact the novel word retention outcome, nor did the proportion of successfully learned words, age, or gender.

To the best of our knowledge, no studies of the direct effect of induced interpersonal behavioral movement synchrony on young children's learning in direct pedagogical contexts have been reported to date. Despite insufficient support for the null hypothesis, these results contribute to our understanding of interpersonal synchrony experience, albeit in its experimentally imposed form. While its effects on prosocial outcomes are well documented, they do not appear to extend to the specific knowledge acquisition domain. Limited research in adults has explored the effect of synchrony on learning, producing inconclusive findings and exposing substantial methodological variability (Miles et al., 2010; Zheng et al., 2018; Nozawa et al., 2019). Our results, nevertheless, are in line with one directly relevant prior study conducted with adults which reported no effect of interpersonal synchrony on word learning in adult pairs tasked with teaching and learning novel labels from each other (Nozawa et al., 2019). This was despite behavioral and neural alignment in the teacher-learner dyad and establishing positive rapport with each other, which have been posited to enhance the learning outcomes (Hoehl et al., 2021).

Our behavioral results therefore do not supply any evidence for the top-down socio-cognitive mechanism, where prosocial perceptions resulting from the interpersonal synchronous interaction would have transferred to the learning domain. The effect of social bonding or teacher-child closeness on learning outcomes, such as vocabulary (Spilt et al., 2015), literacy and maths (Lowenstein et al., 2015), and academic achievement (Roorda et al., 2017) is abundantly reported in developmental literature. However, our direct experimental test of this hypothesized effect using a synchronized movement as an induction, on a specific learning outcome provided no support that children would have a higher chance of encoding information acquired after a synchronous interaction with a social partner, as opposed to asynchronous.

Several speculative explanations of these null results are possible. First, the result may be due to specific methodological choices, both at the (a)synchrony movement episode and at the learning and retention phases of the word learning task. Synchrony may not have had a direct effect because the learning outcome was unrelated to what was happening during the synchrony episode as such: being rocked to the music and later learning novel labels with unfamiliar objects may have been perceived as unique episodes. Further, the movement episode itself involved caregivers who managed the rocking, rather than children doing it spontaneously or autonomously. Notably, this decision was based on prior successfully applied methodological choices with infants in terms of prosocial outcomes (Cirelli et al., 2014; Tunçgenç et al., 2015; Rabinowitch and Meltzoff, 2017), but it may have prevented the transfer to the label learning domain in this case. It is also possible that the choice of the synchrony episode was crucial, specifically because it was induced and experienced indirectly, with the child being a passive partner. Our focus on such conceptualization of synchrony by design allowed us to look at the synchronized movement *per se*, reasoning that in more naturally occurring, self-induced synchrony, there would be confounding inter- and intra-personal effects, making it hard to isolate the precise effect of entrained, rather than rich and embodied experiences of synchrony. We acknowledge the limits of such conceptualizations yet resorted to this method (also commonly used in synchrony research and across other domains of cognition) to look at the general cognitive mechanism of the effect of synchrony on information retention. Future studies should investigate the variety of paradigms, including those where the child spontaneously engages in a synchronous activity with the teacher.

Similarly, with regards to the learning phase, it may be that our choice of the specific learning outcome was not optimal to detect the hypothesized effect. Here, either synchrony may not affect novel word learning broadly, or it may not affect the type of novel word learning examined in our study, which was based on a fast-mapping process (Horst and Samuelson, 2008) that was self-directed and largely independent from social interaction, rather than being teacher-directed, where learning happens in a top-down manner and may be more prone to social influences. Thus, the current study cannot rule out the effect of synchrony on learning broadly, as there might be an effect under different circumstances, or perhaps only a long-term but not an immediate effect, crystallizing through the social bonding process. In other words, a short 2 minute episode with a stranger may not be a sufficient prime to have a considerable effect on specific learning outcomes.

Finally, the null results might be due to both conditions presenting children with highly interactive embodied social activities, where the adult experimenter displayed equal engagement and positive affect. Such interaction in itself may facilitate the learning experience, with the asynchronous episode therefore not leading to disintegrated learning; hence no pronounced exclusive effect of synchrony was detected in our paradigm. This is corroborated by the very similar rates of novel referent retention reported in the seminal study by Horst and Samuelson (2008), where there was no preceding behavioral induction procedure. All these possibilities are fruitful future directions in this line of research.

Our second research question was whether children's physiological responses differed during synchronous and asynchronous movement episodes and affected the subsequent learning phase. We found no evidence that the skin conductance response and heart rate indices differed between conditions, nor did they differentially affect word learning. Prior research proposed that physiological processes underlie synchrony, focusing largely on social and affiliative outcomes (Cirelli, 2018; Davis et al., 2018; Kragness and Cirelli, 2021). To match these to the physiological correlates of learning, we chose to look at heart rate as it has been previously shown to relate to attention in infants during object examination (Lansink et al., 2000), preceded changes in looking behavior (de Barbaro et al., 2017), and predicted infant gaze following (Ishikawa and Itakura, 2019). We also chose to look at the skin conductance response as it has been previously implicated in encoding cognitive engagement, effortful allocation of attentional resources, information-seeking, exploration, and curiosity (Berlyne et al., 1963; Spinks et al., 1985; Boucsein, 1993; Critchley, 2002; Nagai et al., 2004; Merrifield and Danckert, 2014; Jang et al., 2015). Thus, we reasoned that heart rate and skin conductance are good candidates to demonstrate the link between synchrony and learning. Our study, however, showed no relationship between interpersonal synchrony and these physiological data.

Our only statistically significant finding was that tonic skin conductance was higher during the learning as compared to the movement phase, irrespective of the (a)synchrony condition. This is consistent with prior research which suggests that an increase in tonic skin conductance level reflects general engagement of attention and increase in cognitive load (Frith and Allen, 1983; O'Connell et al., 2008; Macpherson et al., 2017), as well as a decrease in boredom (Merrifield and Danckert, 2014; Jang et al., 2015). However, this result should also be interpreted with caution as it is expected that tonic skin conductance level rises with time, so this detected main effect of phase might be in fact unrelated to cognitive processes. Similarly, our unexpected, and only marginally statistically significant, result that skin conductance level, regardless of synchrony condition, predicted poorer performance during word retention should be treated with caution.

We thus find no evidence for the hypothesized bottom-up physiological process underlying synchrony. There may be several reasons for the null results. Our choice of physiology data to collect, the tool (Empatica E4 wristband) and the continuous variables averaging arousal across phases that were subjected to analyses may not have been the most sensitive to detect any differences across phases or conditions. This is supported by vast methodological differences and unique considerations pertaining to measures of arousal, such as differential effects in tonic but not phasic measures, lack of relationship between heart rate and skin conductance measures, and between physiological measures and neural or behavioral measures of synchrony (Wass et al., 2015; Mønster et al., 2016; Kragness and Cirelli, 2021; Nguyen et al., 2021). There is also evidence for individual differences in arousal levels and complexities associated with its measurement (e.g., Pijeira-Díaz et al., 2019), contributing to our lack of confidence in these findings.

A number of general limitations are of note in our study. First, although pre-registered based on the power analysis, the sample size was relatively small, which may have also contributed to the insufficient support for either the alternative or null hypotheses on the Bayes Factor analyses. Second, as already mentioned above, the choice of novel word retention as a target outcome and the specific learning task, while well established as valid in the prior literature, may have been too stringent to broadly investigate synchrony and learning. Finally, our physiological measures may not have been sensitive enough to the changes in arousal since the length of the experiment was relatively short and the physiology band only provided continuous but not event-related measurement of the arousal indices, which would have been more fine-grained. In addition, the Empatica E4 tool has not been yet widely validated in developmental research (but see, e.g., Bainbridge et al., 2021) and its treatment of the heart rate data using a proprietary algorithm makes manual correction of movement artifacts and verification of data difficult.

Broadly speaking, with research on synchrony being no exception here, the developmental literature has recently been concerned with issues of validity, reliability, and generalizability of methodological choices (Kominsky et al., 2022; Yarkoni, 2022; Zettersten et al., 2022). Namely, any measure of any psychological construct that cannot be observed or measured directly (e.g., an experience of synchrony, either induced or achieved through personal agency), even with the highest reported reliability, may fail the validity check or be deemed incomplete or narrowly conceived, even if we can measure individual differences with detail and precision. As noted above, we conceptualized and manipulated synchrony for the purposes of the current experimental investigation as an induced, entrained experience, rather than child-led, embodied, and agentic. In other words, synchronized movement in our paradigm was not embedded in the contextual and situated nature of the social interaction and does not take into account individual developmental capacities. We then tested the effect of such synchronized movement episode on a particular learning outcome, in an experimental setting, where inevitably some of these naturalistic contexts could not be preserved. We acknowledge that it is challenging to base the investigations of the broader notions of development and learning on the somewhat reductionist concepts of both synchrony and learning, without accounting for the existing relational factors between the child and their caregiver who formed a dyad in the synchronized movement induction (Feldman, 2006, 2012; Thelen and Smith, 1998; Harrist and Waugh, 2002; Mayo and Gordon, 2020), although at the same time, it allows to isolate the cognitive process. Balancing ecological and measurement validity and accounting for relational and contextual factors is therefore a challenge that future research on the effect of synchrony should aim to tackle.

To shed light on the underlying mechanisms of interpersonal synchrony experience and its effects on learning, future research should make further attempts to evaluate the role of both social learning and physiological mechanisms on attention and cognition. A number of exciting directions are evident in this under-investigated line of work. First, different methodological choices can be explored including a different synchrony prime (e.g., movement, joint action, or music), a different learning task (e.g., one that is not contingent on experimenters' facilitation, or, instead, directly taught by the adult, and look at both linguistic and non-linguistic outcomes). Second, the effect of synchrony on learning should be tested in a younger age group to better understand the early emerging mechanism. At the same time, more studies with adults could help determine the basis for the existence or lack of this hypothesized effect. Further, physiological arousal should be tested using a variety of reliable measures and tools, including embarking on the analyses of dynamic synchrony of time-synchronized arousal data between the child and the experimenter.

In conclusion, while our work did not produce conclusive results regarding synchrony and word learning in young children, it adds to this growing literature by highlighting the need to investigate both behavioral and physiological arousal indices to better understand the underlying mechanisms of interpersonal synchrony as such, and its possible effect in the knowledge acquisition, rather than prosocial, and domain.

Data availability statement

The materials and the data that support the findings of this study are openly available on the Open Science Framework (https://osf.io/njgyq/).

Ethics statement

The studies involving human participants were reviewed and approved by Faculty of Science and Technology Ethics Committee at Lancaster University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

MB, HK, HT, and GW designed the study. HT booked participants and carried out the experiment. MW handled and processed physiological data. HK performed the statistical analyses. MB, HK, and GW wrote the manuscript. All authors contributed to the article and approved the submitted version.

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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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Family interactions in toddlerhood influence social competence in preschool age: Accounting for genetic and prenatal influences

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Identification of early promotive and risk factors for social competence is important for fostering children's successful social development; particularly given social competence is essential for children's later academic and psychological well-being. While research suggests that the early parent–child relationship, genetics, and prenatal influences are associated with social competence, there is less research considering how these factors may operate together to shape children's social competence in early childhood. Using a genetically informed sample from the Early Growth and Development Study (*N*=561), we examined multiple levels of influence (i.e., genetic, prenatal, parenting, and child characteristics) on children's social competence at 4.5 years old. Results from structural equation models showed adoptive mother overreactivity at 18 months was positively associated with child dysregulation at 27 months, which, in turn, was associated with lower levels of social competence at 4.5 years. Also, child reactivity at 18 months was independently associated with higher levels of adoptive mother overreactivity at 27 months, which, in turn, was associated with lower levels of social competence at 4.5 years. Finally, we found an evocative effect on adoptive fathers' overreactivity at 18 months such that prenatal birth mother distress was negatively associated with adoptive fathers' overreactivity at 18 months. Overall, this study found evidence for genetic influences, and bidirectional associations between parent and child in toddlerhood that are related to lower levels of social competence when children were 4.5 years old. We also found that the prenatal environment was associated with parenting, but not with child behavior directly. This study's ability to simultaneously examine multiple domains of influence helps provide a more comprehensive picture of important mechanisms and developmental periods for children's early social competence.

KEYWORDS

genetic influences, evocative *r*GE, child social competence, prenatal influences, child regulation, parenting

Introduction

Children's social competence, defined as children's ability to engage in their social world appropriately (e.g., control their behaviors and emotions, display prosocial behaviors), are crucial skills to master for successful lifelong adjustment (Masten and Coatsworth, 1998; Blandon et al., 2010; Jones et al., 2015). Extensive research has documented the importance of early childhood, particularly early social interactions between parents and their children, for the development of social competence (Fabes et al., 2006; Karreman et al., 2006; Karam and Degnan, 2021). Extant literature has primarily focused on pinpointing parenting behaviors that promote and hinder the development of social competence (Masten and Coatsworth, 1998; Haskett and Willoughby, 2007; Driscoll and Pianta, 2011). However, even when there is evidence of parents' effects on children's social competence, the mechanisms that underlie these effects are ambiguous because most studies include parents and their biological children. This type of design makes it difficult to distinguish between environmentally-driven parent effects from effects that may be explained by genes shared by parents and their offspring, or prenatal effects (Knafo and Plomin, 2006; Moore and Neiderhiser, 2014). Additionally, while research has primarily focused on parenting effects, there is often evidence of bidirectional effects between children and their parents, pointing to the transactional nature of development (Bell, 1968; Kiff et al., 2011). Therefore, additional research is needed that considers how these factors (e.g., parenting, child characteristics, prenatal factors, and genetics) may operate individually or together to shape children's social competence in early childhood. We employed a genetically informed design that would remove the confound of shared genes between child and parents to begin to address these gaps in the literature.

In early childhood, developmentally salient parenting behaviors like responsiveness and overreactivity (i.e., yelling, criticizing, and harsh punishment) are important promotive and risk factors, respectively, for the development of social competence (Masten and Coatsworth, 1998; Clark and Ladd, 2000; Haskett and Willoughby, 2007; Feldman and Masalha, 2010; Driscoll and Pianta, 2011). These different parenting behaviors are assumed to influence child development because they serve unique functions to socialize and model behaviors for the child. For example, parents' responsivity to their child's needs is critical for facilitating the development of a secure sense of self in the child and modeling emotionally competent behaviors (Thompson, 2000; Waters and Cummings, 2000). Longitudinal and concurrent studies have demonstrated the importance of parental responsivity for children's development of social competence (Leerkes et al., 2009; Feldman and Masalha, 2010; Martin et al., 2010; Rispoli et al., 2013; Raby et al., 2015). One longitudinal study found that parental responsivity toward their infant was associated with higher levels of social competence in the preschool-aged child (Rispoli et al., 2013). On the other hand, overreactive and hostile parenting is detrimental to the child across multiple social outcomes, such as self-confidence, social competence, and overall well-being. Furthermore, children emulate the negative interaction styles with their parents with other individuals outside the home. Subsequently, these styles may adversely affect peer relationships, or children may have inhibitions about engaging in social behavior based on a history of harsh treatment by parents (Patterson, 1982; Anthony et al., 2005; Hartas, 2011). Concurrent and longitudinal studies have found that hostile parenting was associated with lower levels of social competence and fewer prosocial skills in preschool-aged children (Eddy et al., 2001; Laible et al., 2004; Anthony et al., 2005; Hartas, 2011; Walker and Mac Phee, 2011). Overall, this literature finds that responsive parenting and hostile/overreactive parenting shape children's level of social competence.

