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The impact of home and school environment on early literacy and mathematic skills

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The impact of home and school environment on early literacy and mathematic skills

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Editorial: The impact of home and school environment on early literacy and mathematic skills

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Editorial on the Research Topic
The impact of home and school environment on early literacy and mathematic skills

Introduction

Early development of literacy and mathematics skills has been shown to be a cornerstone of children's later academic achievement (e.g., Shanahan and Lonigan, 2010; Watts et al., 2014). The roles of various environmental factors in the development of cognitive and academic skills have received increasing attention from researchers, practitioners, and parents. Current theoretical models such as the bioecological framework (Bronfenbrenner and Morris, 2006) and neuroconstructivism (Westermann et al., 2007) emphasize the dynamic reciprocal relationship between genetic, neurobiological, and environmental factors in child development. In light of this, a growing number of studies have examined the relationships between the home literacy and numeracy environment (HLE and HNE, respectively) and the development of these academic skills (Noble et al., 2019; for meta-analyses, see e.g., Daucourt et al., 2021). Several studies have also shed light on the influences of environmental factors outside the home, such as tutoring and schooling, where children primarily learn literacy and numeracy (e.g., Nag et al., 2019). Furthermore, the profound influences of more distal environmental factors such as family socioeconomic status (SES) and linguistic background (e.g., bilingualism) have been well documented (e.g., Sirin, 2005; Kim et al., 2019; Dong and Chow, 2022). Despite these collective efforts in the literature, the precise mechanisms driving the documented associations between factors inside and outside the child's rearing environment and literacy and numeracy development remain poorly understood. Thus, further research is warranted to unpack the complex developmental dynamics among these factors at different levels of analysis, including both distal and proximal factors.

In this Research Topic, we sought to address this issue and examine how environmental factors influence children's early literacy and numeracy, namely the roots of later academic achievement. Indeed, existing empirical studies have produced mixed findings that do not allow us to draw any definitive conclusions (e.g., Noble et al., 2019; Daucourt et al., 2021). For example, while most previous studies found a positive association between HNE and children's early numeracy (e.g., counting, number sense), the results varied widely in terms of the strength of the associations (see Daucourt et al., 2021). Studies on the role of shared book reading, an important aspect of HLE, have also reported mixed results (Noble et al., 2019). These heterogeneities in existing findings may be due, at least in part, to the involvement of other (possibly confounding) factors that may affect the home environment, early numeracy/literacy, or both. This may include family SES, ethnic and linguistic background (e.g., bilingualism), parental expectations and beliefs, parental attitudes toward literacy and numeracy, as well as parental practices (see Nag et al., 2019).

This Research Topic brings together a Research Topic of ten articles that explore the role of the home environment on literacy and numeracy skills from preschool to primary school in different contexts. The contributions depict a complex picture that underlies the multifaceted nature of home learning environment and of early literacy/numeracy, which includes many dimensions.

First, some studies focused on HLE and related children's skills. Tanji and Inoue reported differential effects of subdomains of HLE on reading skills in two different scripts of the Japanese writing system. In particular, the dimensions evaluated were parent teaching, shared book reading, and access to literacy resources. The results suggested that Japanese parents might adjust their involvement according to both their children's reading performance and social expectations for academic achievement.

Moving to school-age children and the analysis of writing skills, Su et al. examined the associations between the onset age of parental home teaching and the informal occasions of exposure to literacy outside the home (e.g., science center, art gallery). Their findings suggested a significant role of both dimensions. Also, in a longitudinal perspective, Bigozzi et al. showed that HLE predicted reading speed and writing accuracy from preschool to primary school, mediated by notational awareness. From a different perspective, Aram and Yashar evaluated parents' awareness of children's writing abilities. They suggested that parents' general knowledge and understanding of literacy development play a role in fostering their children's literacy skills.

Turning to the numeracy domain, Wei et al. revealed the role of home numeracy practices in a longitudinal study. Specifically, they showed a unidirectional relationship between parents' basic teaching activities (e.g., teaching counting) and subsequent basic number processing (i.e., digit comparison) and between advanced teaching activities (i.e., related to written numbers) and the following children's arithmetic skills. DePascale et al. add another piece to this picture by showing that home-based advanced math activities, literacy activities, and SES are all associated with strategy sophistication in solving numerical problems. Considering the importance of mathematics-related activities in the home environment, Tomasetto et al. offer promising evidence, showing how a non-intensive intervention program delivered by community pediatricians can improve parents' provision of these activities.

Finally, methodological issues were addressed. Eriksson et al. managed an original point related to estimating the number of books at home as a proxy for SES. By analyzing the data from a large international sample, they showed unsystematic errors in estimates of books, revealing an important risk for educational studies: The strength of the association between books at home and achievement may generally be underestimated, particularly in low-achieving countries and/or students. Similarly, Krousorati et al. noted the methodological limitations of the current literature, particularly about the conceptualization and measurement of the home learning environment. They proposed a home learning environment questionnaire that goes beyond the assessment of home learning activities and provides us with a wider range of information, including the quality of parent-child interactions (support, conflict, and inconsistent discipline).

To conclude, this Research Topic of articles highlights the importance of considering various aspects of children's learning environment, with the need for further validated tools that embrace the different dimensions and extend current theoretical models of HLE and HNE. Future development should also include the evaluation of other environmental variables, such as the school domain, and combine them into integrated models of how contextual variables dynamically impact children's early literacy and numeracy development.

Author contributions

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

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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Introducing the Home Learning Environment Questionnaire and examining the profiles of home learning environments in Greece

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The Home Learning Environment (HLE) plays a prominent role in children's development. Several measures have been developed to assess its quality; however, most of them seem to mainly focus on specific aspects of the HLE construct. The aim of this study was to develop and validate the Home Learning Environment Questionnaire (HLEQ); and to examine the characteristics of the HLE and the HLE profiles using the new instrument in the Greek educational context. The HLEQ is a parent-reported measure addressing both activities and interactions, comprising of six factors that are considered key elements of the HLE: indoor, outdoor, and digital learning activities, warmth/support, conflict, and inconsistent discipline. The development of HLEQ followed a robust methodological approach, including the collection of an initial pool of items, expert review to examine its content validity, and piloting. The HLEQ was administrated to 814 parents (M_{age} = 37.86 years, SD = 4.84) of children (M_{age} = 64.12 months, SD = 7.19) attending 84 state funded kindergartens in Greece. A cross-validation approach was used to examine the factor structure of the HLEQ. Exploratory and confirmatory factor analysis and exploratory structural equation modeling procedures were implemented. Latent profile analysis was employed to identify the HLE profiles. Results provided initial support for the factor structure, reliability, and validity of the HLEQ. The HLEQ displayed good psychometric properties for measuring the quality of home learning activities and home learning interactions in the contemporary early HLE. Four HLE profiles were revealed, representing different parent-child interaction patterns during the learning activities. Limitations and implications for policy and practice are discussed.

KEYWORDS

home learning environment, digital learning activities, home learning interactions, early childhood education, scale development, questionnaire psychometrics, latent profile analysis, home learning activities

Introduction

A large volume of recent empirical evidence has shown the beneficial effects of a high-quality Home Learning Environment (HLE) on children's cognitive development (Tamis-LeMonda et al., 2019; Bonifacci et al., 2022), social development (Rose et al., 2018) and their overall well-being (Dearing and Tang, 2010). Researchers acknowledge that while factors like family's socioeconomic status (SES) or educational background influence children's educational attainment (Melhuish et al., 2008; Kluczniok and Mudiappa, 2019), the quality of HLE seems to be equally important. As Sylva and her colleagues stated, "what parents do is more important than who parents are" (2004, p. 164).