While most previous research has focused on the impact of parenting on social competence, it is also likely that children play an active role in their development (Bell, 1968). This perspective has increasingly shifted attention to understand how parenting is influenced by individual children's needs or demands and also incorporating transactional models of development (Patterson, 1982; Sameroff, 2009; Kiff et al., 2011). During early childhood, dysregulation and reactivity may be key early child behaviors that evoke behaviors from parents, and are also influenced by parents (Belsky, 1984; Kiff et al., 2011). Regulation is a multidimensional construct encompassing cognitive, behavioral, and emotional processes that allow the child to coordinate responses to environmental cues (Kopp, 1982; Grolnick and Farkas, 2002; McClelland and Cameron, 2012; Cole et al., 2019) and dysregulation is when an individual has impaired regulation, which this manuscript will focus on. In comparison, reactivity is characterized by the intensity and latency of one's emotional and behavioral response to their environment and includes negative affect (Rothbart and Bates, 2006). Many studies examining the effects of reactivity and dysregulation reflect a broader conceptualization of these constructs, but this study will focus on specific aspects: anger proneness and behavioral dysregulation, measured by Attention-Deficit/Hyperactivity problems. Child anger proneness, in particular, is a salient child emotion that elicits negative parenting (Snyder et al., 2003; Kochanska et al., 2004; Paulussen-Hoogeboom et al., 2007; Shewark et al., 2021), and can also be detrimental to forming and maintaining peer relationships (Sirois et al., 2019). Behavioral dysregulation is associated with negative parenting (e.g., Morrell and Murray, 2003; Bridgett et al., 2009), decreases in positive parenting (e.g., Braungart-Rieker et al., 2001; Eisenberg et al., 2010), and later child maladjustment (e.g., higher externalizing; Eisenberg et al., 2010). Overall, higher levels of regulation and less negative affect are considered prerequisites for the healthy development of social competence because regulatory abilities help children to respond to their peers appropriately, and children who are overly angry have difficulty keeping good quality friendships (Rubin et al., 1995; Denham et al., 2003; Diener and Kim, 2004; Korja et al., 2017).

Research has also highlighted that early interactions between parenting behavior and child regulation and reactivity influence the development of social competence (Fabes et al., 2001;

Eisenberg et al., 2010; Smith et al., 2014). For example, one study found that when parents used harsh parenting strategies in response to negative emotions (including anger) from their children, they had children who were more dysregulated and were less socially competent (Fabes et al., 2001). These negative interactions between parents and children are evidence of coercive family dynamics (Patterson, 1982; Scaramella and Leve, 2004; Smith et al., 2014). Coercion theory outlines a process between parent and child whereby parent hostility and child anger or noncompliance is mutually reinforced during interactions until an individual "wins" by one participant withdrawing or relenting (Patterson, 1982). While this coercive cycle is usually considered within interactions, these learned interactions can also be seen at a larger timescale (Van Ryzin and Dishion, 2012). This cycle can result in long-term destructive interaction patterns between the parent and child that negatively impact child social development (Scaramella and Leve, 2004; Smith et al., 2014). Therefore, parenting can influence children's social competence by affecting children's anger and regulatory abilities, but children's anger and regulation could also impact social competence through eliciting parental responses associated with compromising children's social competencies. Without accounting for child-driven effects, the parenting literature is unable to delineate whether the parenting behavior is the guiding force, or a response elicited by the child. To address these bidirectional processes occurring within the family, this study incorporates child-driven effects as a crucial factor that might be associated with early childhood social competence.

Last, even when bidirectional parent–child effects are identified within transactional models, the mechanisms underlying these effects are not fully understood. While a transactional model can help us determine potential directional patterns (i.e., parent vs. child-driven pathways), they are unable to clarify whether these relationships between parent and child are due to behavioral processes or shared genes. One way that genetics can influence parent–child relationships is through evocative gene–environment correlation (*r*GE). Specifically, how children are parented might be, in part, based on inherited characteristics of the child that elicit specific responses from the parent (Plomin et al., 1977; Scarr and McCartney, 1983; Knopik et al., 2017). Consistent with this possibility, studies have found that children's early regulatory capacities, anger, and social competence are partially influenced by genetics (Edelbrock et al., 1995; Hudziak et al., 2003; Van Hulle et al., 2007; Roisman and Fraley, 2012; Van Ryzin et al., 2015). Furthermore, genetically informed studies have found that evocative *r*GE partially explains the relationship between child behaviors such as child regulatory behaviors and emotions and parenting in infancy and toddlerhood (Harold et al., 2013; Klahr et al., 2013, 2017; Natsuaki et al., 2013; Ulbricht et al., 2013; Klahr and Burt, 2014; Hajal et al., 2015). For example, Lipscomb et al. (2011) leveraged The Early Growth and Development Study (Leve et al., 2019) to remove the potential confound of genetic influences and found that child negative emotionality from infancy to toddlerhood was positively associated with higher levels of parent overreactivity from infancy to toddlerhood. Other studies, using this adoption sample and twin samples, have shown that evocative *r*GE effects on parenting in toddlerhood and preschoolers were associated with higher levels of disruptive and prosocial behaviors (Knafo and Plomin, 2006; Elam et al., 2014). For example, Elam et al. (2014) found that birth parent characteristics were associated with higher levels of parent hostility through child low social motivation. This result is evidence of evocative *r*GE because in an adoption design birth parents only provide genes and not the postnatal rearing environment; thus any influence the birth parent has on the child is assumed to be a genetic effect. These findings suggest that infancy and toddlerhood are important developmental periods to examine evocative *r*GE effects to help clarify how bidirectional parent–child processes might occur.

One final context to consider is the prenatal environment because the prenatal period is a particularly sensitive period for children's early development, including social competence (Rice et al., 2007; Latimer et al., 2012; Behnke et al., 2013; Graignic-Philippe et al., 2014). The fetal programming hypothesis proposes that events that happen during the prenatal period can influence fetal development through reprogramming neural networks (Barker, 1998; Ping et al., 2015). For example, stress during pregnancy can increase hormone production that results in the altered functioning of the HPA axis, changes in glucocorticoid receptors, and alterations in neuroendocrine responses that are linked to fetal neural development (Matthews, 2002; Weinstock, 2005; Van den Bergh et al., 2020). Therefore, the prenatal environment might negatively alter the child's neural network in the womb that starts the child at a higher threshold for being negative or dysregulated, which, in turn, has the potential to impact their normative developmental trajectory. This study focuses on prenatal distress (e.g., anxiety and depressive symptoms) because of its relevance to both early child reactivity (negative emotionality) and dysregulation (Feldman et al., 2009; Blair et al., 2011; Sharp et al., 2015; Korja et al., 2017), and social competence (Carter et al., 2001; O'Connor et al., 2002; Loomans et al., 2011; Dunkel Schetter and Tanner, 2012; Glover, 2014; Eichler et al., 2017). This hypothesis is supported by evidence that prenatal distress is associated with higher levels of negative affect and irritability in infants and toddlers (Davis et al., 2007; DiPietro et al., 2008; Glynn et al., 2018). Additionally, studies have also found that dysregulation or reactivity mediated the relationship between prenatal parent distress and later social development in children (Carter et al., 2001; DiPietro et al., 2008; Blair et al., 2011). In addition, based on previous findings of (1) the effects of prenatal distress on early child reactivity and regulation and (2) child-driven effects on parenting, child effects on parenting might also be indirectly influenced by the prenatal environment. This mediation effect is more challenging to test because of the inability of studies to separate prenatal and postnatal effects, resulting in biased estimates. Prenatal and postnatal stress are often correlated (i.e., if a mother is distressed prenatally, her parenting behaviors might also reflect that postnatally; Glover, 2015); therefore, different designs are needed distinguish between the prenatal and postnatal environment (Loehlin, 2016).

Within a family design where biological parents are raising their biological child(ren), researchers are unable to distinguish genetic, prenatal, and postnatal rearing environmental effects (e.g., parenting). Studies examining prenatal effects are unable to remove the bias of passive gene–environment correlation, where the genes of the mother might influence the prenatal environment (Knopik et al., 2017; Rice et al., 2018). For example, mothers with elevated depressive symptoms, which are heritable, might be more likely to experience depressive or anxiety symptoms during pregnancy (providing an environment correlated with their genetics), which could produce biased estimates in prenatal studies (i.e., larger prenatal effects). There are a few studies, including those examining the sample from the current report, that have examined prenatal effects within genetically informed designs (Rice et al., 2010; Kerr et al., 2013; Marceau et al., 2013; Neiderhiser et al., 2016; Gjerde et al., 2017; Hannigan et al., 2018; Liu et al., 2020). Previous studies have found prenatal effects (e.g., substance use, neonatal complications, prenatal risk) on toddler behaviors (Pemberton et al., 2010; Marceau et al., 2013; Liu et al., 2020); however, some found that the prenatal effect was at least partially due to genetic influences (Rice et al., 2007; Pemberton et al., 2010; Marceau et al., 2013; Hannigan et al., 2018; Liu et al., 2020). Finally, only a few studies have examined the influence of genetics, the prenatal environment, and the rearing environment on children's social development in early childhood (Marceau et al., 2013, 2015; Neiderhiser et al., 2016; Liu et al., 2020). Therefore, the current study addresses the mechanistic pathways by which parent and child bidirectional processes unfold—parent-driven, child-driven, genetically influenced, or prenatally influenced—to influence children's early social competence.

Specifically, we address this gap by employing a parent-offspring adoption design to simultaneously examine the effects of genetic factors, prenatal distress, child behaviors (i.e., dysregulation and anger proneness), and parenting (i.e., responsivity and overreactivity) on child social competence at preschool age (Figure 1). The parent-offspring adoption design allows us to better distinguish genetic, prenatal environmental influences, and postnatal rearing environmental influences as birth parents provide only their genes (and for the birth mother, the prenatal environment), but not the rearing environment, and the adoptive parents provide only the rearing environment because they are genetically unrelated to the child. In this study, genetic influences are indicated by birth parent agreeableness and emotion dysregulation. These are reasonable birth parent proxies (which are included to estimate genetic influences) for children's social competence, early anger proneness, and dysregulation because they are both moderately heritable (Bouchard Jr. and McGue, 2003; Tackett et al., 2013), and both incorporate aspects of regulation and emotion. While the adoption design does not definitively distinguish prenatal influences from genetic influences, the inclusion of both birth mother and birth father characteristics provides some leverage for making this distinction as the birth father does not provide the prenatal environment (Loehlin, 2016). To advance our understanding of the complex nature of transactional family processes, this study examined both positive and negative parenting behaviors (responsivity and overreactivity). Finally, we included both mothers and fathers based on the importance of both parents in the development of children (Karam and Degnan, 2021).

We hypothesized that (1) there would be a bidirectional process between child dysregulation and reactivity and parenting during toddlerhood that, in turn, would be associated with child social competence at age 4.5 years. We hypothesized that child dysregulation would be associated with lower levels of parent responsiveness and higher levels of coercive parenting in the toddler period, leading to lower levels of social competence in children at preschool age. (2) We also hypothesized that we would find evidence of evocative *r*GE, such that birth parent (BP) temperament would be associated with parenting through children's early reactivity and dysregulation, and (3) these evocative pathways would be associated with child social competence at 4.5 years old. (4) Lastly, we hypothesized that prenatal distress would be negatively associated with child social competence through child reactivity and dysregulation.

Materials and methods

Participants

Participants were from the Early Growth and Development Study (EGDS), a longitudinal adoption design, with 561 linked sets of adopted children, adoptive parents, and birth parents (Leve et al., 2019). Recruitment of these families occurred through 45 adoption agencies in 15 states in the USA, and families were eligible to participate if the adoption was domestic, placement occurred within 3 months ($M = 5.57$ days, $SD = 11.30$ days), the child was placed with a nonrelative, the child had no major medical conditions, and the birth parents and adoptive parents could understand English at an 8th grade level. The adopted children were majority male (57.3%), and about half White (54.5%), with 17.8% multiethnic, 13.2% African American, and 13.4% Hispanic, 0.5% America Indian or Alaskan Native, 0.2% Asian, and 0.2% Native Hawaiian or Pacific Islander, and 0.2% unknown or not reported. Demographic information about the adoptive parents (APs) and birth parents (BPs) are provided in Table 1. BPs were generally younger than APs, had less education, and lower income.

Measures

BP temperament

We used latent temperament factors that were constructed for both birth mothers (BMs) and birth fathers (BFs) to estimate genetic influences previously created (Shewark et al., 2021). We used the following factors: emotion dysregulation and

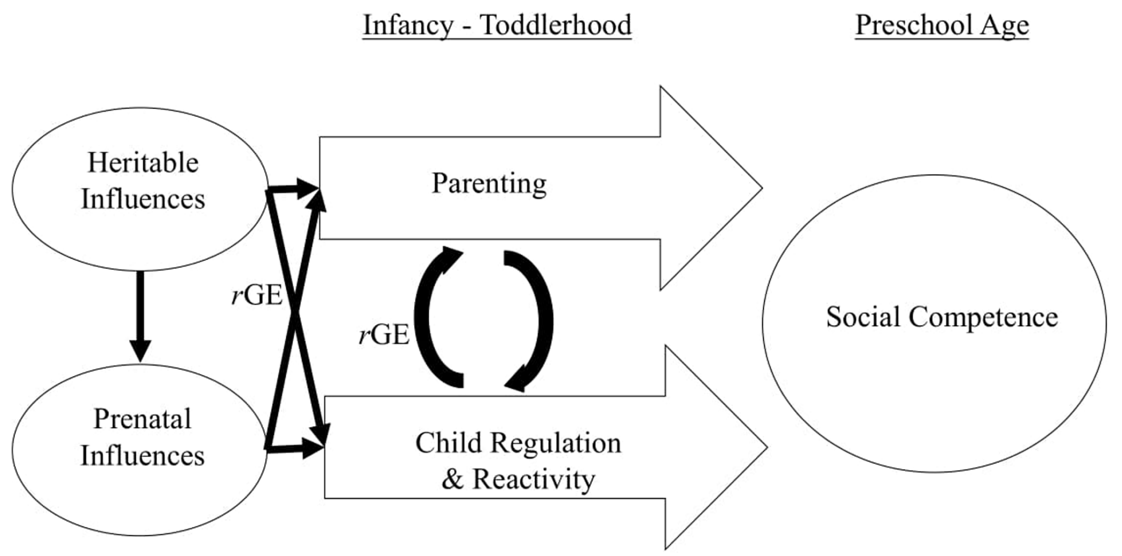

FIGURE 1
Conceptual model of genetic, prenatal, and the bidirectional process between parent and child on social competence in early childhood.

TABLE 1 Full Sample descriptives.