The quality of the early HLE is also associated with long-term effects on children's literacy and numeracy competencies and their academic achievement (Niklas and Schneider, 2017). Several studies using different measures for assessing the HLE (e.g., Foster et al., 2005; Melhuish et al., 2008; Bonifacci et al., 2021) have shown the impact of the HLE on children's outcomes. Rodriguez and Tamis-LeMonda (2011) used a measure for all aspects of the HLE, and found strong associations between the HLE and children's skills in receptive vocabulary and emergent literacy. Melhuish et al. (2008) used another measure and reported that the early HLE predicted numeracy achievement at the age of five. Manolitsis et al. (2013) examined the effects of home literacy and numeracy activities on emergent reading and math acquisition by using more content-specific measures for the aspects of HLE. Due to the influence of HLE on children's outcomes, researchers have reported the need for reliable early assessments of the quality of children's home environments as a first step to identify children at risk of not achieving their full potential and to design effective and targeted interventions (Niklas et al., 2016; Aminipour et al., 2018).

Given the importance of HLE on children's development is well-documented, researchers (Lehrl et al., 2020) suggested a more in-depth examination of the role of HLE by following person-centered approaches. Person-centered approaches can capture the profiles of parental involvement in the HLE and evaluate the importance of environmental stimulations across the preschool years in detail. In addition, researchers acknowledge that the characteristics of the HLE may be influenced by cultural factors (Aminipour et al., 2018). The aim of this study is to introduce a newly developed measure for the assessment of the quality of the HLE in families with preschool children and examine its psychometric properties. An additional purpose is to investigate the quality and the profiles of the HLE in Greece using a person-centered approach.

Defining the home learning environment

A review of the existing literature revealed two major approaches to the way the HLE is operationalized. In the first approach, researchers perceive the HLE as a broad construct suggesting that the overall quality and quantity of stimulation offered to a child within the family's microsystem constitutes a learning environment that significantly influences the child's development (Dearing and Tang, 2010). The HLE is viewed as a wide context with multiple dimensions that facilitates different processes through which children learn (Kluczniok et al., 2013). In the second approach, researchers perceive the HLE as more content-specific and focused on elements that promote literacy and numeracy. The content-specific approach includes various dimensions of the HLE for example the home literacy environment (Rose et al., 2018), the home numeracy environment (Manolitsis et al., 2013; Bonifacci et al., 2021), and the home digital environment (Sonnenschein et al., 2021).

Researchers from both approaches acknowledge two central dimensions of the HLE. The first dimension refers to the participation of parents and children together in stimulating activities. The Home Learning Activities (HLA) constitutes "the range of formal and informal activities in which parents and children engage. These activities provide opportunities for communicative exchanges and interpersonal interactions that facilitate learning" (Hayes et al., 2018, p. 1405). The literature describes several categories when classifying the types of HLA. A broad approach of HLAs divides them into *indoor* or home-based and *outdoor* or enrichment activities. Indoor HLA include the learning stimulation that the child receives within the home (e.g., learning letters or numbers, doing crafts), whereas outdoor HLA refer to the various learning experiences provided to the child outside of the home (e.g., visiting a library, doing sports) (Foster et al., 2005). Cultural activities (e.g., going to the museum, cinema) constitute another individual type of outdoor learning activities (Kluczniok and Mudiappa, 2019). A more content-specific approach of HLAs classifies them as formal and informal (Sénéchal and LeFevre, 2002) or direct and indirect activities (Manolitsis et al., 2013), which refer to the degree a parent either directly teaches the child or incidentally provides learning stimulation during their everyday activities. Another important type of activities that hold a center place in the HLE nowadays is *digital* activities. The "intrusion" of smart devices in family' lives introduced new types of learning and entertainment activities and transformed the concept and the content of HLE (Griffith and Arnold, 2019; Sonnenschein et al., 2021). Some studies for example categorize HLA in digital and non-digital activities (e.g., Neumann, 2018).

The second dimension refers to the quality of parent-child interactions during HLA as a core component of the HLE (Rodriguez and Tamis-LeMonda, 2011; Griffith and Arnold, 2019). A positive parent-child relationship is associated with beneficial developmental outcomes (Bradley and Corwyn, 2005). *Warm* and *supportive* interactions allow the child to feel secure to explore the environment and learn (Ainsworth et al., 2015). In contrast, harsh parenting, such as negative control, results in more *conflicted* parent-child interactions and problematic outcomes in children (Baumrind et al., 2010). Moreover, *inconsistent discipline*, permissive and chaotic parental practices are associated with increased child behavior difficulties (Arnold et al., 1993). In the present study the term "Home Learning Interactions" (HLI) is used to refer to various parent-child interactions during HLA.

Based on the above, the HLE constitutes a multifaceted construct that includes both "what" and "how" HLAs are implemented (Dearing and Tang, 2010). To this point, a recent study that introduced a new model, the Home Learning Ecosystem (Gregoriadis and Evangelou, 2022), describes a high-quality home learning environment as "a safe and developmentally conducive environment that offers consistent opportunities for formal and informal teaching and playing activities, indoors and outdoors. It provides space, stimuli and time for autonomy and individual play and also for ample caregiver-child learning activities of various types, executed in a positive and supporting climate. The warmth, support and responsiveness of the caregiver–child interactions (e.g., parents, siblings, grandparents) during these activities defines to a great extent the quality of this home learning ecosystem" (p. 4).

Similarly, the current study conceptualizes the term "Home Learning Environment" during the early childhood period, as a broad construct that represents the quality of indoor, outdoor, and digital learning activities and interactions among parents and children.

Measuring the quality of the home learning environment

There are various instruments available to assess the quality of the HLE. Some of the most widely used are the Home Observation for the Measurement of the Environment Inventory (HOME; Bradley and Corwyn, 2005), the early years HLE Index (Melhuish et al., 2008), the Questionnaire on the HLE (Niklas and Schneider, 2017) and the HLE subscale of Parenting Questionnaire (Morrison and Cooney, 2002). Most of the existing instruments measuring the HLE have some applicability limitations. For example, some instruments capture effectively the multidimensional nature of the HLE but are not very easy to apply when collecting data from a large sample as it exceptionally time consuming (e.g., HOME observation scale). Other instruments with strong psychometric properties (e.g., HLE Index) focus on a relatively narrow selection of learning activities and therefore do not collect information about all the dimensions of the HLE (e.g., parent-child interactions). Some instruments measure domain-specific activities (e.g., for numeracy or literacy) (e.g., the Questionnaire on the HLE or the HLE subscale of Parenting Questionnaire), and therefore do not capture the full range of the HLE dimensions (e.g., home digital practices).

To avoid focusing mainly on the HLA, some studies attempted to assess the nature of parent-child interactions during the learning activities by using small sets of items, for instance by asking the parent "How often do you express affection by hugging, kissing?," "Overall, how close would you say you are to child?" (e.g., Hartas, 2012, p. 864). However, these individual items did not represent the various dimensions of parenting practices and do not seem to fully capture the nature of the parent-child relationship (Niklas et al., 2016). In addition, while studies on general parenting measure the parent-child relationship through exploring either parenting styles (Baumrind et al., 2010) or the dimensions of parenting practices (Skinner et al., 2005), research on HLE is still unclear on how to measure the quality of interactions during learning activities. For instance, the HOME includes items representing the parenting dimensions of warmth/responsiveness and harshness/discipline, whereas other studies (e.g., Rose et al., 2018; Tamis-LeMonda et al., 2019) use qualitative methods to observe the interactions and measure their quality by using rating scales of mother's sensitivity and cognitive stimulation. Furthermore, most of the existing measures seem to be relatively outdated regarding the important role of digital HLA in daily family practices.

The review of the existing instruments revealed a number of limitations regarding their length, focus and methodology used. These limitations highlight the need for the development of a new and updated HLE measure. The current study suggests that a measure that assesses the parent-child learning interactions in a variety of indoor and outdoor activities–including the family's digital practices–may be particularly useful in bringing a broader insight into the quality of the contemporary HLE. Based on the above, the new instrument addresses both activities and interactions, but not the physical environment of a child's home.

Home learning environment profiles

Previous longitudinal studies demonstrated patterns of changes and improvements in the HLE over time (Son and Morrison, 2010), that predicted children's literacy and academic skills. For instance, Rodriguez and Tamis-LeMonda (2011) identified a variation in early HLE trajectories. Specifically, six different HLE profiles were identified, namely environments that were characterized as consistently low or high, and environments displayed varying patterns of change. Hayes et al. (2018) identified three longitudinal profiles of parental involvement in shared reading (high-stable involvement, medium-stable involvement, and low-increasing involvement). Based on the evidence for the changes of the HLE over time and the existence of sub-profiles within the broad context of the HLE, a question arises of whether distinct HLE types do exist that reflect particular patterns of variations in parent-child interaction during learning activities. A more in depth understanding of the characteristics and patterns of early HLEs can assist to determine the profiles of families who provide lower quality learning environments and whose children are at risk of school failure (Lehrl et al., 2020).

Only a few studies have employed person-centered approaches to identify profiles of family involvement in home and center-based programs in Early Head Start. The aim was to recognize the role of the different dimensions and patterns of family engagement in these programs in order to further support them (Bulotsky-Shearer et al., 2012; Jeon et al., 2020). To the best of our knowledge, existing research has not examined the multifaceted construct of the HLE by identifying typologies that share particular patterns of parent-child interactions during the learning activities. The present study addresses the aforementioned gap in the literature by following a person-centered approach and employing a classic latent profile analysis (LPA) to identify distinct HLE profiles. Such an understanding can contribute to further address the needs of each of these profiles and intervene to support them.

The home learning environment of Greek families

Many studies from several countries and cultural contexts from North America (Rodriguez and Tamis-LeMonda, 2011) and South America (Foster et al., 2005), to Europe (Melhuish et al., 2008; Kluczniok et al., 2013), Asia (Aminipour et al., 2018; Zhang et al., 2020), and Australia (Niklas et al., 2016; Hayes et al., 2018) enhance our understanding of the characteristics of the HLE. As far as Greece is concerned, there is limited evidence about the quality and the profile of HLE with the few available studies mainly focusing on Greek parents supporting their children's literacy and numeracy practices. For instance, in their cross-cultural study, LeFevre et al. (2010) found that Greek parents indicated less frequent engagement with their children in literacy and numeracy activities than parents in Canada. A higher frequency of formal home numeracy practices were related to children's numeracy outcomes and home literacy practices also predicted children's numeracy skills. In another study, Manolitsis et al. (2013) found that Greek parents reported more frequent engagement in formal home numeracy than in formal home literacy activities, while the frequency of both formal home literacy and numeracy activities predicted children's early reading and math outcomes. Furthermore, recent findings indicated that Greek parents support children's access and interactions with smart mobile devices as they consider them as a means to develop a stimulated HLE (Papadakis et al., 2019). However, the above studies did not examine how parents were involved with children in the activities and what kind of interactions they used to enhance children's learning. The present research adds to the sparse literature and provides an insight into the characteristics of the HLE in Greece assessed by a new broad measure.

The present study

The purpose of the present study was to introduce a new measure, the Home Learning Environment Questionnaire (HLEQ), to assess the quality and the profile of the HLE of families with preschool children. The specific research aims were: (a) to explore the psychometric properties of HLEQ, namely internal consistency, construct validity, and the pattern of associations among the HLEQ dimensions; (b) to provide an initial assessment of the characteristics of the HLE in Greece and (c) to identify typologies of the HLE which reflect patterns of parent-child interactions during the learning activities. Based on the reported purpose, the research questions of this study are as follows:

RQ1: Is the HLEQ a suitable measure to evaluate the quality of a contemporary early HLE?

RQ2: What are the characteristics of the Greek HLE?

RQ3: Which profiles of the HLE are identified in the Greek cultural context?

Materials and methods

Participants

A total of 814 parents participated in the study and filled out the new instrument. Using a multi-stage sampling technique, participants were recruited from 84 state funded kindergarten classes from urban and suburban areas of Western and Central

Macedonia in Greece. 84.2 percent of the participating parents were mothers (n = 685), and 15.8 percent were fathers (n = 129). The mean age of the parents was 37.86 years (SD = 4.84, range = 38) and the majority of them were Greek (94.2% of mothers, 95.9% of fathers). Mother's educational level was as follows: 1.8% of them attended only elementary school, 3.4% graduated from low secondary school, 17.4% obtained a high school degree, 19.5% obtained a college/vocational training institute degree, 39.3% obtained a university degree, and 18.1% had completed post-graduate studies. Father's educational level was as follows: 2.1% of them attended only elementary school, 5.8% attended only junior high school, 33.7% obtained a high school degree, 14.5% obtained a college/vocational training institute degree, 31% obtained a university degree, and 12.5% had completed post-graduate studies. Based on the National Statistics of Greece (Hellenic Statistical Authority, 2022), parent's educational level in this study was representative of the selected region. Regarding the mother's occupation, 65.1% were employed, 17.4% were unemployed, and 17.5% had selected household as their occupation. 97.4% of fathers were employed and only 2.4% were unemployed. Their children's age ranged between three to 6°years (M_{age} = 64.12 months, SD = 7.19, range = 45) at the time of parental consent.

For this analysis, the sample was randomly divided into two groups, group A (N = 405) and group B (N = 409). Group A was used to investigate the factorial validity of the HLEQ, and Group B served to cross-validate findings. Preliminary examination revealed that there were no differences between the two groups with respect to age ($p > 0.05$) and gender ($p > 0.05$). The total sample was used to examine the profile and the characteristics of the Greek HLE.

Measures

Home learning environment questionnaire

The Home Learning Environment Questionnaire (HLEQ) was developed to assess the characteristics of the early years HLE. HLEQ is a self-reported instrument comprised of 32 items that measure activities and interactions with six dimensions of HLE, namely Indoor learning activities (six items), Outdoor learning activities (five items), Digital learning activities (five items), Warmth/Support (six items), Conflict (five items), and Inconsistent discipline (five items). Responses are rated on a six-point Likert-type scale ranging from 1 (never) to 6 (always). Parents indicate the frequency with which they implement a specific practice.

Indoor learning activities were conceptualized as the activities that parents do with children at home to promote child's learning (e.g., "The parent helps the child "write" letters and words," Hayes et al., 2018). Outdoor learning activities refer to the range of out-of-home activities parents offer to their children (e.g., "The parent takes the child to a sport activity, e.g., swimming lessons," Foster et al., 2005). Digital learning activities assess the digital practices of families for learning purposes (e.g., "The parent plays with the child with numeracy applications, e.g., tablet, smartphone," Neumann, 2018). Warmth/Support reflects the degree to which a parent responds to the child's learning needs in a supportive way (e.g., "The parent encourages the child to keep up with an activity, when the child finds it challenging," Bradley and Corwyn, 2005). Conflict captures the degree to which parents disagree with children when they engage in a learning activity (e.g., "The parent gets upset and raises his/her voice, when the child does not meet his/her expectations in any activity," Baumrind et al., 2010). Inconsistent discipline refers to parenting behaviors that are lax, chaotic, and weak to set limits and control (e.g., "The parent is inconsistent between warning and applying negative consequences," Skinner et al., 2005).