	Adoptive parent 1 ($N=561$)	Adoptive parent 2 ($N=552$)	Birth mother ($N=556$)	Birth father ($N=210$)
Age at child birth [*M (SD)*]	37.43 (5.59)	38.30 (5.83)	24.35 (6.03)	26.08 (7.77)
Race/ethnicity				
White	91.8%	90.4%	70.1%	69.9%
African American	3.9%	4.9%	13.3%	11.5%
Hispanic	2%	1.6%	6.7%	9.6%
More than 1 race	0.4%	1.1%	4.9%	4.8%
Asian	0.9%	0.5%	1.8%	0%
American Indian or Alaskan Native	0.2%	0%	2.5%	0.5%
Native Hawaiian or Pacific Islander	0%	0.5%	0.2%	0.5%
Other	0.4%	0.9%	0.5%	3.3%
Income (median)	$100,000–$125,000		<$15,000	$15,000–$40,000
Education (median)	College degree		High school degree	

agreeableness. Emotion dysregulation consisted of attentional control, activation control, fear, and frustration subscales from the Adult Temperament Questionnaire—short form completed when the child was 18 months old (ATQ; Rothbart et al., 2000). Agreeableness consisted of the sociability subscale from the ATQ, and the nurturance and intimate relationship subscales from the Harter Adult Self-Perception Profile completed when the child was three to 6 months old (Messer and Harter, 1986). Higher scores on the emotion dysregulation factor are indicative of higher levels of dysregulation with lower scores indicative of higher levels of attentional control and activation. Higher agreeableness indicates higher levels of sociability and better interpersonal relationships. Birth fathers were less likely to participate, most often because they could not be located, which resulted in between ~60%–71% missing data. Missing data were handled with Full Information Maximum Likelihood (Graham, 2003). More information on the construction of these factors is provided in Shewark et al. (2021). In analyses, BM and BF factor scores were used and paths were constrained to be equal to provide a single genetic influence estimate for each temperament construct. The inclusion of BF data within the genetic estimates provides a better representation of the full genetic influence and can help distinguish this from the prenatal effects.

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Birth mother prenatal distress

When the child was approximately 5 months old, BMs reported their depressive and anxiety symptoms during pregnancy. To aid mothers in their recall, interviewers helped mothers generate a list of life events that occurred throughout the pregnancy to create a Life History Calendar (Freedman et al., 1988; Caspi et al., 1996). BMs completed shortened versions of the Beck Anxiety Inventory (BAI; Beck and Steer, 1993) and the Beck Depression Inventory (BDI; Beck and Steer, 1993), adapted by the study team for the pregnancy period. Mothers who endorsed sadness or anhedonia for at least a 2-week period during pregnancy were asked to rate an additional five items from the BDI. Similarly, mothers were asked about anxiety symptoms with an additional set of four items from the BAI. Both subscales were on a 4-point Likert scale and had good reliability (BDI $\alpha = 0.86$; BAI $\alpha = 0.80$). Example items include: "I have been able to laugh and see the funny side of things" and "Things have been getting on top of me." Prenatal depressive and anxiety symptoms were combined by summing their scores ($r = 0.55$, $p < 0.001$).

Adopted child dysregulation

To capture dysregulation, we used adoptive parent reports on the Attention-Deficit/Hyperactivity Problems subscale of the Child Behavior Checklist (Achenbach et al., 1987). This subscale includes 6 items on a scale from 1 (Not True) to 3 (Very True), for example, "Cannot concentrate." This subscale shows good reliability at 18 months [adoptive mother (AM) $\alpha = 0.85$; adoptive father (AF) $\alpha = 0.87$] and 27 months (AM $\alpha = 0.77$; AF $\alpha = 0.80$). AM and AF scores were averaged to create composites (18 months, inter-rater $r = 0.39$; 27 months: $r = 0.42$).

Adopted child anger proneness

To capture anger proneness, we used parent reports on the anger proneness subscale of the Toddler Behavior Assessment Questionnaire (Goldsmith, 1996). This subscale consists of 28 items that assess the child's likelihood of presenting anger in situations, for example, "When you did not allow your child to do something for her/himself, for example, dressing or getting into the car seat, how often did your child try to push you away?" Each parent reported on these child behaviors at 18 (AM $\alpha = 0.89$; AF $\alpha = 0.89$) and 27 months (AM $\alpha = 0.85$; AF $\alpha = 0.87$). AM and AF scores were averaged to create composites (18 months: $r = 0.42$; 27 months: $r = 0.44$).

Adoptive parents' parenting

We assessed both positive and negative parenting behaviors at 18 and 27 months. For *positive parenting behaviors*, we assessed parents' responsivity. To assess parents' responsivity using the Home Observation for Measurement of the Environment (HOME) Inventory. The HOME was designed to measure the emotional and social responsiveness of the parent to the child. This assessment was completed by the study interviewers upon the completion of the in-home interview. The responsivity subscale consists of 11 items. An example item is: "mother/father responds to the child's vocalizations with a verbal or vocal response." This measure showed good reliability for both parents at both waves (18 months: AM $\alpha = 0.76$, AF $\alpha = 0.71$; 27 months: AM $\alpha = 0.58$, AF $\alpha = 0.70$). As responsivity was negatively skewed, we performed a reciprocal transformation of it with the intention of keeping the high scores meaning higher responsivity.

For *negative parenting behaviors,* adoptive parents self-reported on the Parenting Scale (Arnold et al., 1993) at 18 and 27 months for which we used the overreactivity subscale, which reflects displays of anger, meanness, and irritability. An example item is: "When my child misbehaves, I get so frustrated or angry that my child can see that I am upset." This subscale consisted of 10 items on a 7-point Likert scale and showed good reliability for both parents across both timepoints (18 months: AM $\alpha = 0.79$, AF $\alpha = 0.77$; 27 months: AM $\alpha = 0.79$, AF $\alpha = 0.77$).

Adopted child social competence

We used parent reports on child social competence at child age 4.5 years on the Social Skills Rating System (Gresham and Elliott, 1990), using the total social skills score that includes 39 items (AM $\alpha = 0.87$; AF $\alpha = 0.87$) that includes items about cooperation, communication, responsibility, and self-control during interactions with peers. Example items include "Ends disagreements with you calmly" and "Requests permission before leaving the house." Parents respond to items on a 3-point Likert scale. AM and AF scores were averaged to create a composite ($r = 0.48$, $p < 0.001$).

Covariates

Openness of adoption, child sex, obstetric complications (e.g., prenatal complications, neonatal complications, substance use), parent age at the child's birth, education, and income were tested as covariates on all study variables. Significantly related covariates were controlled for in subsequent analyses by regressing them out of the study constructs and creating standardized z-scores.

Analytic strategy

Hypotheses were tested using structural equation models in Mplus 8 (Muthén and Muthén, 1998–2012). Due to power concerns, we had to model the birth parent indices and child behaviors in separate models, resulting in four models: BP emotion dysregulation-adopted child dysregulation, BP emotion dysregulation-adopted child anger proneness, BP agreeableness-adopted child dysregulation, and BP agreeableness-adopted child anger proneness. There was a small amount of missing data across ages (18 months: 3%, 27 months: 5%, 4.5 years: 18.36%), so we used full information maximum likelihood (FIML) estimation to reduce bias of missing data (Graham, 2003). Fit statistics were used to examine the fit of the models including, Chi-square goodness of fit index ($p > 0.05$), CFI (0.90 or above), SRMR (less than 0.08), and RMSEA (less than 0.08). Main effects and indirect effects were examined within each model. Birth mother and birth father emotion dysregulation and agreeableness paths were constrained to be equal in the models to estimate a single genetic influence and help separate the genetic and prenatal influence.

Results

Descriptive statistics and correlations among the raw study variables are presented in Tables 1, 2, respectively. Correlations reflect that adoptive parents' overreactivity was significantly associated with early child regulation, reactivity, and social competence with moderate effect sizes (*r*'s range from −0.25 to 0.30). Also, child early dysregulation and reactivity were significantly associated with later social competence (*r*'s range from −0.19 to −0.28). Finally, birth parent temperament was significantly correlated with social competence at 4.5 years ($r = -0.12$ to 0.12).

Birth parent emotion dysregulation models

Both models fit well: child dysregulation [$\chi^2(25) = 29.82$, $p = 0.23$, RMSEA = 0.02, CFI = 1.00, SRMR = 0.02], and child reactivity [$\chi^2(26) = 29.15$, $p = 0.30$, RMSEA = 0.02, CFI = 1.00, SRMR = 0.02]. Results (depicted in Figure 2) indicate that BP emotion dysregulation was negatively associated with child social competence at 4.5 years. In addition, adoptive mothers' overreactivity was negatively and adoptive mothers' responsivity was positively associated with child social competence, but adoptive fathers' parenting was not associated with child social competence. Adopted child dysregulation was also negatively associated with child social competence. Finally, we found that birth parent emotion dysregulation was positively associated with birth mother's prenatal distress and that prenatal distress was negatively associated with adoptive fathers' AF overreactivity at 18 months.

We found differences when examining the bidirectional effects between child dysregulation and child reactivity in relation to parenting. For the *child dysregulation model* (Figure 2A), we found that adoptive mothers' overreactivity at 18 months was positively associated with child dysregulation at 27 months; however, adoptive fathers' overreactivity was not associated with child's dysregulation. Additionally, adoptive fathers' responsivity was positively associated with child dysregulation at 27 months, but not adoptive mothers' responsivity. We also found that adoptive mothers' responsivity at 18 months was negatively associated with adoptive fathers' responsivity at 27 months. Additionally, child dysregulation at 18 months was not associated with adoptive parents' parenting at 27 months. For the *child reactivity model* (Figure 2B), we found that adoptive parents' parenting at 18 months was not associated with children's reactivity at 27 months. However, we found that child reactivity at 18 months was positively associated with adoptive mothers' overreactivity at 27 months; however, child reactivity was not associated with other parenting behaviors. We also found that adoptive mothers' responsivity at 18 months was negatively associated with adoptive fathers' responsivity at 27 months.

Indirect effects

There was an indirect effect from adoptive mothers' overreactivity at 18 months to child social competence at 4.5 years through adoptive mothers' overreactivity at 27 months ($\beta = -0.15$, $SE = 0.05$, $p < 0.01$). There was a marginally significant indirect effect from birth mother emotion dysregulation to adoptive fathers' overreactivity through prenatal distress ($\beta = -0.01$, $SE = 0.01$, $p = 0.06$). For the *child dysregulation model,* adoptive mothers' overreactivity at 18 months to child social competence at 4.5 years was significant through child dysregulation at 27 months ($\beta = -0.02$, $SE = 0.01$, $p = 0.05$). Additionally, there was an indirect effect of child dysregulation at 18 months to child social competence through child dysregulation at 27 months ($\beta = -0.11$, $SE = 0.04$, $p < 0.05$). Finally, adoptive fathers' responsivity to child social competence was not significant through child dysregulation at 27 months ($\beta = 0.01$, $SE = 0.01$, $p > 0.05$). There were no additional significant evocative *r*GE pathways in this model. For the *child reactivity model,* child reactivity at 18 months was associated with child social competence at 4.5 years through adoptive mother overreactivity at 27 months ($\beta = -0.02$, $SE = 0.01$, $p = 0.05$). However, because birth parent emotion dysregulation was not associated with adopted child reactivity, there were no additional significant evocative *r*GE pathways.

Birth parent agreeableness models

Both of the models fit well: child dysregulation [χ^2 (25) = 26.34, $p = 0.39$, RMSEA = 0.01, CFI = 1.00, SRMR = 0.04] and child reactivity [χ^2 (26) = 23.51, $p = 0.60$, RMSEA = 0.00, CFI = 1.00, SRMR = 0.02]. Results (depicted in Figure 3) showed that birth parent agreeableness was positively associated with child social competence at 4.5 years old. Birth parent agreeableness was also negatively associated with child reactivity at 27 months, but not child dysregulation. Birth parent agreeableness was also negatively associated with prenatal distress and adoptive fathers' overreactivity at 18 months. We also found that birth mother prenatal distress was negatively associated with adoptive fathers' overreactivity at 18 months. In addition, both adoptive mothers' overreactivity and responsivity were associated with child social competence ($\beta = -0.22$, $p < 0.05$; $\beta = 0.13$, $p < 0.05$, respectively), but adoptive fathers' parenting behaviors were not associated with child social competence. Child dysregulation during toddlerhood was negatively associated with child social competence.

When examining the bidirectional effects of parenting and child behavior, we found for the *child dysregulation model* (Figure 3A) that adoptive mothers' overreactivity at 18 months was positively associated with child dysregulation at 27 months; however, adoptive fathers' overreactivity was not associated with child dysregulation. Additionally, adoptive fathers' responsivity

TABLE 2 Correlations and mean and standard deviations of the raw study variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. BP emotion dysregulation	--	−0.67**	0.11*	−0.02	0.05	0.03	−0.02	0.01	−0.04	−0.01	0.03	−0.01	−0.08	0.07	−0.01	−0.12*
2. BP agreeableness	−0.47**	--	−0.05	−0.02	−0.10*	−0.02	0.02	−0.01	0.04	0.01	−0.04	−0.07	0.02	−0.06	−0.01	0.08
3. Prenatal distress	0.25**	−0.21**	--													
4. AM overreactivity, 18 months	−0.01	−0.03	−0.05	--												
5. AF overreactivity, 18 months	−0.03	−0.07	−0.10*	0.34**	--											
6. AM responsivity, 18 months	0.03	−0.01	0.01	−0.02	−0.01	--										
7. AF responsivity, 18 months	0.01	0.04	−0.07	−0.01	0.01	0.54**	--									
8. AC dysregulation, 18 months	0.00	−0.08	−0.02	0.22**	0.12**	0.05	0.08	--								
9. AC Anger proneness, 18 months	−0.03	−0.02	−0.09^{+}	0.24**	0.24**	0.02	0.03	0.36**	--							
10.AM overreactivity, 27 months	−0.04	0.06	−0.07	0.73**	0.27**	0.02	0.03	0.24**	0.26**	--						
11.AF overreactivity, 27 months	−0.02	−0.03	−0.11**	0.27**	0.69**	−0.05	−0.05	0.16**	0.24**	0.27**	--					
12. AM responsivity, 27 months	0.01	−0.02	0.00	−0.07	−0.06	0.23**	0.22**	0.10*	−0.05	0.02	−0.02	--				
13. AF responsivity, 27 months	0.01	0.04	−0.07	−0.04	−0.04	0.10**	0.27**	0.10*	−0.01	−0.01	0.00	0.37**	--			
14. AC dysregulation, 27 months	0.04	−0.08	−0.01	0.27**	0.10**	0.02	0.10^{+}	0.67**	0.26**	0.27**	0.24**	0.04	0.07	--		
15. AC anger proneness, 27 months	0.00	−0.08	−0.04	0.23**	0.24**	0.05	0.05	0.35**	0.68**	0.30**	0.25**	−0.02	−0.01	0.37**	--	
16. AC social competence 4.5 years	−0.07	0.12*	0.00	−0.23**	−0.18**	0.03	0.02	−0.19**	−0.27**	−0.25**	−0.12*	0.14**	0.02	−0.27**	−0.28**	
Mean	0.00	0.00	8.70	1.86	1.90	10.58	10.05	5.13	3.40	2.07	2.06	10.70	10.27	4.59	3.58	48.87
Standard deviations	0.83	0.77	7.43	0.60	0.60	1.14	1.57	2.03	0.62	0.62	0.62	0.78	1.43	2.13	0.60	7.90

BP - Birth mother correlations are shown down the columns, Birth father correlations are shown across the rows.
$^{+}p<0.06$; $^{*}p<0.05$; $^{**}p<0.001$.

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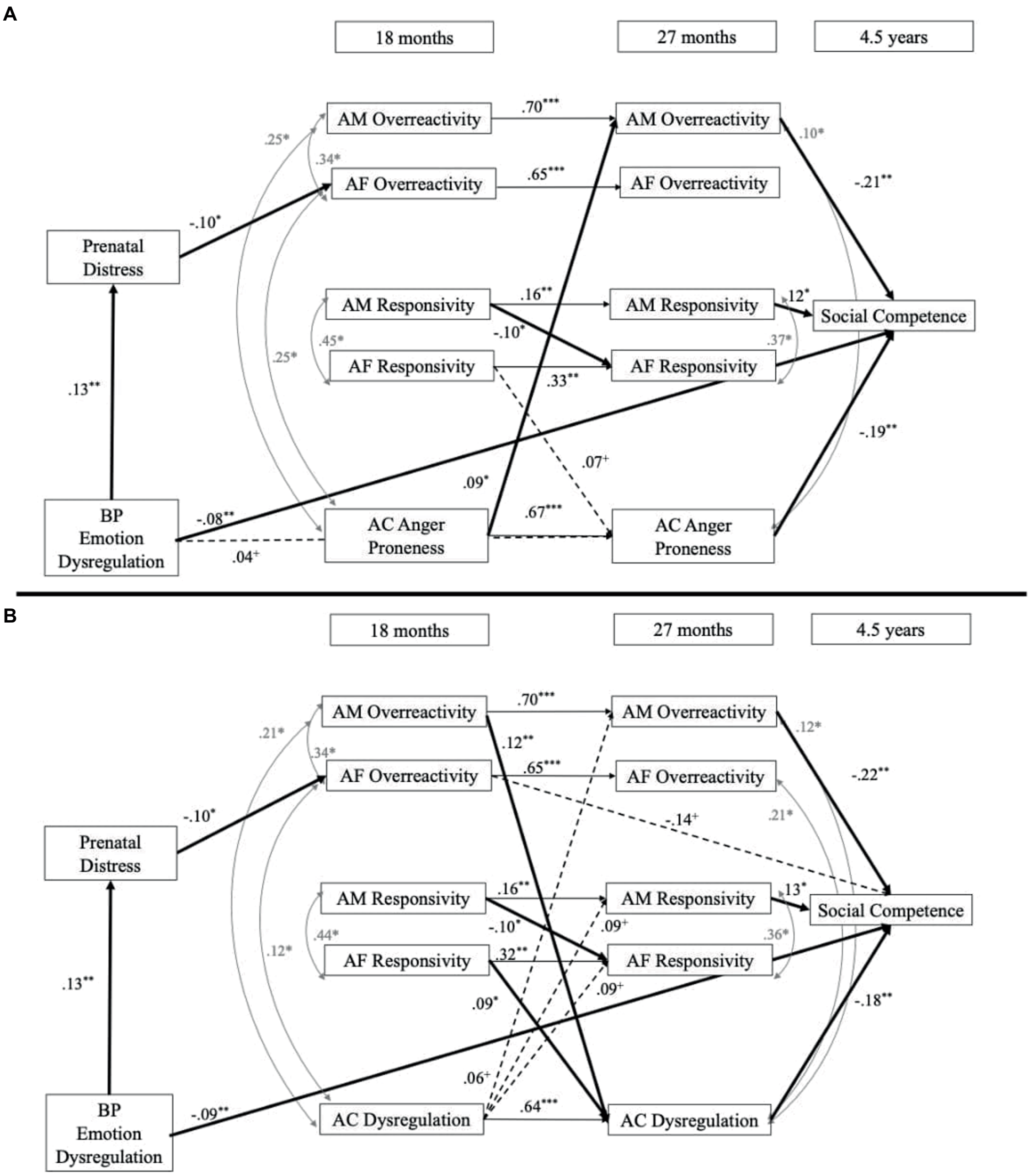

FIGURE 2

Birth parent emotion dysregulation models. **(A)** Presents the results with adopted child reactivity and **(B)** presents the results with adopted child dysregulation. BP, birth parent; AM, adoptive mother; AF, adoptive father; AC, adopted child. Nonsignificant paths are not included to assist with readability but were included in the statistical model. Solid lines indicate a significant effect and dashed lines indicate a trend-level association. $^{+}p < 0.07$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. Indirect prenatal effect BP emotion dysregulation-Prenatal distress-AF overreactivity: β = −0.01, *SE* = 0.01, *p* = 0.06. Panel **A** indirect effect AM overereactivity-AC dysregulation-Social competence: β = −0.02, *SE* = 0.01, *p* = 0.05. Panel **B** indirect effect AC reactivity-AM overreactivity-Social competence: β = −0.02, *SE* = 0.01, *p* = 0.05.

was positively associated with child dysregulation at 27 months, but not adoptive mothers' responsivity. We also found that adoptive mothers' responsivity at 18 months was negatively associated with adoptive fathers' responsivity at 27 months. Additionally, child dysregulation at 18 months was not associated with adoptive parents' parenting at 27 months. For the *child reactivity model* (Figure 3B), we found that adoptive parents' parenting at 18 months was not associated with child reactivity at 27 months. However, we found that child reactivity at 18 months was positively associated with adoptive mothers' overreactivity at 27 months; however, child reactivity was not associated with other parenting behaviors. We also found that adoptive mothers' responsivity at 18 months was negatively associated with adoptive fathers' responsivity at 27 months.

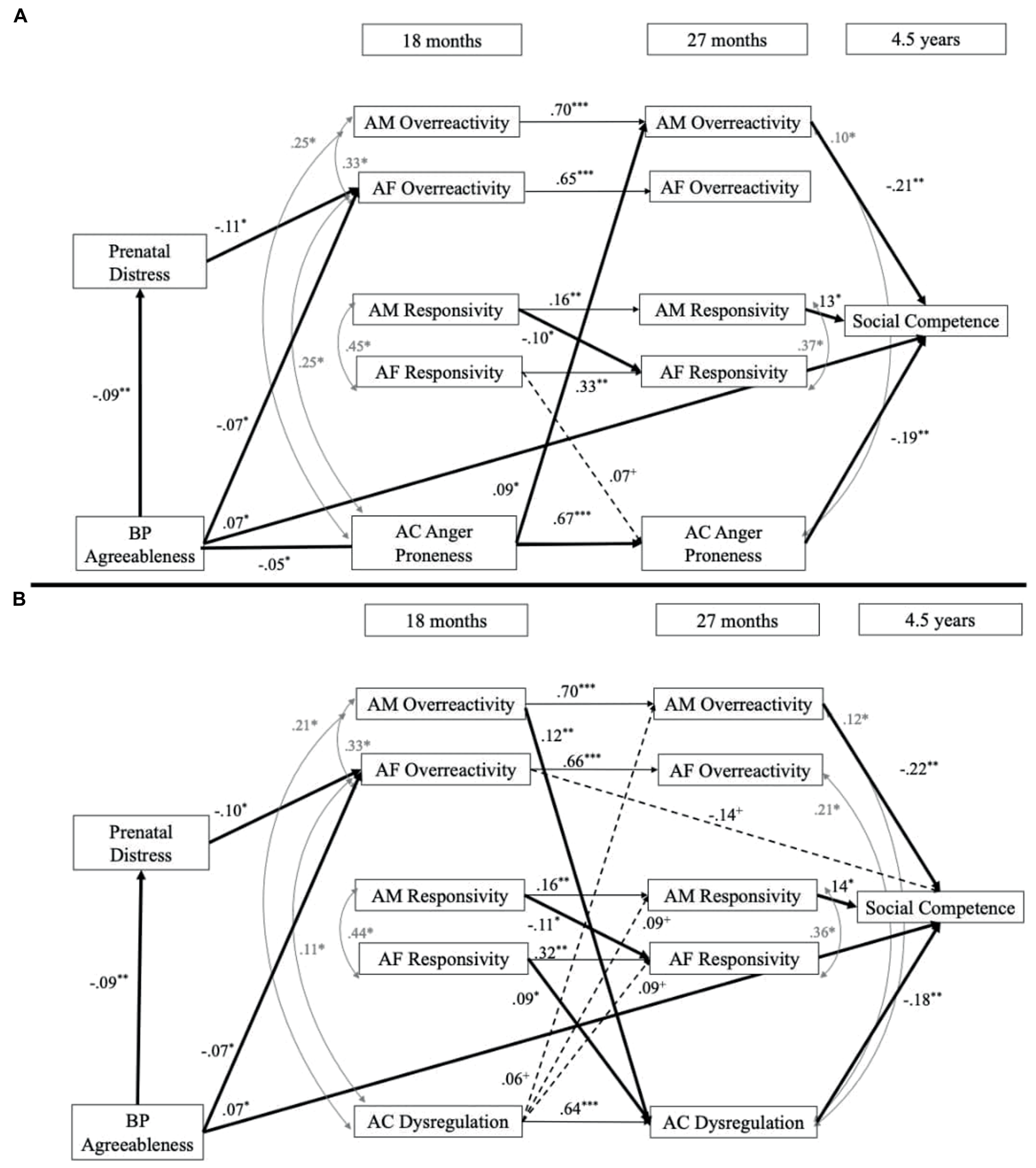

FIGURE 3
Birth parent agreeableness models. **(A)** Presents the results with adopted child reactivity and **(B)** presents the results with adopted child dysregulation. BP, birth parent; AM, adoptive mother; AF, adoptive father; AC, adopted child. Nonsignificant paths are not included to assist with readability but were included in the statistical model. Solid lines indicate a significant effect and dashed lines indicate a trend-level association. $^{+}p < 0.07$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. Indirect prenatal effect BP emotion dysregulation-Prenatal distress-AF overreactivity: β = 0.01, *SE* = 0.01, *p* = 0.06. Panel **A** indirect effect AM overereactivity-AC dysregulation-Social competence: β = −0.02, *SE* = 0.01, *p* = 0.05. Panel **B** indirect effect AC reactivity-AM overreactivity-Social competence: β = −0.02, *SE* = 0.01, *p* = 0.05.

Indirect effects

There was an indirect effect from adoptive mothers' overreactivity at 18 months to child social competence at 4.5 years through adopted mothers' overreactivity at 27 months (β = −0.15, *SE* = 0.05, *p* < 0.01). The indirect effect from birth parent emotion dysregulation to adoptive fathers' overreactivity through prenatal distress also was marginally significant (β = 0.01, *SE* = 0.01, *p* = 0.06). For the *child dysregulation model,* adoptive mothers' overreactivity at 18 months was associated with child social competence through child dysregulation at 27 months (β = −0.02, *SE* = 0.01, *p* = 0.05). Additionally, there was an indirect effect of child dysregulation at 18 months to child social competence through child dysregulation at 27 months (β = −0.11, *SE* = 0.04, *p* < 0.05). Finally, adoptive fathers' responsivity to child social competence was not significant through child dysregulation at 27 months ($\beta = 0.01$, $SE = 0.01$, $p > 0.05$). For the *child reactivity model,* child reactivity was associated with child social competence at 4.5 years through adoptive mothers' overreactivity at 27 months ($\beta = -0.02$, $SE = 0.01$, $p = 0.05$). However, there were no additional significant evocative *r*GE pathways.

Discussion

This study is one of the few genetically informed projects to examine genetic, prenatal, and postnatal rearing influences in early childhood and specifically in relation to children's early social competence. The findings indicate different bidirectional pathways by which parents and children can influence each other and negatively influence children's social competence. Additionally, there was evidence of unique genetic influences on social competence, evidence of evocative *r*GE, as well as an association between prenatal distress and fathers' overreactivity. Together these findings provide a more comprehensive picture of the longitudinal effects of risk factors across multiple domains for children's social skill development.

First, we found direct associations of genetic influences (birth parent emotion dysregulation and birth parent agreeableness), child early regulatory capacities (dysregulation and reactivity), and adoptive mother parenting behaviors, but not adoptive father parenting on children's social competence at 4.5 years old. The current study extends previous work on children's social competence in this sample (Van Ryzin et al., 2015), which examined gene–environment interaction and found that genetic influences buffered children's social competence at 6 years old against less sensitive parenting. We considered another genetic mechanism (evocative *r*GE) by examining bidirectional processes between parent and child across early childhood, as well as directly examining prenatal effects on social competence in preschool-age children. Our study's findings support previous research that social competence is subject to genetic influence (DiLalla et al., 2012; Van Ryzin et al., 2015; Battaglia et al., 2017), and that early regulatory capacities promote the development of social competence (Hubbard and Coie, 1994; Cole et al., 2004; Denham, 2006).

In addition, our work supports previous findings that adoptive mothers' parenting behaviors can be both deleterious and promotive to children's early social competence (Masten and Coatsworth, 1998; Clark and Ladd, 2000; Haskett and Willoughby, 2007; Driscoll and Pianta, 2011). However, fathers' parenting was not uniquely associated with children's social competence above and beyond adoptive mothers' parenting. This pattern of results for mothers' effects is supported by the majority of studies using only mothers (Laible et al., 2004; Leerkes et al., 2009; Rispoli et al., 2013; Raby et al., 2015), which might be due to mothers most often being the primary caregiver. However, in a study of both parents, Martin et al. (2010) found that having at least one parent who uses positive parenting behaviors is enough to help promote the child's social competence, and then the child could hit a "ceiling"—the child is scoring at the highest level of the scale—and the other parent provides no added benefit. The current study's finding does not negate the importance of the father and his role in children's development as we only considered two parenting behaviors and fathers may help to advance the child's social competence development in different ways. For example, some research suggests that fathers use more activation parenting (e.g., intense play with limit setting) that is focused on challenging the child while setting boundaries (Feldman and Shaw, 2021; Karam and Degnan, 2021). Therefore, examining these more traditional, and to some extent, more maternal-centric parenting behaviors (i.e., responsiveness) might not capture the independent role that fathers play in promoting or undermining children's social competence. These direct effects highlight the complex nature of equifinality, whereby multiple risk and promotive factors might come together over time to influence social competence in early childhood.

Second, consistent with our hypothesis, we found bidirectional pathways between parent and child that were associated with lower levels of child social competence at 4.5 years, while accounting for both genetic and prenatal influences. Specifically, we found both a child-driven pathway (i.e., child anger proneness at 18 months was associated with lower levels of social competence at 4.5 years through adoptive mother overreactivity at 27 months) and a parent-driven pathway (i.e., adoptive mother overreactivity at 18 months was associated with less social competence through child dysregulation at 27 months). These indirect pathways support previous non-genetically informed work exploring the unfolding of a coercive cycle between children and parents (Patterson, 1982), but provide new insights into its implications for social competence during early childhood (Shaw and Bell, 1993; Eddy et al., 2001; Smith et al., 2014). More specifically, these findings along with prior work (Eisenberg et al., 1996, 2010; Fabes et al., 2001) provide evidence that these coercive cycles between mother and child could be detrimental to children's early social competence. These early negative transactions are associated with decreased children's social skills prior to school entry which could set the child up for more negative child behaviors at school-age (Shaw et al., 1994, 1998; Smith et al., 2014). These indirect pathways could also suggest a more involved process whereby the coercive cycle between mother and child might increase the child's dysregulation, which, in turn, could negatively impact their social competence; however, this study was unable to test this directional association. The findings that both early emerging child-and parent-directed coercive cycles are associated with deficits in social competence highlight how early negative parent–child relationships can decrease critical social milestones that place a child at risk for later maladjustment.