Home learning environment questionnaire: Scale development

A robust methodological approach was used for the development of the HLEQ comprising of the following stages. Based on a thorough examination of the relevant literature and the available instruments for the HLE an initial bank of 136 items was developed, containing items that already existed in published measures, adapting existing items, and new items created by the authors. The item bank contained the following information: item description, item dimension, and the source of the item. From the initial 136 items, the most representative ones were selected for the two main HLE dimensions (HLA and HLI) and they were adapted to the Greek context and language. The reduced item bank contained 83 items and it was sent to seven scholars with relevant expertise for review. The academic experts evaluated and provided feedback regarding the clarity and improving the content validity of each item in two areas: (a) the dimension to which they consider the item belongs to, and (b) how well each item addresses the dimension it is destined to cover. Based on the experts' feedback, the final version of the Home Learning Environment Questionnaire (HLEQ) consisted of 60 items.

Subsequently, two pilot studies were conducted. In the first pilot study 20 parents of preschool children assessed the wording and the clarity of the HLEQ items. Parents did not report any issues during the completion of the instrument. Afterward, a second pilot study was run on 175 parents for assessing the construct validity and reliability of the instrument. Results of exploratory factor analysis and reliability analysis showed that 28 of the 60 initial items should be dropped because of low loading, cross-loading, and low item to total correlation. After discarding these items, a new analysis showed six factors with eigenvalues above unity (indoor, outdoor, and digital learning activities, warmth/support, conflict, inconsistent discipline) with satisfactory α values (ranging from 0.885 to 0.658). The version including 32 items was used in the main study on a sample of 814 parents.

Procedure

The Greek Institute of Educational Policy (official institute of the Ministry of Education) approved the ethics of the study and issued permission to access kindergartens (License number: 46/4-10-2018). Parents were contacted through schools. The authors informed the teachers, parents, and children about the study's purpose and procedures. They assured participants that their responses would be held in strict confidence and that they would be solely used for academic purposes. After consent forms were collected from each school, ten children were randomly selected from each classroom, and they gave the HLEQ to their parents to complete it at home at their convenience. Parents' participation in the study was voluntary. A total of 89% (814 out of 917) of the children returned the questionnaires to their kindergarten teachers.

Statistical analysis

A cross-validation approach was used to examine the factor structure of the HLEQ. Initially, exploratory factor analysis (EFA) was employed on parents' responses of group A ($N = 405$) to understand the underlying structure of HLEQ. Principal axis factoring as the extraction method and direct oblimin rotation as the oblique rotation method were used because factors were expected to be intercorrelated. For determining the number of factors that should be retained parallel analysis was performed. Rotated factor matrices were examined to evaluate the factor loadings. Items with factor loadings above 0.30 were considered statistically significant and were used to interpret the emerged factors.

Based on the EFA results, confirmatory factor analysis (CFA) and exploratory structural equation modeling (ESEM) were conducted on parents' responses of group B ($N = 409$) to further examine the underlying structure of the HLEQ. Marsh et al. (2014) urged researchers to routinely examine the fit of CFA and ESEM when testing the dimensionality of an instrument. In case of a similar fit, the more parsimonious model (CFA) should be retained. Apart from the chi-square values along with its degrees of freedom, three supplementary goodness of fit indices were used to examine the fit of the postulated models, namely comparative fit index (CFI), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA). According to Hu and Bentler (1999) values close to 0.95 for CFI, 0.08 for SRMR, and 0.06 for the RMSEA suggest a good fit of the examined model to the data. Modification indices and standardized residuals were used to locate the model ill fit. Factors' score reliability was calculated using the omega coefficient (McDonald, 1999).

A latent profile analysis (LPA) was employed to identify the underlying latent HLE profiles. A range of different goodness-of-fit indexes and tests of statistical significance were used to determine the optimal model with k profiles for the patterns of HLA and HLI. Smaller values of the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) indicate a better fit, while higher values up to 1 for entropy indicate a better fit (Nylund et al., 2007). The Vuong-Lo-Mendell-Rubin Statistic Likelihood Ratio Test (VLMR LRT; Lo et al., 2001) was examined to test whether a model with k profiles fits the data better than a model with k–1 profiles. A statistical significant p-value (e.g., $p < 0.05$) for the sample size adjusted VLMR LRT (Adj. VLMR LRT) and the Bootstrap Likelihood Ratio Test (BLRT) indicates that a model of k profiles provides significantly better fit when contrasted with a solution including one fewer profile (k–1) (Voulgaridou et al., 2022). When the profiles obtained in each sub-sample were finalized the proportion of the class was considered (Marsh et al., 2009). All analyses were conducted using Mplus ver. 7.3 (Muthén and Muthén, 2015).

Results

Factor structure of home learning environment questionnaire

Parents' responses to the 32 items of the HLEQ from group A were submitted to EFA. Parallel analysis procedures suggested that six factors should be retained (**Figure 1**). All items were associated with their respective factors and yielded statistically significant loadings ranging from 0.345 to 0.886. The factor correlation matrix revealed significant associations ranging from −0.438 to 0.537. Factors' internal consistency using the omega coefficient showed satisfactory values. Specifically, the omega coefficient was 0.855 for Digital learning activities, 0.811 for Warmth/support, 0.801 for Indoor learning activities, 0.782 for Conflict, 0.668 for Outdoor learning activities and 0.710 for Inconsistent discipline.

Based on the EFA findings a six-factor correlated model submitted to CFA and ESEM using responses of group B. Goodness-of-fit indices showed that ESEM solution (χ^2 = 581.42, df = 319, CFI = 0.928, RMSEA = 0.045, SRMR = 0.032) provided a better fit to the data in relation to the CFA solution (χ^2 = 869.86, df = 449, CFI = 0.882, RMSEA = 0.048, SRMR = 0.060). The chi-square difference showed that the ESEM model provided a significantly better fit to the data in relation to the CFA ($\Delta\chi^2$ = 278.96, df = 130, $p < 0.001$). Further examination of the ESEM model modification index suggested that a correlation between the residuals of items "The parent plays with the child with literacy applications (e.g., tablet, smartphone)" and "The parent plays with the child with numeracy applications (e.g., tablet, smartphone)" should be introduced. With this slight model modification, the model fit was substantially improved: χ^2 = 493.77, df = 318, CFI = 0.951, RMSEA = 0.037, SRMR = 0.028. Moreover, the magnitude of the correlated

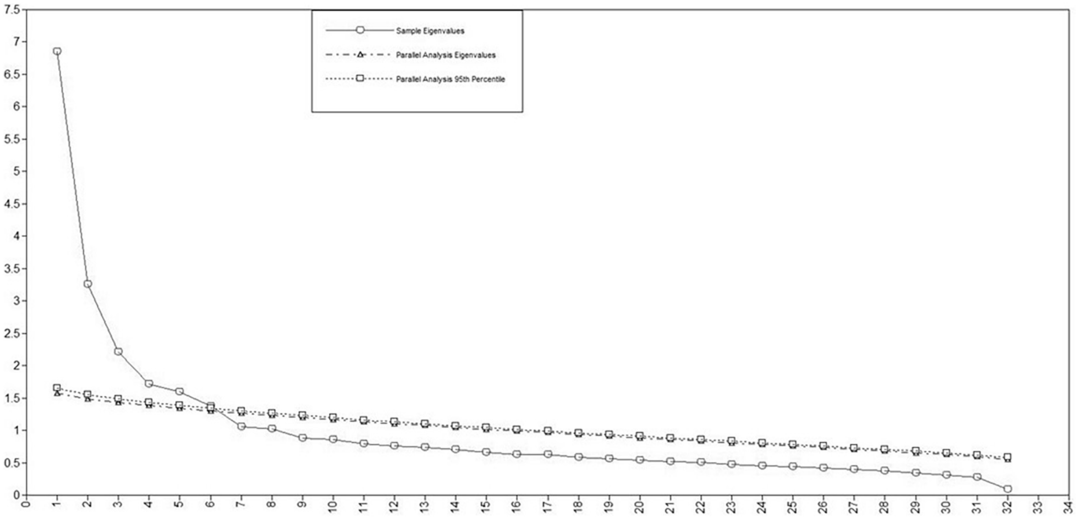

FIGURE 1
Parallel analysis results of the home learning environment questionnaire (HLEQ).

residuals was statistically significant and meaningful (0.793), providing additional support to our decision.

All items were associated with the latent factor designed to assess and with the exception of one item [The parent plays sports with the child (e.g., riding bicycles, playing football) they all yielded moderate to high loadings (range 0.300–0.851) (**Table 1**)]. Despite the fact that the pattern of significant positive and negative associations among HLEQ factors was similar from ESEM and CFA solution, associations from ESEM solution were more pronounced (**Table 2**). Based on the above findings, the ESEM model was selected as the more tenable for parents' responses to HLEQ. Omega values for HLEQ factors from group B were all satisfactory (**Table 2**). The internal consistency reliability of the HLEQ was 0.754.

Characteristics of the Greek home learning environment

Means and standard deviations of the several learning activities that parents do with children and the types of learning interactions during the activities are provided in **Table 1**. The Warmth/Support factor showed the highest mean (*M* = 5.40, *SD* = 0.58) and the Conflict the lowest (*M* = 2.13, *SD* = 0.75). The item of the HLAs with the highest scores reported by parents was the share-reading and discussing a book with the child (*M* = 4.72, *SD* = 1.11). Concerning the interactions in the HLE parents, reported that they very frequently show their pride about their child's effort, even when it is incomplete (*M* = 5.64, *SD* = 0.69), while they almost never belittle the child when the child does not complete an activity or follows instructions (*M* = 1.24, *SD* = 0.73).

Identifying home learning environment profiles

In response to the third research question, LPA was conducted to unveil the number of HLE profiles in the dataset. **Table 3** presents the fit indices (i.e., AIC, BIC, Adjusted BIC, entropy value, VLMR LRT, Adjusted LMR LRT, and its *p* value) for the various LPA models with one through six profiles for HLE. AIC, BIC, and adjusted BIC values were decreasing as the number of classes were increasing. The same tendency was also noticed for the Bootstrap LRT. However, the VLMR LRT and adjusted LMR LRT clearly showed that a four-profile model should be retained. Moreover, a solution of six or more classes would result in extremely small sizes for some groups and it would make the interpretation difficult. Wang and Wang (2020) maintain that each of the derived latent classes should not be too small and that the number of classes should also be theoretically defendable and conceptually meaningful. Based on above findings and considerations we considered that the best-fitting model (bolded in **Table 3**) is composed of four classes for the profiles of HLE. Such an approach was followed in prior studies when facing a similar situation (Voulgaridou et al., 2022). The entropy of the selected model was 0.75, suggesting a good level of classification (Asparouhov and Muthén, 2014). Thus, the four-classes model was selected as the one that best describes the typology of Greek HLE. In the analysis, average posterior probabilities for the four-classes profile solutions were acceptable ($p < 0.05$), indicating a high degree of probability that families were correctly classified into the best HLE profiles.

Once the number of classes was identified, HLE profiles were classified based on their most likely latent class pattern in regard to HLEQ factors. The final latent class solution

TABLE 1 Home learning environment questionnaire (HLEQ) items loadings for the exploratory structural equation modeling (ESEM) solution and descriptive statistics.

	ESEM						*M*	*SD*
	F1	F2	F3	F4	F5	F6	4.31	0.84
F1–indoor learning activities								
The parent. . .								
Shares reading and discusses a book with the child	0.436	0.008	0.185	0.155	−0.017	−0.109	4.72	1.11
Helps the child "write" letters and words	0.413	0.104	0.207	0.046	−0.035	0.036	4.68	1.10
Plays shape recognition games with the child	0.419	0.143	0.147	−0.093	−0.003	−0.017	3.82	1.36
Does art and craft activities with the child	0.851	0.009	−0.041	0.008	−0.046	0.029	4.42	1.12
Plays construction games with the child (e.g., building blocks)	0.724	−0.040	0.010	−0.092	0.090	−0.164	4.48	1.07
Plays role-play games with the child (e.g., the baker and the customer)	0.466	−0.041	0.141	0.118	0.005	0.062	3.72	1.35
F2–digital learning activities							2.39	1.10
The parent. . .								
Shares reading an e-book with the child on smart devices (e.g., tablet, e-reader, and smartphone)	−0.009	0.788	−0.060	0.057	−0.038	−0.006	2.29	1.35
Plays with the child literacy applications (e.g., tablet, smartphone)	0.020	0.682	0.047	0.020	−0.020	0.021	2.43	1.42
Plays with the child numeracy applications (e.g., tablet, smartphone)	0.007	0.724	0.077	−0.037	−0.020	0.037	2.42	1.40
Surfs the web with the child (e.g., to find a story or a song)	0.063	0.672	0.022	0.009	0.094	0.017	2.90	1.45
Plays video games with the child	−0.079	0.636	−0.034	−0.037	0.043	−0.052	1.92	1.19
F3–warmth/support							5.40	0.58
The parent. . .								
Listens and respects the child's opinion during a learning activity	0.183	0.057	0.496	−0.002	−0.166	0.059	5.22	0.90
Enjoys "teaching" the child (e.g., how to fold clothes)	0.062	0.072	0.493	−0.076	−0.111	−0.094	5.41	0.76
Encourages the child to explore and ask questions	0.042	0.022	0.658	0.058	0.026	−0.050	5.52	0.78
Encourages the child to keep up with an activity, when the child finds it challenging	−0.009	−0.014	0.673	0.134	0.154	0.008	5.50	0.83
Corrects the child's efforts without telling him/her off	−0.004	−0.018	0.649	−0.072	−0.021	−0.036	5.07	0.88
Shows his/her pride about the child's effort, even when it is incomplete	0.002	−0.018	0.564	0.029	−0.095	−0.040	5.64	0.69
F4–outdoor learning activities							3.59	1.12
The parent. . .								
Visits a library with the child	0.259	0.069	−0.074	0.300	−0.060	−0.101	2.30	1.45
Plays sports with the child (e.g., riding bicycles, playing football)	0.151	0.159	0.056	0.162	−0.081	−0.079	4.15	1.43
Takes the child to a sport activity (e.g., swimming lessons)	−0.064	−0.023	0.033	0.628	0.057	−0.105	4.0	2.00
Takes the child to an art activity (e.g., dance, painting lessons)	0.004	−0.026	−0.025	0.739	−0.015	0.050	3.47	2.18
Takes the child to cultural events (e.g., cinema, theater, museums)	0.096	0.051	0.078	0.581	−0.003	−0.002	4.0	1.45
F5–conflict							2.13	0.75
The parent. . .								
Gets frustrated, when she/he spends a whole day sharing a number of activities with the child	−0.068	−0.020	0.026	0.084	0.647	0.082	2.50	1.22

(Continued)

TABLE 1 (Continued)