We also found developmentally salient bidirectional pathways that show directional associations and might suggest how child and parent responses mutually reinforce each other on a longer timescale. Specifically, we found that child anger proneness at

18 months was associated with adoptive mother overreactivity at 27 months, while adoptive mother overreactivity and adoptive father responsiveness at 18 months were associated with child dysregulation at 27 months. Child anger proneness eliciting negative parenting is consistent with prior literature on child reactivity (Bridgett et al., 2009; Liu et al., 2020), but expands upon this work by also considering parenting pathways to child anger proneness. In contrast, when examining child dysregulation, we found only parent to child pathways. Specifically, we found that the child's dysregulation is being influenced by negative parenting, consistent with prior work (Grolnick and Farkas, 2002; Karreman et al., 2006). Finally, the finding that fathers' responsivity at 18 months was associated with more child dysregulation at 27 months was unexpected. While studies generally find that being a responsive parent is important for the child's development (Davidov and Grusec, 2006; Feldman et al., 2009; Rispoli et al., 2013; Raby et al., 2015), a meta-analysis found that responsiveness was not associated with child regulation (Karreman et al., 2006). A further consideration is that fathers' concept of responsiveness might serve different functions dependent on the child behavior (Kochanska and Aksan, 2004). This idea is supported by research finding that when fathers interact with their children, their synchrony of play is categorized by high peaks of intensity (e.g., overstimulation) without limit setting that could increase the child's dysregulation (Feldman, 2003; Paquette, 2004; Meuwissen and Carlson, 2018; Karam and Degnan, 2021). Overall, these findings allude to the potential differences these child behaviors might have within a dyad. Generally, child reactivity is an emotional response to the environment (i.e., parent) that poses a challenge to the parent, who, in turn, responds to the child (Paulussen-Hoogeboom et al., 2007). Meanwhile, regulation is developed over time by the child and supported by the parents who help the child to regulate their emotions and behaviors at an early age. While parents' overreactivity is in response to the child's displays of anger, parents' overreactivity could be also an indicator of dysregulated behavior. Thus, parent overreactivity could be modeled to the child, which disrupts and over time hinders the child's growing regulatory abilities.

This study also was able to distinguish between genetic and environmental influences to examine whether bidirectional effects between parent and child might be partially due to genetic influences. Although we did not find support for our main hypotheses regarding evocative *r*GE—whereby birth parent temperament would be associated with parenting at 27 months through child reactivity or dysregulation, we did find an evocative *r*GE effect on adoptive fathers' overreactivity at 18 months from birth parent agreeableness. However, this study did not model the specific child behavior that was evoking the fathers' behavior. One possible earlier child behavior could be children's early sociability or positive affect—which is heritable (Van Hulle et al., 2007), as birth parent agreeableness is indicative of higher sociability and better interpersonal relationships. Therefore, even before toddlerhood, children might be eliciting behaviors from their parents, partially based on their genetically influenced characteristics. This result supports a meta-analysis finding that evocative *rGE* has a larger effect in early childhood and decreases over time (Klahr and Burt, 2014). This pattern also supports previous genetically informed studies that found evocative effects on fathers and not mothers (Ulbricht et al., 2013; Hajal et al., 2015), which could suggest that specific parenting behaviors from fathers might be more susceptible to characteristics of the child at an early age that are at least partially due to genetic influences. We did not, however, find other evocative effects on mother or father responsivity, suggesting that these particular genetic propensities (emotion dysregulation, agreeableness) might be relevant only for overreactivity in infancy, whereas other genetic propensities (e.g., psychopathology) might be more relevant for other parenting behaviors (Trentacosta et al., 2019).

Although we did not find support for our hypothesis with either direct associations between prenatal distress and child behaviors (anger proneness, dysregulation, social competence) or an indirect pathway, we found that higher birth mother prenatal distress was associated with less adoptive fathers' overreactivity at 18 months. This finding could partially support the influence of prenatal distress on children's early behavior, as prenatal distress is presumably associated with father overreactivity through a child behavior that was not measured. Some research suggests that prenatal distress blunts children's cortisol responses, which is associated with less reactivity, and this could be why fathers respond less negatively to their children (Laurent et al., 2013; O'Connor et al., 2013). This study did include anger proneness at 18 months, but found no indirect pathway from prenatal distress to overreactivity at 27 months; however, future work may explore earlier child reactivity or other behaviors in infancy that might be impacted by maternal prenatal distress. We also found that both birth parent emotion dysregulation and birth parent agreeableness were associated with birth mothers' prenatal distress; however, the indirect effects to adoptive father overreactivity were not significant. Thus, the genetic influences of the parents were correlated with the prenatal environment (which might be indicative of passive *r*GE), but the indirect effect to fathers' parenting was not significant. Therefore, the prenatal association is likely to be an environmental influence on parenting, supporting previous work on the importance of prenatal distress (Booth et al., 1991; Barker et al., 2011).

Limitations

The results of the current study should be considered within the context of a few limitations. The first limitation is our ability to fully disentangle genetic and prenatal influences. This issue is challenging because birth mothers are reporting on both their behaviors and their prenatal experiences, increasing the potential for reporter bias. However, compared to other study designs, the adoption design is better able to disentangle genetic and prenatal influences, especially if birth fathers participate and are modeled with birth mothers (Loehlin, 2016). The inclusion of birth fathers' information in this study allows us to model the full genetic influence (birth mother and birth father), and better separate the genetic and prenatal influences. However, our birth fathers had lower levels of participation and might have influenced our estimates of genetic influences. Birth father missing data were handled with Full Information Maximum Likelihood (FIML) to account for the missing data and would likely introduce minimal bias in the birth father estimates. FIML has been found to be a superior approach to handling large amounts of missing data compared to listwise deletion and substitution methods and performs equally well when compared to multiple imputation (Graham, 2003; Lang and Little, 2018).

Second, adoptive parents are reporting on both parenting behavior (overreactivity and responsivity) and child behaviors; therefore, increasing the potential for reporter bias. To partially minimize this bias in our study, we combined parent reports of the child behaviors so that one parent was not providing the report on themselves and their child alone. Parent report of child behaviors can be influenced by the parents' own personality and child behavior (e.g., Treutler and Epkins, 2003), thus future studies should examine if consistent patterns of effects emerge with observational measures. It should be noted that observational measures provide a snapshot in time of behaviors that might not always have ecological validity depending on the observational setting (Gardner, 2000). Studies of child social competence suggest that there is small to moderate convergence of parent report and observation (Kotler and McMahon, 2002; Hawes and Dadds, 2006; Bennetts et al., 2016), suggesting that parents and observations can provide unique insights into child behavior. Third, these findings might not be generalizable to other populations, as the experiences of adoptive parents can be different from other parents (e.g., at-risk families, non-adoptive families). Additionally, our adoptive parents were majority White and highly economically advantaged. However, one study suggests that the potential for the restricted range of behaviors (i.e., less negative behaviors) does not differentially impact child outcomes compared to non-adoptive families (McGue et al., 2007). Finally, the prenatal experiences of birth mothers placing their children for adoption might be more unique than other samples (e.g., substance use and emotional difficulties). However, these mothers' experiences are not largely different from those of other mothers who did not place their child for adoption (Marceau et al., 2016; Ramos et al., 2020). They typically have similar levels of substance use, but often have a higher prevalence of depressive episodes that decrease over time, compared to national averages.

In addition, we were not able to consider trimester specific effects of prenatal distress on child social competence given the constraints of secondary data analysis; therefore, the findings reflect prenatal distress across pregnancy. Future studies should consider the effects of trimester specific prenatal distress within a genetically informed study. Finally, while there is value in understanding specific aspects of reactivity and dysregulation given the potential for unique mechanistic pathways and effects (e.g., McClelland and Cameron, 2012; Shewark et al., 2021), this specificity might limit our findings to these specific aspects of reactivity and dysregulation. Therefore, future work should continue to consider the implications of both specific aspects of reactivity and dysregulation on child development as well as broader conceptualizations of reactivity and dysregulation that can capture the complex nature of these constructs. There has been work done in early and later childhood to capture the multidimensional nature of dysregulation (e.g., Bellani et al., 2012; McClelland and Cameron, 2012), and future work can consider the utility of this measure alongside other multidimensional measures of regulation in infancy and toddlerhood to improve measurement of this critical construct.

Conclusion

Despite these caveats, this study is one of a few to examine multiple levels of influence (genetic, prenatal, child behaviors, and parenting) on the development of early social competence. The current study simultaneously assessed multiple levels of influence to better capture the complex multifaceted mechanisms of influence on children's social competence. These findings suggest not only that child and parent interactions are impacting child social competence, but that some of the parenting behaviors might be elicited by children's behaviors and influenced by both genetic and prenatal influences. Identifying the presence of coercive cycles in early childhood within a genetically informed design also provides converging evidence for the importance of the bidirectional processes between parent and child. Additionally, the lack of finding direct prenatal influences on child behavior does not imply that these influences do not exist. Rather, the child behaviors examined in this report may not be the most sensitive to the effects of prenatal distress. Future genetically informed studies should continue to examine the influence of the prenatal environment as a risk mechanism on positive child outcomes. For example, child cortisol could be examined as a mechanism through which the prenatal environment influences child development. The genetic influences found here are not trivial and suggest important mechanisms in the development of social competence. Therefore, future studies should continue using genetically informed designs to examine the bidirectional relationship between parents and children that influence children's social competence. Ultimately, examining the influence of these environment and genetic factors simultaneously within a genetically informed design can help researchers examine important mechanisms and important developmental periods where change might be more influential.

Data availability statement

Data are not publicly available due to privacy or ethical restrictions, but are available on request from the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by the University of Oregon Institutional Review Board (Project No.: 08082016.007; Title: The Early Growth and Development Study Pediatric Cohort). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

AR and JN developed the study idea. AR conducted the analyses, with assistance from ES, and drafted the manuscript. DR, DS, JG, LL, MN, and JN designed the larger study and supervised data collection. DR, DS, JG, LL, MN, ES, and JN provided conceptual and written feedback on the manuscript. All authors contributed to the article and approved the submitted version.

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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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Parental responsiveness and children's trait epistemic curiosity

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Curiosity, the desire to learn new information, has a powerful effect on children's learning. Parental interactions facilitate curiosity-driven behaviors in young children, such as self-exploration and question-asking, at a certain time. Furthermore, parenting quality predicts better academic outcomes. However, it is still unknown whether persistent parenting quality is related to children's trait epistemic curiosity (EC). The current study examined whether parenting practices, responsiveness, and demandingness are cross-sectionally related to the trait EC of children in different age groups (preschoolers, younger and older school-aged children). We adopted a shortened Japanese version of the parenting style questionnaire and modified the trait EC questionnaire in young children. A sample of 244 caregivers (87.37% mothers) of children (ages 3–12) was recruited through educational institutions in Japan and reported on their parenting practices and trait EC. All data analyses were performed using SPSS version 26. Hierarchical regression analyses were performed to determine the explanatory variables for children's trait EC. Self-reported parental responsiveness significantly explained EC scores. To the best of our knowledge, this is the first study to show a cross-sectional relationship between parental responsiveness and children's trait EC. Future research should clarify whether parental responsiveness in early childhood predicts children's EC later in life.

KEYWORDS

curiosity, responsiveness, middle childhood, late childhood, early childhood, parenting

Introduction

Curiosity is a fundamental learning motivation that involves the desire to know new or specific information (Berlyne, 1954, 1966). Epistemic curiosity (EC), one of the two branches of curiosity, is the drive not only to seek novel information but also to remove uncertainty (Berlyne, 1966; Loewenstein, 1994; Litman and Spielberger, 2003; Litman, 2005, 2008; Jirout and Klahr, 2012). Especially, experimental studies have shown that children's active self-exploration occurs for the purpose of reducing uncertainty rather than merely seeking novel information (Schulz and Bonawitz, 2007; Cook et al., 2011; Blanco and Sloutsky, 2021). It has been suggested that EC is linked to well-being (Kashdan and Steger, 2007; Engel, 2009; Wang and Li, 2015) as well as academic achievement (Shah et al., 2018). Despite the positive aspects of EC, according to Engel (2009), children show less EC as they age, especially after starting school. Thus, supporting and maintaining children's EC has long attracted caregivers and educators (Engel, 2011; Jirout, 2020).

EC was widely defined as a desire to seek various novelty stimuli and a specific knowledge or activity (Berlyne, 1954, 1960, 1966; Litman and Spielberger, 2003). According to Berlyne (1954, 1966), when humans encountered ambiguous stimuli, they experienced conflict. This experience motivates humans to explore new information to reduce this state (Berlyne, 1954, 1966). Litman and Spielberger (2003) theorized that individual differences exist in EC regarding the frequency of expressing EC. Building on this idea, Litman and Jimerson (2004) proposed that this personality trait is related to different emotions, pleasurable and aversive feelings of uncertainty, and pivotal aspects to motivate information seeking, and developed two types of EC model (Interest type EC/ Deprived type EC). Interest type EC (IEC) increases with the positive anticipation of learning new knowledge and motivates new information seeking (Litman, 2005). Deprived EC (DEC) increases undesirable feelings and motivates specific information seeking to reduce uncertainty (Litman, 2008). EC is the basic component of intrinsic motivation (Ryan and Deci, 2000), and IEC and DEC are related to different learning goals; as IEC is related to motivation to learn new knowledge simply for joy, while DEC is related to motivation to learn specific knowledge because of the "need to solve" (Litman and Jimerson, 2004). Specifically, DEC increases through extrinsic as well as intrinsic motivation (Litman et al., 2010).

Parenting is a factor that may affect children's EC. Parenting style is defined as a persistent "constellation of attitudes toward the child that are communicated to the child and that, taken together, create an emotional climate in which the parent's behaviors are expressed" (Darling and Steinberg, 1993, p. 488). Over the past decades, the impact of parenting style on child development has been investigated from two dimensions: responsiveness and demandingness (Baumrind, 1966; Maccoby and Martin, 1983). Responsiveness is referred to as the degree of warm acceptance with a sensitive response to children's needs and interests (Landry et al., 2001, 2006). Demandingness refers to the degree of parental control with strictness in a child (Rodriguez et al., 2009). One of the major approaches to studying parenting styles is the typological approach. Parenting styles were classified into four categories based on this approach (Baumrind, 1967; Maccoby and Martin, 1983), which is one of the most adopted typology approaches (person-centered): authoritarian (low responsiveness, high demandingness), authoritative (high responsiveness, high demandingness), permissive (high responsiveness and low demandingness), and uninvolved/neglectful (low responsiveness and low demandingness). Another approach to studying parenting style is the dimensional approach (variable-centered), which examines the relationships between variables. This approach has been adopted to investigate parental practices (Power, 2013). In this study, we focus on a dimensional approach to examine the independent relationships of each parenting dimension.

The accumulated evidence indicates that parenting influences the development of children's competence (for review, see Darling and Steinberg, 1993; Jeong et al., 2021). There has been empirical evidence of associations between responsiveness, demandingness, and cognitive development. For example, it has been noted that an authoritative parenting style, compared to authoritarian, permissive, and uninvolved/neglectful styles, has been positively associated with positive outcomes: academic achievement and cognitive development among adolescents (Steinberg et al., 1992; Llorca et al., 2017). Additionally, studies using the dimensional approach have also revealed a significant positive relationship between responsiveness and cognitive development, and academic success among elementary and middle school children (Dumont et al., 2014). A recent study has shown positive relations among parenting, which include parental encouragement and involvement in children's school/home activities, learning motivation, and children's EC among preschoolers (Kwok et al., 2022). Thus, warm and supportive parenting, such as high responsiveness, may guide children to achieve academic goals. However, existing evidence for the links between parenting and children's EC is limited.