	ESEM						*M*	*SD*
Does not pay enough attention during activities to what the child says to him/her, when the parent feels tired	−0.081	0.071	−0.052	0.017	0.588	0.034	2.64	1.18
Gets upset and raises his/her voice, when the child does not meet his/her expectations in any activity	0.033	0.025	−0.122	−0.056	0.717	−0.001	2.14	1.09
Belittles the child, when the child does not complete an activity or follows instructions	0.007	0.097	−0.204	0.026	0.347	−0.096	1.24	0.73
Gets easily upset with the child during learning activities	0.014	−0.064	0.009	−0.012	0.711	0.016	2.13	0.90
F6–inconsistent discipline							2.50	0.85
The parent. . .								
Let's the child get away with things, that she/he really should not be doing (e.g., spending more time than allowed watching TV)	−0.232	0.173	0.006	−0.057	0.112	0.386	2.80	1.14
Reprimands the child in an inconsistent way	0.072	0.000	−0.134	−0.041	0.199	0.458	2.44	1.15
Is inconsistent between warning and applying negative consequences	−0.039	−0.032	0.136	−0.027	0.261	0.474	2.62	1.32
Is less strict with the child's discipline, when they are outdoors	0.045	−0.046	−0.057	0.130	0.018	0.581	2.58	1.33
Gives in to the child's demands, when the child throws a tantrum (e.g., screams for sweets in a supermarket)	−0.106	0.082	−0.021	0.000	−0.054	0.626	2.11	1.16

TABLE 2 Associations among home learning environment questionnaire (HLEQ) factors and internal consistency.

	1	2	3	4	5	6
1. Indoor learning activities	(0.817)					
2. Digital learning activities	0.178*	(0.882)				
3. Warmth/support	0.450**	0.218**	(0.808)			
4. Outdoor learning activities	0.196**	0.019	0.240**	(0.663)		
5. Conflict	−0.370**	−0.103	−0.365**	−0.076	(0.748)	
6. Inconsistent discipline	−0.286**	0.038	−0.270**	−0.166*	0.390**	(0.760)

Below diagonal ESEM solution $^*p < 0.05$, $^{**}p < 0.001$, values in parenthesis are the omega coefficients.

TABLE 3 Comparison of fit indices for latent class analysis models with 2–6 classes for home learning environment (HLE) profiles.

No. of profiles	AIC	BIC	Adj. BIC	Entropy	VLMR LRT	Adj. VLMR LRT	BLRT
2	11749.9	11839.3	11778.9	0.748	576.3 (7)*	564.3*	576.3 (7)*
3	11619.4	11741.6	11659.1	0.740	144.6 (7)*	141.5*	144.6 (7)*
4	**11460.6**	**11615.7**	**11511.0**	**0.749**	**126.5 (7)***	**123.9***	126.5 (7)*
5	11393.2	11581.3	11454.3	0.777	81.4 (7) ns	79.7 ns	81.4 (7)*
6	11340.5	11561.4	11412.2	0.767	66.7 (7) ns	65.4 ns	66.7 (7)*

AIC, Akaike information criteria; BIC, Bayesian information criteria; Adj. BIC, sample size adjusted BIC; VLMR LRT, Vuong-Lo-Mendell-Rubin Statistic Likelihood Ratio Test; Adj. VLMR LRT, sample size adjusted VLMR LRT; BLRT, Bootstrap Likelihood Ratio Test. Bold indicates the best-fitting model. $^*p < 0.05$.

is shown in Table 4 and the corresponding profiles are visualized in Figure 2. Profile 1, representing 4.8% of the participants, presented high levels of Warmth/Support, moderate levels of Indoor and Outdoor learning activities, Conflict and Inconsistent discipline, and low levels of Digital learning activities. Profile 2, which represented the majority of the participants (45.45%), was characterized by high levels of Warmth/Support and involvement in Indoor and Outdoor learning activities, and low levels of Digital learning activities, Conflict, and Inconsistent discipline. Profile 3, representing 33.17% of the participants, presented high levels of Warmth/Support and involvement in Indoor learning activities, moderate levels of Outdoor learning activities and Inconsistent discipline, and low levels of Digital learning activities and

TABLE 4 Classification of home learning environment (HLE) profiles based on their most likely latent class pattern in regard to home learning environment questionnaire (HLEQ) factors.

HLEQ factors	Latent profile			
	Profile 1 (4.8%)	Profile 2 (45.5%)	Profile 3 (33.2%)	Profile 4 (16.6%)
Indoor learning activities	2.869	4.617	3.804	4.887
Outdoor learning activities	2.846	3.847	3.141	3.992
Digital learning activities	2.043	2.037	2.036	4.104
Warmth/support	3.872	5.684	5.072	5.669
Conflict	3.205	1.813	2.481	1.985
Inconsistent discipline	3.455	2.111	2.892	2.521

N = 814.

Conflict. Profile 4, representing 16.6% of the participants, presented high levels of Warmth/Support and all three types of learning activities and low levels of Conflict and Inconsistent discipline.

Discussion

The aim of this study was to develop and validate an instrument that measures the quality of various dimensions of the early HLE. Despite the well-established importance of the HLE for children's development, several studies have used different measures to assess its quality that mainly focus on specific aspects of the HLE (Aminipour et al., 2018; Kluczniok and Mudiappa, 2019). An instrument for assessing the broad construct of the contemporary early HLE was recently reported as still missing (Niklas et al., 2016; Gregoriadis and Evangelou, 2022). Findings suggested that HLEQ is a promising self-report measure developed for assessing the HLE across families with preschool children.

Specifically, HLEQ's psychometric properties showed that the multidimensional construct of HLE can be measured with high levels of precision and accuracy. The validity of the HLEQ was obtained using a robust methodological approach, including extensive literature review, content analysis by experts, pilot study, and three statistical techniques for understanding its factorial structure. Results showed that a six-factor model was the most tenable among other examined models. Reliabilities of the HLEQ's factors were acceptable and relatively high for a self-reported parenting questionnaire. The six-factor solution of HLEQ consisted of factors that they were separately included in existing HLE measures (e.g., Indoor learning activities, Outdoor learning activities, Warmth), while new factors were incorporated (e.g., Digital learning activities, Support, Conflict, Inconsistent discipline). The six-factor structure of the HLEQ agreed with findings from previous studies (Kluczniok et al., 2013; Tamis-LeMonda et al., 2019) regarding the multidimensional nature of HLE.

An advantage of the present study was the employment of a sophisticated statistical technique, namely the ESEM. According to Asparouhov and Muthén (2009), ESEM combines the advantages of both EFA and CFA into a single framework. Previous studies showed that the application of ESEM resulted in a superior model fit compared to CFA in various instruments in the field of social sciences (e.g., Tsigilis et al., 2018; Tsigilis and Koustelios, 2019). The usefulness of ESEM in describing the empirical data was also evident in the current study. Analysis using ESEM showed that HLEQ's fit was superior compared to CFA, as all goodness-of-fit indices yielded satisfactory values in contrast to the CFA analysis, which was unsatisfactory. Forcing HLEQ items to load only on their respective latent factors seems to be a restrictive assumption. Furthermore, because ESEM allows items to have multiple cross-loadings, the correlations among the latent factors are not inflated (Marsh et al., 2014), resulting in a more accurate estimation of the associations. Thus, researchers and practitioners can have increased confidence in the derived associations of HLEQ within the Greek educational context. Future studies examining the quality of HLE could benefit from the usage of ESEM as an alternative approach to CFA.

The present study extended the field knowledge on HLE by studying the core characteristics of a contemporary HLE. The six-factor solution of HLEQ indicated that within the HLE parents engage with their children in digital and several learning activities inside and outside of the home. Their interactions during these activities were characterized as warm and supportive, with low levels of conflict and inconsistent discipline. Overall, the findings of this study confirmed that the families' engagement in HLAs and the quality of HLIs are fundamental elements of a modern HLE (Gregoriadis and Evangelou, 2022).