Parental support may play a major role in curiosity-driven behavior among children. Previous studies have revealed that a secure environment fosters children's self-exploration in early childhood (Posada et al., 2007; Stupica et al., 2011), whereas an insecure environment is a key factor in infants' poor exploration (Gaertner et al., 2008). Children's information exploration is known to increase when they detect novelty (Berlyne, 1954, 1966), uncertainty (Schulz and Bonawitz, 2007; Blanco and Sloutsky, 2021), and knowledge gaps (Loewenstein, 1994; Stahl and Feigenson, 2015). Supporting children in recognizing EC-driven situations lead to higher levels of EC expression. For example, in an informal learning environment such as a museum, children aged three to seven actively engaged in complex material exploration when their parents guided them to do so. Conversely, children show less material exploration when parents actively explore tasks instead of guiding them to engage (Callanan et al., 2020). Furthermore, parental attitudes that encourage children to observe objects and ask questions at home increase complex exploration in preschoolers (Vandermaas-Peeler et al., 2019).

Based on these findings, the parent–child interactions over time are believed to be critical for the development of children's trait EC. Trait EC is the individual difference in the frequency of curiosity-state experiences in general (Litman et al., 2005). This is a more persistent form of EC and is distinguished from curiosity-driven behavior at a particular moment (e.g., Naylor, 1981). It has been proposed that IEC, related to intrinsic motivation, is observable in infants without external encouragement to seek information (Oudeyer et al., 2016). However, consistent responsive parental behavior across infancy has been suggested to facilitate infants' object exploration (Landry et al., 2003). Furthermore, responding to children's interests and EC encouraged them to ask more questions and seek information (for review, see Torrance, 1966; Ronfard et al., 2018). A recent study showed that asking questions is a fundamental and important tool for children to express EC (Alaimi et al., 2020). Such parental practices may facilitate DEC expression, which involves extrinsic motivation such as reducing uncertainty or praise (Litman et al., 2010). Therefore, responsive parental practice may be related to an increase in opportunities for children to feel the desire to explore new objects (IEC) or detect ambiguity (DEC) in their daily lives. Specifically, responsive parental practices play an important role in creating a secure environment expressing IED and detecting uncertainty or information gap results in expressing DEC. However, although encouraging and responsive parental behavior facilitates children's curiosity-driven behavior at a particular moment, little is known about whether responsive parenting is related to children's trait EC.

Several studies have revealed that children's EC expression changes from preschool to school age (Engel and Randall, 2009). It is commonly agreed that young children are naturally curious (Engel, 2009). Young children exhibit EC under more complex circumstances that require, for example, knowledge of cause-and-effect relationships in accordance with their cognitive maturity levels (FitzGibbon et al., 2019). However, in an observational study, researchers found that fifth-grade children showed less EC in the classroom than preschoolers (e.g., Engel, 2009). Engel (2009) pointed out that EC expression declines as people grow older after schooling. One possible interpretation for this is that the dominant goal of schools is mastery of skills rather than inquiry. Decreased EC levels in children may be partially related to school participation (Engel, 2009). Schools tend to provide fewer opportunities for children to express EC during late childhood (Engel, 2011). For instance, research has shown that in fifth-grade classrooms, educational priority focuses on mastering skills such as calculations and forms of grammar. This tendency has been observed in the early grades (Engel, 2011). Elementary school-aged children showed less exploration without the teacher's permission to explore, especially girls (Coie, 1974). In the Japanese educational context, it has been suggested that elementary school teachers use a teacher-directed teaching approach (e.g., instruct declarative knowledge) when they consider the student's need to master the targeted concept (Inoue et al., 2019), which may result in less opportunity for the student to show their EC at school. Additionally, a recent study has shown a significant relationship between parental school involvement, such as checking homework, and better academic outcomes among fourth-year students in Japan (Otani, 2020). The assumption is that EC might be generally high during early childhood, and children in this age group might have little room for an increase in EC because of parental influence. Therefore, the influence of parenting styles may be much greater for school-aged children than for preschoolers. Additionally, EC expression may be affected more by the school environment in older school-aged children; children reach adolescence when parental involvement declines (Steinberg, 2005).

Another view suggests that decreased levels of EC among school-aged children may be related to cognitive control development. Cognitive control enables children to regulate their behavior to achieve their goals. In general, school-aged children demonstrate better performance on cognitive control tasks than preschoolers (Davidson et al., 2006; Moriguchi and Hiraki, 2013; Chevalier et al., 2019; Plebanek and Sloutsky, 2019). Cognitive control abilities, such as executive function, enable older children to focus on goal-oriented information searches, which may be related to an increase in DEC expression. Simultaneously, cognitive control is also a predictor of better academic performance among elementary school students (Pascual et al., 2019). Academic activities or social academic expectations may influence whether older school-aged children express EC. Conversely, preschoolers performed better than older children on tasks such as remembering irrelevant information (Plebanek and Sloutsky, 2017; Gopnik, 2020; King and Markant, 2020; Blanco et al., 2023). One interpretation is that limited cognitive control encourages younger children to explore more information that is irrelevant to goals (Gopnik et al., 2017; Gopnik, 2020), which may be related to an increase in IEC expression.

In summary, parental support may facilitate the development of trait EC among children. Although several studies have focused on parental roles in encouraging children to explore new information at a certain time, the relationship between parenting and children's EC remains poorly understood. Moreover, there is consistent evidence that preschool-aged children are more likely to express a higher EC than school-aged children. The EC in school-aged children dwindles as children get older. However, it is unclear whether the relationship with parenting differs between early and late childhood.

To the best of our knowledge, no studies have examined the relationship between parenting and children's EC at different school levels. In the current study, we examined the relationship between parenting and trait EC in a sample of Japanese preschoolers and school-aged children. To this end, we classified children into three age groups (early, middle, and late childhood) because different educational and cognitive developmental levels may be related to children's EC expression. To investigate whether parenting is related to children's trait EC during different childhood periods, we analyzed the relationship between parenting and trait EC in preschoolers and younger and older school-aged children. This analytical approach is one of the main contributions of this study to the literature. We hypothesized that responsive parental practice would be related to children's EC in middle childhood and would show fewer relationships in early and late childhood. We used a parent-reported-based questionnaire because it reflected children's EC observed in a real-life setting (Piotrowski et al., 2014; Acar et al., 2019).

Methods

Participants

The participants were 245 caregivers of children aged 3–12 (girls 58.78%; mean age = 95.8 months; range 47–154 months; $SD = 31.84$). We determined the sample size based on the rule of thumb according to Harris's formula for a correlation or regression sample size (VanVoorhis and Morgan, 2007). A sample of 10 to 30 participants per predictor variable was appropriate, or at least 50 plus the number of predictor variables ($N > 54$). In total, 245 parents answered questionnaires regarding their children's EC and self-parenting styles. There was one case that was dropped from the analysis because of concerns about the validity of the data ($n = 1$). Based on the demographic questionnaire data completed by parents about themselves, the majority of caregivers described themselves as the child's mother (87.37%). Details of the children's current age in years and months and sex were provided. Participants' children were divided into separate groups: preschoolers ($n = 99$, 55 girls, mean = 63.3 months, range = 47–83, $SD = 10.18$), younger school-aged ($n = 72$, 44 girls, mean = 99.5 months, range = 83–117, $SD = 10.75$), and older school-aged ($n = 73$, 45 girls, mean = 135.6 months, range = 118–154, $SD = 10.47$).

Research design

A cross-sectional study was conducted to examine the relationship between parenting and children's trait EC at different school levels. Participants were recruited from two Japanese educational institutions: a private elementary school that follows the Japanese national curriculum and a center for early childhood education under the jurisdiction of the Cabinet Office in mid-sized cities in Japan. All participants were Japanese speakers. Questionnaires were distributed to children by their teachers during January and February 2022. One of the main caregivers was asked to complete the questionnaire. Teachers distributed envelopes containing questionnaires to their students' parents. Those who agreed to participate in the study returned a sealed, anonymous envelope to the children's teachers. Before the study began, informed consent was obtained from each child's caregiver. We included data when participants completed all items for at least one measure of children's EC or self-parenting styles. All procedures were approved by the local psychological research ethics committee (3-P-23).

Measures

Parenting style questionnaire

We used a parent-style questionnaire to investigate the quality of parental practices. Participants completed a shortened version of the Parenting Style Questionnaire (Robinson et al., 1995) developed in Japanese (Nakamichi and Nakazawa, 2003). Parenting style was assessed based on two dimensions: responsiveness and demandingness. Responses were recorded on a 4-point Likert scale (1 = *strongly disagree*, 4 = *strongly agree*). The responsiveness dimension scale was measured by eight items, for example: "When a child is playing alone and seems bored, join in and play with him or her" (one question was reverse scored) (Cronbach's $\alpha = 0.79$). The demandingness dimension was measured using eight items, for example, "Tell the child what to do" (two questions were reverse scored). For this study, we modified the demandingness scales by removing two statements that showed negative internal correlations in the factor of both items 12 and 14 (Cronbach's α for the six demandingness items was 0.61). For more information, see Supplementary material S1.

Parent-reported epistemic curiosity

The caregivers completed the EC questionnaire (Piotrowski et al., 2014), which was translated into Japanese. In the questionnaire, five items assessed IEC, for example, "My child has fun learning about new topics or subjects" (Cronbach's α = 0.88), and five items assessed DEC, for example, "When presented with a tough problem, my child focuses all of his/her attention on how to solve it" (Cronbach's α = 0.90), using a 5-point Likert-type scale (1 = *almost never*, 5 = *almost always*). For more information, see Supplementary material S2.

Data analysis

Since this study included a small sample size, determining the distribution of the variable parenting dimensions and children's IEC/DEC was important for choosing an appropriate statistical method. Therefore, a Shapiro–Wilk test was performed, which showed that each variable deviated significantly from normality. Based on these results, a nonparametric test was used. The Kruskal–Wallis test was performed to examine group differences between the means of the three independent age groups. Spearman's rank-order correlations were calculated to investigate the relationship between variables (sex, age in months, parenting styles, and EC) in this study for each age group. To examine whether parenting explained a statistical amount of variance in children's IEC and DEC, a hierarchical regression analysis was performed. All data analyses were performed using SPSS version 26.

Results

Initial analysis

Descriptive and correlational analysis

Table 1 shows means and SD as well as comparisons *via* the Kruskal–Wallis test between the three different age groups. We did not find any significant group differences in IEC (Chi-square = 3.50, $p = 0.174$, $df = 2$) or DEC scores (Chi-square = 4.77, $p = 0.09$, $df = 2$). Table 2 illustrates the Spearman's rank-order correlations between variables in each age group (preschoolers, younger school-aged, and older school-aged children) and across all children (age-collapsed). Responsiveness is positively related to DEC among preschoolers and EC (IEC and DEC) among younger-aged children. There were no significant relationships between parenting styles, responsiveness, demandingness, and children's EC among older-aged children. The age-collapsed analysis showed weakened correlations between responsiveness and EC (IEC and DEC).

Relationship between parenting styles and children's curiosity

A hierarchical regression analysis was performed to determine whether parenting practices are a significant predictor of children's IEC and DEC beyond their age. A two-step hierarchical multiple regression analysis was performed with each of the children's IEC and DEC as the dependent variables. Children's sex was entered in Step 1, and their age, parenting dimensions, responsiveness, and demandingness were entered in Step 2 as predictors. For all children, children's sex, age, and parenting dimensions did not contribute significantly to the regression model IEC [$F(4,224) = 0.41$, $p = 0.119$]. In contrast, Children's sex, age, and parenting dimensions contributed significantly to the regression model DEC [$F(4,225) = 3.37$, $p = 0.011$]. Furthermore, we found that parental responsiveness significantly explained IEC score, and children's age and parental responsiveness significantly explained DEC score. These results indicated that children's IEC and DEC were higher with increasing levels of responsive parental practice and children's DEC decreases as they mature. For preschoolers, multiple regression analysis revealed that at Stage 2, children's sex, age, and parenting dimensions did not contribute significantly to the regression models IEC [$F(4,84) = 1.40$, $p = 0.242$] or DEC [$F(4,85) = 1.09$, $p = 0.366$]. We found that children's age explained IEC, indicating that preschoolers' IEC increases as they get older. For younger-aged children, children's sex, age, and parenting dimensions contributed significantly to the regression models IEC [$F(4,65) = 5.17$, $p < 0.001$] and DEC [$F(4,64) = 5.04$, $p < 0.001$]. Furthermore, we found that parental responsiveness significantly explained IEC and DEC scores. For younger-aged children, ECs were higher with increasing levels of responsive parental practice. For older school-aged children, children's sex, age, and parenting dimensions did not contribute significantly to the regression models IEC [$F(4,65) = 1.86$, $p = 0.128$] or DEC [$F(4,66) = 0.36$, $p = 0.838$] (Table 3).

Discussion

In the present study, we investigated whether responsive and demanding parental practices are related to children's trait EC during early, middle, and late childhood in a sample of Japanese children. The results showed that responsive parenting was related to children's trait EC. In addition, parents who exhibited acceptance and warm behavior

TABLE 1 Sample descriptive separately for the three age groups.

	Total (n=244)		Preschoolers (n=99)		Younger school-age (n=72)		Older school-age (n=73)		Group differences	
	n	M (SD)	n	M (SD)	n	M (SD)	n	M (SD)	Value of p	Kruskal-Walls Test
Responsiveness	241	3.00 (0.50)	97	2.89 (0.49)	72	3.10 (0.52)	72	3.06 (0.45)	0.018	Yo > Pr
Demandingness	237	3.38 (0.39)	95	3.22 (0.39)	70	3.45 (0.34)	72	3.50 (0.38)	0.000	Yo > Pr, Ol > Pr
IEC	240	4.38 (0.65)	97	4.41 (0.68)	72	4.46 (0.50)	71	4.25 (0.72)	0.174	
DEC	241	3.61 (0.84)	98	3.72 (0.77)	71	3.66 (0.81)	72	3.43 (0.93)	0.092	

Higher scores indicate higher parenting practices of each dimension. Higher scores indicate more curious. IEC, I-type epistemic curiosity; DEC, D-type epistemic curiosity; Pr, preschoolers; Yo, younger school-age; Ol, older school-age.

TABLE 2 Spearman's rank order correlations between variables.

	1	2	3	4	5
All (n = 244)					
1. Sex	–				
2. Age in months	0.05	–			
3. Responsiveness	−0.03	0.10	–		
4. Demandingness	−0.10	0.29**	0.23**	–	
5. IEC	0.00	−0.10	0.22**	0.07	—
6. DEC	−0.02	−0.12	0.19**	0.01	0.70**
Preschoolers (n = 99)					
1. Sex	—				
2. Age in months	0.01	–			
3. Responsiveness	0.06	−0.17	—		
4. Demandingness	0.04	0.06	0.34**	–	
5. IEC	−0.07	0.10	0.08	0.19	–
6. DEC	−0.03	0.00	0.23*	0.09	0.66**
Younger school-age (n = 72)					
1. Sex	–				
2. Age in months	0.11	–			
3. Responsiveness	−0.25*	−0.17	—		
4. Demandingness	−0.13	−0.15	0.07	—	
5. IEC	−0.13	−0.05	0.50**	0.24*	—
6. DEC	−0.16	−0.02	0.51**	0.14	0.70**
Older school-age (n = 73)					
1. Sex	—				
2. Age in months	0.05	—			
3. Responsiveness	0.12	0.00	—		
4. Demandingness	−0.27*	0.11	0.13	—	
5. IEC	0.22	−0.17	0.14	−0.09	—
6. DEC	0.12	−0.03	−0.08	−0.04	0.69**

*p < 0.05, **p < 0.01.

were more likely to have children who expressed higher levels of IEC and DEC, especially during middle childhood. However, parental practices were not significantly related to trait EC in older school-aged children (9-to 12-year-olds). We found no significant relationship between sex and trait EC in any age group. This is partly consistent with a previous study that reported that the trait EC of 3-to 8-year-old children was not significantly different between the sexes (Piotrowski et al., 2014).

Our results indicate that parental responsive involvement was related to trait EC, both IEC and DEC. Inconsistent with the evidence that school-aged children showed less EC than preschoolers (Engel, 2011), our data indicate that there are no significant EC differences between children. This may be because the present study reflected children's EC observed at home, whereas the previous study reflected children's EC observed in a school setting. Our findings could imply that responsive parenting from preschool age through middle childhood may promote children's EC. Previous studies have reported that parental responsive interactions during early childhood predict children's social or cognitive abilities in later childhood, including prosocial behavior (Stern and Cassidy, 2018), cognitive skills (Hurtado-Mazeyra et al., 2022), and math achievement (Duncan et al., 2019). Responsive parenting has also been linked to parental involvement in schools. These studies indicate that parental school involvement could be a moderator in predicting future outcomes in children. Previous studies have also suggested that parental beliefs influence children's attitudes and interests (Leibham et al., 2005; Cevher-Kalburan and Ivrendi, 2016; Pattison and Dierking, 2019). When parents believed that curiosity was important for their children's future, they tended to provide more opportunities related to their children's interests (Leibham et al., 2005). In contrast, demanding-only parenting may be related to less encouragement of children's interests (LaForett and Mendez, 2017). Taken together, we propose that parental responsiveness facilitates children's EC development.

When we looked more closely, no significant relationship was detected between parenting practices and trait EC among older children. One possible interpretation is that older school-aged children's EC levels may be affected by other factors such as school-related activities as children reach a period of becoming more independent from their parents (Feder et al., 2019). Furthermore, cognitive control skills enable older children to focus on goal-related activities. The influence of the school context increases when children in late childhood place greater importance on academic activities. Another possibility is that parents

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TABLE 3 Hierarchical regression analysis for variables predicting IEC and DEC scores.

	All			Preschoolers			Younger school-age			Older school-age		
	B	SE B	β	B	SE B	β	B	SE	β	B	SE	β
IEC												
Step 1												
Child's sex	0.027	0.087	0.021	−0.056	0.146	−0.041	−0.105	0.123	−0.103	0.278	0.176	0.188
R2	0.000			0.002			0.011			0.035		
Step2												
Child's sex	0.044	0.087	0.034	−0.072	0.144	−0.053	0.042	0.115	0.041	0.259	0.182	0.176
Child's age	−0.003†	0.001	−0.126	0.014*	0.007	0.222	0.002	0.005	0.033	−0.015†	0.008	−0.223
Responsiveness	0.183*	0.088	0.141	0.039	0.154	0.028	0.447**	0.109	0.468	0.026	0.192	0.016
Demandingness	0.003	0.116	0.002	0.165	0.194	0.095	0.232	0.162	0.159	−0.207	0.232	−0.111
R2	0.032			0.062			0.241**			0.103		
DEC												
Step 1												
Child's sex	−0.085	0.113	−0.049	−0.122	0.168	−0.078	−0.275	0.196	−0.169	0.178	0.226	0.094
R2	0.002			0.006			0.029			0.009		
Step2												
Child's sex	−0.056	0.112	−0.032	−0.127	0.167	−0.081	−0.068	0.185	−0.042	0.220	0.242	0.116
Child's age	−0.005*	0.002	−0.172	0.006	0.008	0.084	0.002	0.008	0.033	−0.004	0.011	−0.046
Responsiveness	0.303**	0.113	0.179	0.308†	0.180	0.193	0.726**	0.176	0.470	−0.214	0.253	−0.105
Demandingness	0.024	0.149	0.011	0.038	0.227	0.019	0.168	0.260	0.072	0.070	0.310	0.029
R2	0.056*			0.049			0.240**			0.021		

†$p < 0.10$. *$P < 0.05$. **$P < 0.01$. B, partial regression coefficient; SE, standard error; β, standardized partial regression coefficient.

who show responsive parenting may focus on their children's academic achievement during late childhood. Indeed, responsiveness has been reported to be related to parental involvement in education during late childhood and to be a predictor of better academic outcomes among adolescents (Dumont et al., 2014). In the Japanese educational context, teachers tend to teach knowledge to master skills instead of adopting a student inquiry approach (Henry and Brown, 2008; Inoue et al., 2019). This may reflect that the standardized entrance exam is a central determinant of acceptance into higher education in Japan (Yamamoto and Brinton, 2010). Responsive parents may consider the importance of academic success involving academically related activities when their children get older. However, it is important to consider both EC development and knowledge enhancement. Importantly, a recent longitudinal study indicated that 8-to 10-year-old children's curiosity predicted longer-term curiosity characteristics (Fandakova et al., 2018). Middle and late childhood can be critical ages for fostering a later curious mind. Thus, further research is required to understand whether the dominance of mastering skills affects children's curiosity development as they get older. Previous studies have revealed that encouraging parental interaction promotes object exploration in children at a certain age (Posada et al., 2007; Stupica et al., 2011; Vandermaas-Peeler et al., 2019; Callanan et al., 2020). We investigated a more sustained relationship between parent–child interaction and EC development. Our results showed that responsive parenting was cross-sectionally related to trait EC among, especially, younger school-aged children. However, the relationship with parenting did not persist in later childhood. Previous studies have indicated that the parenting combination of responsiveness and demandingness (authoritative) parenting is positively correlated to children's academic achievement (Burchinal et al., 2002) and school adjustment (Chen et al., 1997). A key feature of our findings is that school activity may have a greater influence on children's EC development than parental involvement in late childhood. Furthermore, parenting may also influence school-related tasks that are prioritized in the educational system.

Implication

The main aim of the current study was to address whether parenting practices are linked to the trait EC of children in different age groups. While previous research has focused on parental roles in enhancing children's EC at a certain age, our results show that responsive parenting is cross-sectionally related to children's trait EC in middle childhood. Responsive parenting may be beneficial for curiosity development among children, especially in middle childhood. Future work could examine the relationship between the educational approach (knowledge enhancement or inquiry) and children's EC.

Limitation

The current study had several limitations. First, cross-sectional correlations do not determine whether parental responsiveness influences EC development. Longitudinal studies are needed to examine whether (a) EC changes during childhood and (b) parental responsiveness at an early stage of life predict children's EC development in later childhood. Second, we did not investigate educational expectations or beliefs about the importance of curiosity among parents and teachers. Further research is needed to address how social and educational expectations affect children's EC, especially during late childhood. Specifically, it will be of interest to examine how parental beliefs affect children's EC development over the long term. Additional research is needed to examine the relationships between children's IEC and DEC, cognitive control ability, teaching approach (e.g., inquiry-based teaching or teacher-direct teaching), and parenting style in different age groups.

Conclusion

Our findings shed new light on the importance of a responsive parental attitude for fostering and maintaining trait EC in middle childhood. Our results showed no significant association between parenting practices and children's trait EC during early and late childhood. These findings suggest the contribution of other factors, such as cognitive status and school activities, to curiosity. This study offers some guidance for future investigations of factors predicting children's curiosity. Future research should clarify whether parental responsiveness at an early age plays a vital role in EC in later childhood when children engage in school activities.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://osf.io/p2utz/?view_only=2ef5c25bbe2a4e268b4d3f0cbe1a5de1.

Ethics statement

The studies involving human participants were reviewed and approved by Kyoto University Psychological Science Unit. The participants provided their written informed consent to participate in this study.

Author contributions

SI contributed to the conceptualization of the study based on suggestions made by YM and KS, collected the data, conducted the analyses, and drafted the original manuscript. All authors critically reviewed and revised the manuscript draft and approved the final version for submission.

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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.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.1075489/full#supplementary-material

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Prospective associations between child screen time and parenting stress and later inattention symptoms in preschoolers during the COVID-19 pandemic

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Introduction: Child attention skills are critical for supporting self-regulation abilities, especially during the first years of life. On the other hand, inattention symptoms in preschoolers have been associated with poor school readiness, literacy skills and academic achievement. Previous research has linked excessive screen time with increased inattention symptoms in early childhood. However, most research has only focused on TV exposure and did not investigate this association during the COVID-19 pandemic. This atypical context has increased screen time in children worldwide, including preschoolers. We hypothesize that higher levels of child screen media and parenting stress at age 3.5 will be associated with higher child inattention symptoms at age 4.5.

Method: This study draws on participants followed longitudinally over the span of 2-years for an investigation of Canadian preschoolers' screen media use during the pandemic (N = 315, 2020). A follow-up with this sample was completed in 2021 (N = 264).

Results: Analyses using multiple linear regression, revealed a positive association between child screen time at age 3.5 and inattention symptoms at 4.5 years. Parental stress was also positively associated with child inattention symptoms. Associations were observed above individual (child age, inhibitory control, and sex) and family (parent education and family income) characteristics.

Discussion: These results confirmed our hypothesis and highlight that preschooler screen use and parenting stress may undermine attentional skills. Since attention is a crucial component for children development, behavior and academic outcomes, our study reinforces the importance for parents of adopting healthy media habits.

KEYWORDS

screen time, digital media, inattention, early childhood, pandemic (COVID-19)

Introduction

Child attention skills evolve dramatically during the first 5 years of life (Diamond, 2002) and are critical for school outcomes from preschool through university, including job success (Diamond, 2014). During the preschool years, children progressively learn how to sustain their attention while engaging with their social and physical environment (Shannon et al., 2021). As attention skills evolve, children become more alert and sensitive to external stimulus. This alertness helps them identify task-relevant stimuli, and purposefully engage or disengage with a task (Corkin et al., 2021). Attention skills are also foundational for children's burgeoning awareness of the world and their ability to regulate their thoughts and feelings (Posner and Rothbart, 2007). Thus, the development of attentional skills in early childhood has been directly linked to improved effortful control, working memory, and emotion regulation which can then underlie behavioral and cognitive outcomes later in life (Nigg, 2017).

Child inattention and preschooler outcomes

Attention deficit hyperactivity disorder (ADHD) is one of the most common neurodevelopmental disorders during childhood (Cerrillo-Urbina et al., 2018). Based on epidemiological data, the prevalence of inattention symptoms in preschoolers ranges from 1.3 to 3.9% (Spira and Fischel, 2005; Alhraiwil et al., 2015). In general, symptoms of inattention are related to failing to pay close attention to details, trouble in organizing tasks, careless mistakes in activities, and being easily distracted (American Psychiatry Association, 2013). Hence, preschoolers who have poor attention are most likely to experience a lower level of school readiness (Perrin et al., 2019), low literacy skills (Sims and Lonigan, 2013; Hume et al., 2016), and academic achievement (Spira and Fischel, 2005; Duncan et al., 2007). Even subclinical levels of inattention result in a decline in academic attainment (Sasser et al., 2015). Being inattentive has been negatively correlated with child language comprehension (Parks et al., 2021) and uniquely contributes to lower levels of social competence above and beyond the related constructs of hyperactivity and impulsivity (Parks et al., 2021). Previous studies have also linked inattention to lower emotion regulation, lower executive functions, higher rates of oppositional-aggressive behaviors in preschoolers, worse eating habits, and worse general health, which can compromise developmental and health outcomes throughout childhood (Diamond and Lee, 2011; Ebenegger et al., 2012; O'Neill et al., 2017; Landis et al., 2021).

Preschooler screen time and inattention

Previous studies have identified several lifestyle factors that may influence the development of child attention. In particular, studies have found that greater preschooler TV viewing contributes to increases in inattention symptoms (Cao et al., 2018; Mostafa, 2019; Li et al., 2020). Research has mostly focused on TV viewing rather than newer media (Christakis et al., 2018). However, the adverse effect of portable devices, such as smartphones and tablets, on attention has also been documented (Konok et al., 2021). According to other studies, preschoolers exposure to screens can lead to increases in inattention symptoms (Tamana et al., 2019; Hetherington et al., 2020; Xie et al., 2020; McArthur et al., 2021a). When investigated over a 22 month periods, multiple exposure to media, such as background use and screen time, significantly decreased child focused attention (Gueron-Sela and Gordon-Hacker, 2020). It is important to note that the data analysed in the aforementioned studies was collected before the pandemic. Child screen time of all ages significantly increased during the COVID-19 pandemic (Bergmann et al., 2022). Globally, an increase from 0.75 h to 6.5 h a day has been reported (Toombs et al., 2022). In Canada, this increase ranged from 2.6 h to 5.9 h a day (Toombs et al., 2022).

Family and child characteristics, preschooler screen time, and inattention

Screen time and inattention are related to child and family characteristics. For example, media use can vary based on age and sex, with boys and older children being more likely to have longer screen time (Duch et al., 2013; Atkin et al., 2014). Children presenting more difficult temperaments are also exposed to more screen time (Corkin et al., 2021). Similarly, inattention can be affected by child individual traits (e.g., cognitive capacity and children neurodevelopment) (Sasser et al., 2015; O'Neill et al., 2017). Child deficits in inhibitory control have also been linked to increased risk of developing inattention problems (Barkley, 1997). Indeed, poor inhibitory control in preschoolers was predictive of later attentional disorders (Miller et al., 2019). The larger social context of families is also likely to contribute to child screen time and their development of symptoms of inattention. For instance, children from lower income families spend more time using media (Ribner et al., 2017). Low parental education and low family income are also negatively associated with child attention regulation (Mistry et al., 2010).

Contextual factors, such as the COVID-19 pandemic and the parent stress experienced during this atypical historical event are also likely to have contributed to child screen use and inattention. Lockdown measures during the COVID-19 pandemic have resulted in numerous disruptions to family life and have increased parenting stress and family screen use (Hartshorne et al., 2021). Before the pandemic, parenting stress was already associated with greater child screen use (Shin et al., 2021) and less likelihood parental limit and rule setting on the quantity of media intake by children (Walton et al., 2014). Along the same lines, family stress can influence the development of attention in the preschool years (Greenhill et al., 2008). Data collected with 878 parents in the pandemic context showed that parent distress significantly predicted children's inattention during this period (Marchetti et al., 2020).

The current study

Previous studies have shown that greater screen time intake by preschoolers can comprise their development of attention skills. However studies have focussed mostly on television exposure, have not considered the role of parenting stress, and have been conducted pre-pandemic. Since inattention has been linked to several adverse developmental and academic outcomes throughout childhood and screen time has increased considerably during the pandemic context, it is crucial to better understand this association while controlling for characteristics of the child and family environment. The present study therefore aims to examine the contribution of preschooler screen time and parenting stress during the COVID-19 pandemic to later inattention symptoms. Individual child (e.g., age, inhibitory control, and sex) and family (e.g., parents' education, family income) characteristics are included as covariates.