Specifically, results indicated that parents participated in various indoor, outdoor, and digital learning activities. A high level of engagement in stimulating activities within HLE has been reported in the majority of existing studies, confirming that the dimensions of indoor, outdoor, and digital learning activities are well-settled in the core of the HLE construct (e.g., Foster et al., 2005; Melhuish et al., 2008; Niklas and Schneider, 2017). Shared book reading was the most frequent learning activity reported by parents confirming that it is the most common home learning activity that parents engage with their preschool children (Morrison and Cooney, 2002;

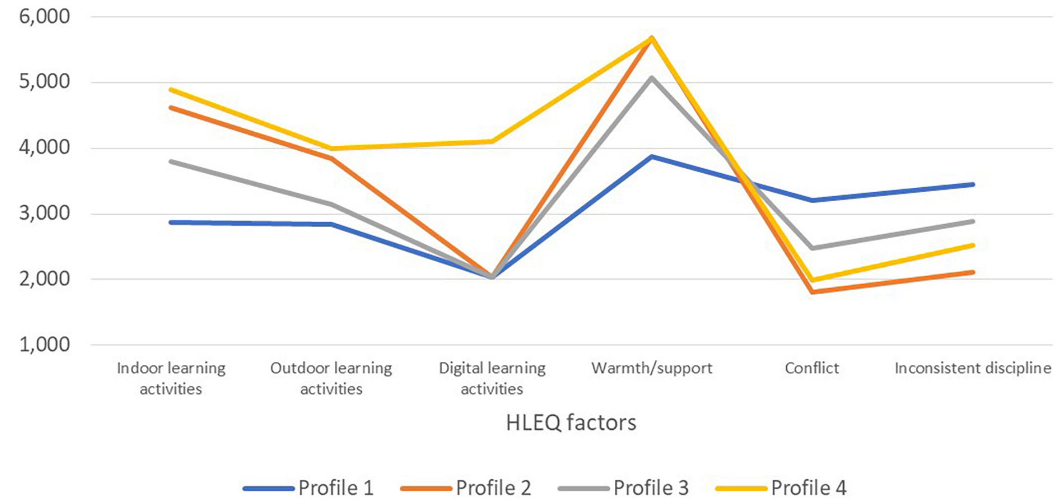

FIGURE 2
Mean scores of home learning environment (HLE) profiles in each of the home learning environment questionnaire (HLEQ) factors.

Sénéchal and LeFevre, 2002; Hayes et al., 2018). In addition, the content of the items retained in the Outdoor learning activities confirmed its cultural value (Kluczniok and Mudiappa, 2019). Outdoor learning activities included activities like visiting the library, museums, theaters, or participation in extracurricular activities like dance, music, or sports; such activities require by nature specific financial resources; thus, they reflect a lifestyle that may differentiate family opportunities. Additional research is needed to further explore the relationship between the family's SES and the quality of the HLE in the Greek context.

As far as digital learning activities are concerned, results were aligned with previous evidence showing that children are exposed daily to a variety of digital media within the home digital environment (Sonnenschein et al., 2021), and they are fluent in using portable digital devices and software from the earliest years of their lives (Neumann, 2018; Papadakis et al., 2019). The non-significant associations between the Digital learning activities with Conflict and Inconsistent discipline suggest that future studies should further examine the patterns of parent-child interactions in both digital and non-digital activities.

Besides the well-established effects of the quantity and the quality of the various types of shared stimulating activities on a child's development, the quality of parent-child interactions during learning activities also matters (Bradley and Corwyn, 2005; Rodriguez and Tamis-LeMonda, 2011). A strength of the present study is that it attempted to assess three distinct types of parent-child interactions during their shared HLAs. Therefore, this study suggests that an essential feature of the HLE is not only what parents do with children (Sylva et al., 2004) but also how they do it (Dearing and Tang, 2010; Gregoriadis and Evangelou, 2022); thus, emphasis in intervention programs can be placed in supporting the quality of interactions during learning activities.

The patterns of associations revealed that Warmth/Support was positively correlated with the Indoor, Outdoor, and Digital learning activities, whereas Conflict showed negative correlations with Indoor and Outdoor learning activities. Thus, results indicated that Greek parents exert more positive and supportive behaviors and less negativity and disapproval during the learning process. The high levels of frequency in Warmth/Support in contrast to the average and lower levels of frequency in the HLA was in agreement with previous studies showing that Greek parents engage less frequently in learning activities at home compared to parents from other cultures (LeFevre et al., 2010). A warm and responsive home environment across the globe empowers children's learning and improves learning outcomes (Bradley and Corwyn, 2005). However, one possible interpretation of the very positive parent-child HLIs in Greece could be that it has been described as a more collectivist society, in which the family system is considered a crucial source of emotional support for its members (Georgas et al., 1997). Similar patterns of adult-child relationships have been reported in Greek educational settings too. A series of Greek studies (Gregoriadis and Tsigilis, 2008; Gregoriadis et al., 2020, 2021) found that kindergarten teachers characterized their relationships with their children as warm, supportive, and close with low levels of conflict and dependency.

The negative correlation of Inconsistent discipline with Indoor learning activities and its positive correlation with Outdoor learning activities indicated that Greek parents set more limits and rules inside their homes, and they are more relaxer with children's discipline outside of their homes. This might reflect parents' beliefs that by giving in to their children's challenging behaviors, they can temporarily prevent children's antisocial behavior (Arnold et al., 1993). To the best of our knowledge, this is the first study that attempted to measure the quality of parent-child interactions in the HLE through the parenting dimension of Inconsistent discipline. Future studies should explore in more depth the quality of learning interactions within the HLE.

An additional purpose of this study was to examine the number and the nature of the existing latent profiles of the HLE in the Greek cultural context by following a person-centered approach. The advantage of a person-centered approach is that it has the potential to identify the typologies of the HLE that share particular patterns of variations in parent-child interactions and activities (Jeon et al., 2020). Based on the conceptual framework of the Home Learning Ecosystem, higher levels of involvement in HLAs (indoor, outdoor, and digital) and Warmth/support practices reflect a more positive aspect of the HLE, where participants receive positive learning experiences (Gregoriadis and Evangelou, 2022); in contrast higher levels of conflicts and inconsistent discipline practices indicate poor or negative parent-child interactions in the HLE. In the present study four underlying latent subgroups were identified indicating different patterns of parent-child interactions during the learning activities at home. These profiles are presented and discussed in a decreasing order in relation to the percentage covered in the sample.

Profile 2, *the Supportive HLE*, was characterized by high levels of Warmth/Support and involvement in Indoor and Outdoor learning activities, and low levels of Digital learning activities, Conflict, and Inconsistent discipline. Profile 2 implies a good quality HLE, but the low levels of Digital learning activities may represent parents who perceive children's engagement with digital technology, even for learning purposes, as a negative aspect of the HLE similar to Conflict and Inconsistent discipline.

Profile 3, *the Average HLE*, was characterized by high levels of Warmth/Support and involvement in Indoor learning activities, moderate levels of Outdoor learning activities and Inconsistent discipline and low levels of Digital learning activities and Conflict. The average levels of Outdoor learning activities and Inconsistent discipline practices of families in this profile may represent parents with some minor permissive and chaotic characteristics compared to more strict parents of Profiles 2 and 4. In addition, although Profile 3 and Profile 2 have a similar trajectory, families of Profile 3 showed lower levels of involvement in Indoor and Outdoor learning activities and higher levels of Conflict and Inconsistent discipline in contrast to families of Profile 2. These results may represent parents who may need support to become aware and understand how to be supportive to their children's learning compared to parents of Profiles 2 and Profile 4.