Method

Sample

In the context of a larger longitudinal study, parents with children between the ages of 2 and 5 (mean age 3.46) completed an assessment of child digital media use in the spring of 2020 during the first wave of the COVID-19 pandemic (2020, $N = 315$). Participants were recruited by distributing eye-catching posters and flyers to preschools and pre-kindergarten classes, through sign-up sheets and presentations given at preschool and pre-kindergarten registration nights, a Facebook page, and newspaper and radio advertisements. Data was collected during a provincially declared state of emergency and lockdown in the province of [omitted for non-identification of authors], Canada. Mothers were the primary respondent in most cases ($N = 295$ or 93.4%). Most respondents reported being married (82%), born in Canada (91%), and White (90.5%). Our sample contained slightly more boys ($N = 170$) than girls ($N = 145$). Finally, our sample was predominantly English-speaking, with 88.1% ($N = 280$) reporting that English is the main language spoken in their home. A follow-up was carried out 1 year later in 2021. The outcome variable data ($n = 264$, 2021, 83% retention rate) were collected 1 year later (mean age of 4.5 years).

Procedure

Parents completed the Media Assessment Questionnaire (MAQ, Barr et al., 2020) when children were 3.5 and 4.5. This is a web-based assessment of family media exposure that includes questions on child and family characteristics and child screen use habits. For the purpose of our study questions on child inattention were integrated to our online questionnaire. This assessment has been described in detail elsewhere (Barr et al., 2020). All measures are described in more details below. The present research was approved by two Ethics Committees at [omitted for non-identification of authors] and [omitted for non-identification of authors]. Informed consent to participate was obtained from parents.

Measures

Child inattention

Parents reported inattention symptoms in preschoolers when they were 4.5. More specifically parents reported the extent to which their child had shown inattention symptoms over the last 6 months using the following items: Was unable to concentrate; could not pay attention for long; Was inattentive and; Was easily distracted, and had trouble sticking to any activity. Participants responded using a 3-point Likert scale ranging from Never or not true scored as 1, to Sometimes or somewhat true scored as 2, and Often or very true, scored as 3. Items were derived from the Child Behavior Checklist and Preschool Behavior Questionnaire (Achenbach et al., 1987). We calculated the mean scores and treated this variable as a continuous variable, in which higher scores reflect higher levels of inattention. The Cronbach's alpha for these inattention items was $\alpha = 0.74$.

Child screen time

Parents reported the average amount of time children spent doing each of the following on weekdays and weekend days separately: (1) watching TV or DVDs; (2) using a computer; (3) playing video games on a console; (4); Using an iPad, tablet, LeapPad, iTouch, or similar mobile device (excluding smartphones); or (5) Using a smartphone. Response options included: (1) Never; (2) Less than 30 min; (3) 30 min to 1 h; (4) 1–2 h; (5) 2–3 h; (6) 4–5 h; (7) more than 5 h. We then converted these categorical responses into variables reflecting the number of hours spent with each type of media device. Our approach involved using the midpoint for each response range, except for "Never" where a score of 0 was used, and "5 or more hours a day" where a more conservative score of 5 was used. Weighted daily averages of time spent with each type of media device were then created by multiplying weekday estimates by 5 and weekend day estimates by 2 and dividing the total by 7. Last, we estimated an overall daily screen time by summing the weighted daily average across media devices.

Parenting stress

Parents also completed the parenting distress subscale of the Parent Stress Index (Abidin, 2012). In total, parents completed 12 items (i.e., I find myself giving up more of my life to meet my child's needs than I ever expected). Items were rated on a 5-point Likert scale as: 1 (strongly disagree); 2 (disagree); 3 (not sure); 4 (agree); or 5 (strongly agree); and were then summed to create a total score (Cronbach's alpha = 0.85).

Child and family characteristics

Parents reported their child's sex and age in years. Child sex was categorized as: (0) Boys and (1) Girls. Parents also reported their level of education and family income. All these variables were collected during Time 1. Education reflects the highest school grade completed by the parent. Responses were categorized as either: (1) High school or college vocational; (2) Undergraduate; or (3) Graduate degree. Income was categorized as either (1) less or equal than 59.000 CND; (2) 60,000 or higher CND.

Child temperamental attention was measured at 3.5 years using the Children's Behavior Questionnaire—Short Form (Putnam and Rothbart, 2006). In the present study, child inhibitory control was measured based on six items (i.e., Can wait before entering into new activities if s/he is asked to). The short version uses a 7-point Likert scale ranging from 1 (extremely untrue of your child) to 7 (extremely true of your child). Cronbach's alphas were 0.79.

Data analytic strategy

We use multiple linear regression to estimate associations between child screen time and parenting stress at age 3.5 years and inattention symptoms at 4.5 years, while controlling for child and family confounders. We use continuous measures of screen time to increase our ability to directly compare our effect sizes with those of previous studies (Madigan et al., 2019; Tamana et al., 2019). This analytical strategy has been used by others (Orben and Przybylski, 2019).

TABLE 1 The mean and standard deviation for continuous variables in the model.

	Mean (95% CI)	SD	Min-max	*N* (% missing)
Predictors				
Children screen time (hours)	3.44 (3.15–3.74)	2.45	0–10.4	315 (0%)
Parenting stress	18.02 (17.35–18.70)	5.52	12.00–0.43.00	315 (0%)
Outcome				
Child inattention	1.67 (1.31–0.1.73)	0.50	1.00–3.00	264 (16.2%)
Covariates				
Child				
Age (years)	3.46 (3.36–3.56)	0.84	2.00–5.42	315 (0%)
Inhibitory control	4.60 (4.49–4.71)	0.97	1.33–7.00	315 (0%)

TABLE 2 Frequency distribution for categorical variables in the model.

	%	*n*	Total *N* (% missing)
Covariates			
Household income (Canadian dollars)			295 (6.3%)
<60,000/year	15.9	47	
≥60,000/year	84.1	248	
Parent education			315 (0%)
High school diploma, college or lower	25.7	81	
University degree	74.3	234	
Child's sex			315 (0%)
Boys	54.0	170	
Girls	46.0	145	

Results

Attrition analysis

Retained and unretained participants did not significantly differ in screen time, inattention, child sex and age, inhibitory control, parenting stress, and family income. However, parents with a university degree were more likely than those with a high school/vocational degree to remain in our sample at the follow-up, $\chi(1)^2 = 4.24$. The proportion of missing data on the outcome variable was 16.2%. Missing data were examined with the MVA module in SPSS. We computed Little's test to evaluate if data were missing completely at Random (MCAR). This test was non-significant ($\chi^2 = 1.75$, df = 4, $p = 0.78$) indicating that data could be deemed missing completely at random. To reduce the bias due to the attrition rate and to maintain statistical power, we carried out multiple imputations using SPSS. The results of regression represent pooled estimates over five imputed estimated data sets.

Sample characteristics

Descriptive statistics and frequencies for all variables are presented in Tables 1, 2.

Multiple linear regression

The results of the multiple regression model are presented in Table 3. Child screen time (hours) at age 3.5 during lockdown contributed positively and significantly to child inattention symptoms one year later ($\beta = 0.14$; $p = 0.02$). Parenting stress at baseline positively predicted child's inattention symptoms at follow-up ($\beta = 0.24$; $p = 0.01$). Finally, higher scores on child inhibitory control at age 3.5 was also associated with less inattention symptoms at age 4.5 ($\beta = -0.25$; $p = 0.01$).

Clinical significance

In our regression results, each hour of daily screen time contributed to a 14% of standard deviation increase in inattention scores, as well as parenting stress contributed to a 24% of standard deviation increase in this outcome (Table 3). Despite its small size, this association is likely more clinically meaningful for heavy screen media exposure. Heavy screen use, characterized by a use of 4 h or more of screen media daily, would therefore result in a standard deviation increase of 14% multiplied by 4 h. As such, heavy media using children could experience a 56% of a standard deviation increase in their inattention symptoms.

TABLE 3 Predicting the relationship between child screen time and inattention symptoms in preschoolers.

	Child inattention symptoms (time 2)		
	β	*p* value	Adjusted R^2
Predictors (time 1)			0.18
Child screen time (hours)	0.14	0.02	
Parenting stress	0.24	0.01	
Covariates			
Child's age (years)	0.11	0.07	
Child's inhibitory control	−0.25	0.01	
Household income (Canadian dollars)			
<60 K/year (ref)	–	–	
≥60 K/year	0.26	0.12	
Educational attainment			
Sec./College (ref)	–	–	
University	0.02	0.63	
Child's sex			
Boys (ref)	–	–	
Girls	−0.08	0.38	

The analysis was done on pooled imputed data.

Discussion

The purpose of our study was to investigate associations between preschooler screen time, parenting stress, and later inattention symptoms during the COVID-19 pandemic. Our results showed that children exposed to more screen time during the pandemic at age 3.5 exhibited more inattention symptoms at age 4.5. Children whose parents had higher levels of parenting stress during the pandemic also experienced more symptoms of inattention 1 year later.

The current study provided support that preschooler screen time during the pandemic can have a negative impact on child attention development. Child screen use could displace time for attention building activities such as parent–child interaction, joint play, and outdoor play (Neuman, 1988; Christakis, 2009; Radesky J. et al., 2015). Indeed, a recent longitudinal study found that screen use decreased offline activities such as reading books, pretend play, and parent–child interaction (McArthur et al., 2021b). During screen-based activities, young children engage in fewer verbal and non-verbal interactions with parents which could also contribute to less optimal development in self-regulatory and attentional skills (Kirkorian et al., 2009; Radesky J.S. et al., 2015). More specifically, parent–child interactions play a central role in helping children internalise their self-regulation of attention during early childhood (Gartstein et al., 2008; Spruijt et al., 2020).

Preschoolers are likely to be more vulnerable to the screen exposure and the resulting displacement of developmentally enriching activities due to their increased brain plasticity during this time (Dumuid, 2020; Santos et al., 2022). Research with preschoolers and older children has linked screen time to decreased brain connectivity (Horowitz-Kraus and Hutton, 2018), lower microstructural integrity of brain white matter tracts (Hutton et al., 2020), and lower grey matter integrity (Paulus et al., 2019). There is also evidence that preschool screen time is associated with patterns of brain activation consistent with those observed in attention disorders (Zivan et al., 2019).

In light of the sensory overstimulation hypothesis, excessive and intense auditory and visual stimulation might condition the developing brain expect an intensity of inputs that reality cannot provide, forecasting later inattention problems (Christakis et al., 2018). Common features of media directed at children include, for example, changes in light, frequent camera cuts and quick pacing. As such children exposed to more screen time are also likely to have been exposed to contents with these characteristics. All these elements presents in new media devices can undermine sustained attention (Christakis et al., 2018).

In this sense, our results are consistent with the sensory overstimulation hypothesis (Christakis et al., 2018) and with previous research that showed positive associations between media use and reduced attentional skills. For example, screen time contributed to reduced effortful control in preschoolers (Fitzpatrick et al., 2022). Increased screen time contributed to worse inattention problems in a cohort of preschool children (Tamana et al., 2019). Multiple exposure to screen media, such as screen time and background use, is also related to decreased subsequent focused attention abilities in children (Gueron-Sela and Gordon-Hacker, 2020). As such, the present research provides further empirical support that screen time can undermine the development of attentional skills during preschool years.

In our study, parenting stress during lockdown was also associated with inattention symptoms in preschoolers one year later. Parents reported higher levels of stress during the pandemic (Spinelli et al., 2020; Malhi et al., 2021; Riter et al., 2021). According to an Italian study, parent distress contributed to higher inattention/hyperactivity in children aged between 3 and 13 (Marchetti et al., 2020). More highly stressed parents presented a reduction in the ability of the parent to enjoy and appreciate the parent–child relational experience, which in turn, have a negative impact on the child's well-being (Spinelli et al., 2020). Parental stress can also decrease parent–child interactions (Chung et al., 2022). This could contribute to parents using and allowing more screens at home (Hartshorne et al., 2021).

Practical implications

Early inattention symptoms are related to later impairment and more academic difficulties (Duncan et al., 2007; O'Neill et al., 2017; Landis et al., 2021). As such, it remains important to identify modifiable risk factors that contribute to their development. Preventive interventions implemented during the preschool years are more likely to be effective than those that take place in later childhood (Lakes et al., 2011). Interventions such as the *Incredible Years* (Jones et al., 2007) and *Behavioral Parent Training* (Hornstra et al., 2021), have been shown to improve child attention by improving the quality of parent–child interactions (Murray, 2010). Our findings suggest that interventions could benefit from coaching parents on how to establish healthy screen media use routines with children. Some recommendations, such as establishing routines for screen use with time limits, preferring media-free alternatives to shared activities, taking breaks during the media exposure to interact with the child (e.g., asking questions about the content watched) and adopting screen-time free moments can be important to reduce the potential harmful effects of media (Vanderloo et al., 2020). Furthermore, interventions could also address parenting stress, since overwhelmed parents may have more difficulty establishing and following a family media plan.

The COVID-19 pandemic disrupted many family routines, including screen use habits. For this reason, future research should seek to track the medium and long-term effects of child screen time during this time on later cognitive and behavioral outcomes. In particular, it remains important to investigate association between child screen time during the pandemic and later academic adjustment and achievement upon entering school. Last, future studies may help clarify the mechanisms by which child screen time contributes to increases in inattention symptoms.

Strengths and limitations

This study is not without limitations. First, our abridged inattention measure was based only on three items and does not allow us to detect clinically significant levels of inattention. However, prior studies have shown that our measure is sensitive enough to forecast later behavioral and academic difficulties in children (Pagani et al., 2010). Second, our measures of child screen time, parenting stress, and inattention symptoms were parent-reported, which could have led to shared measurement bias, as well recall or social desirability bias. For example, parents reporting higher stress could allow longer child screen time and may also perceive their child as having more inattention symptoms. Third, we did not consider the content child uses on screen media. As previously discussed, some contents may be overstimulating for child attentional systems. In addition, the context of child screen use (i.e., using alone without adult supervision) could moderate associations between child screen time and later attention. Fourth, our findings are based on a correlational design which does not allow us to establish causal associations. Furthermore, our outcome was evaluated only at follow-up, which does not allow us to examine the possibility of reverse causation or bi-directional associations. Nevertheless, we did control for child inhibitory control at baseline, which reduces the possibility that children with more difficulty regulating their attention were exposed to higher amounts of screen time. Finally, this was based on a convenience sample that was relatively homogeneous and low risk, in terms of its socio-demographic characteristics. This could limit the generalizability of our findings to more vulnerable populations of preschooler.

On the other hand, this study has several strengths. The current study is one of the first to prospectively address the association between preschooler screen time and inattention symptoms during the pandemic. We are also one of the first studies to examine parenting stress during COVID-19 lockdown, a highly stressful context, and its association with later child inattention. Our study is enhanced by using a more exhaustive measure of child screen time, including multiple activities besides tv viewing, and screen devices, such as smartphone and tablets.

Conclusion

Since attention is a crucial component for children development, behavior and academic outcomes, our study reinforces the importance of adopting healthy media habits and providing social support to parents of young children. Our results were observed above and beyond family characteristics which suggests that children may be vulnerable to the negative impacts of screens regardless of their sociodemographic background. The pandemic has increased screen use and parenting stress around the world. The association presented in this study can contribute to the development of evidence-based practices and recommendations for parents.

Data availability statement

The data presented in this article are not readily available. As per the participant consent form, data are only available to the research team. Requests to access the data should be directed to caroline.fitzpatrick@usherbrooke.ca.

Ethics statement

The studies involving human participants were reviewed and approved by Comité d'Étique, Université Sainte-Anne; Comité d'Étique, Université de Sherbrooke. Written informed consent to participate in this study was provided by the participant's legal guardian/next of kin.

Author contributions

ML and CF designed the study. ML conducted the analyses and drafted most of the manuscript. GG-C, EC, GF, and CF provided critical theoretical feedback on the entire manuscript. All authors contributed to the article and approved the submitted version.

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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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