Profile 4, *the Positive HLE*, showed high levels of Warmth/Support and involvement in HLAs (indoor, outdoor, and digital) and low levels of Conflict and Inconsistent discipline. Parents in this profile provide more often a variety of stimulation to children within the home affective environment in order to support children's learning, while negative parent-child interactions are rare. So, this profile reflects a positive HLE.

Profile 1, *the Accompanying HLE* was characterized by high levels of Warmth/Support, average levels of Indoor and Outdoor learning activities, Conflict and Inconsistent discipline, and low levels of Digital learning activities. Despite the average levels of Indoor learning activities, Outdoor learning activities, Conflict, and Inconsistent discipline, a detailed examination of the results indicated that families in Profile 1 show a slight tendency for more frequent conflicts and chaotic practices during the engagement in indoor and outdoor learning activities. This slight tendency, alongside the low levels of engagement in digital learning activities, may represent higher risks or needs, which may require more support for these families on how to provide a positive HLE. Overall, higher levels of learning interactions and lower levels of engagement in learning activities were observed in Profile 1, which could reflect parents who do not actively provide learning stimulation but accompany the child in the learning process in a more passive way.

Previous studies showed distinctive and varying patterns of family engagement in children's learning at home (Bulotsky-Shearer et al., 2012; Jeon et al., 2020) and demonstrated several trajectories of HLE during the early years (Son and Morrison, 2010; Rodriguez and Tamis-LeMonda, 2011; Hayes et al., 2018). To the best of our knowledge this is the first attempt to identify typologies of HLEs with specific characteristics concerning the type of parent-child interactions during HLAs by using the LPA. Thus, it is hard to compare our findings with previous ones. This study extends the current knowledge base by identifying four distinct types of profiles comprised of varying levels of HLIs during the HLAs. A deeper knowledge of the early HLEs and its patterns can function as a guide to identify families who may need further support. In addition, it can help practitioners to design and implement interventions that support a positive HLE.

Limitations and future research

The present study is not free of limitations. First, acknowledging the relationship between the HLE and children's outcomes, additional research is needed to examine the concurrent validity of the HLEQ by exploring its association with several child competencies, like literacy, numeracy, or socioemotional skills. Second, future studies, apart from replicating the present findings, could examine other types of the measure's quality characteristics such as the temporal stability of the HLEQ and investigate the concurrent validity of the HLEQ with other existing HLE measures. Third, the current report provides initial validation of the HLEQ in a sample from northern Greece, limiting the generalizability of the results. Therefore, supplementary research is needed to validate the HLEQ in different cultural settings.

Fourth, HLEQ is an instrument that measures the frequency of various parent-child learning activities in and out of home as well as the frequency of parenting practices (e.g., warm, supportive, conflict, and chaotic practices) during the parent-child learning interactions. These parenting practices reflect warmth, support, and responsiveness of the caregiver–child interactions during the home learning activities, thus providing information-to a certain degree-about the quality of the home learning ecosystem (Gregoriadis and Evangelou, 2022). Therefore, despite the quantitative indicators for the frequency of activities and parenting practices, the HLEQ offers the opportunity for measuring what parents do with their children and how they do it in the HLE; thus offering information for the quality of parent-child relationship in the HLE. However, it is suggested the needs for future mixed method studies that will also obtain qualitative information for various aspects of the early HLE (e.g., how stimulating is the reading to the child or how effective are the supportive practices for children's learning). Finally, as the physical environment of the home constitutes another core aspect of the HLE (Tamis-LeMonda et al., 2019; Gregoriadis and Evangelou, 2022), an additional shorter scale than the HOME, with descriptive items about the home's physical environment and the availability of learning materials in combination with the psychometric scale of HLEQ could provide a holistic assessment of the quality of HLE.

Conclusion and implications

The HLE has important effects on children's development. Several measures have been developed for assessing its quality. However, they mainly focus on specific aspects of its construct. There is little work on the quality properties of HLEs. The self-reported HLEQ is a reliable instrument for measuring the quality of parent-child interactions during several learning activities within a HLE. A robust methodological approach was followed for the development of the HLEQ, whereas its psychometric properties were analyzed using ESEM, a promising, recently developed statistical methodology. Findings provided initial support for its factor structure, reliability, and validity.

Overall, the HLEQ confirmed the multidimensional construct of the HLE by indicating six dimensions. A strength of the HLEQ is that it constitutes a measurement that has a bifold function. On the one hand, it can be used to measure the broad construct of the HLE. On the other hand, its multidimensional content allows for more targeted measures of specific domains of the HLE. For instance, a researcher interested in focusing on the impact of HLAs on particular outcomes could utilize the relevant factors of the instrument. Furthermore, the identification of the four profiles of HLE that show different patterns of parent-child interactions during the HLAs could help researchers and practitioners focus on developing interventions designed to support families and offer their children high-quality experiences at home. Ongoing research on early assessments of children's HLE can provide evidence about their stability over time, their impact across children's developmental domains, and their relationship to other learning environments as is the school.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the Greek Institute of Educational Policy (Ministry of Education, Research and Religious Affairs) (License number: 46/4-10-2018). The patients/participants provided their written informed consent to participate in this study.

Author contributions

KK was responsible for the data collection procedure. KK and NT worked on the statistical analysis of the datasets. KK, AG, NT, VG, and ME worked together for the writing and completion of the manuscript. All authors contributed to the study's research design.

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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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The influence of the literacy environment on children's writing development in Chinese

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The present study investigated the influence of literacy environment on the performance of writing narratives for primary school students. Two hundred and fifty Chinese children participated in this study. There were 146 third graders (71 boys and 75 girls) and 104 fifth graders (53 boys and 51 girls). Results showed that children's writing abilities differed at the word level and sentence level between third grade and fifth grade. Formal literacy experience (parent teaching of characters) predicted the writing performance of third graders, while informal literacy experience (the visiting frequency of various places) predicted the writing performance of fifth graders. After controlling the effect of reading efficiency on the writing skills, the prediction of formal and informal literacy experiences on the writing performance remained. The results suggest the importance of formal and informal literacy experiences on the writing development of primary school students.

KEYWORDS

writing development, reading, home literacy environment, primary school, Chinese

Introduction

Writing composition is an essential and challenging part in children's literacy acquisition. As children have mastered how to speak and read, they start to learn writing composition, which is an important skill for learning and working in their later life (Abbott et al., 2010). However, writing as a focus of research has been neglected relative to reading and oral language in recent decades (Miller and McCardle, 2011). Until now, the majority of writing research is in alphabetic languages, whereas writing research in Chinese is scarce. To contribute to expanding knowledge of writing beyond alphabetic languages, the present study focused on the writing skills of Chinese students. In particular, there is still a lack of investigation on the effect of family and social contexts that writing occurs within. The present study therefore seeks to investigate the influence of home literacy environment (HLE) on the performance of Chinese writing for primary school students.

The most influential model of writing to date was proposed by Hayes and Flower (1980) and revised by Hayes (1996). In this model, writing comprises four processes, including planning, translation, reviewing, and revising (Hayes and Flower, 1980; Hayes, 1996). Subsequently, Berninger et al. (2002) proposed a simple view of writing model. In this model, translation is the most important process in writing and it could be modeled as (a) text generation component at different levels of language (word, sentence, and text) and (b) transcription component (handwriting and spelling). According to this model, the most important goal of the developing writer is the text generation component at different levels of language (word, sentence, and text) (Berninger et al., 2002). Assessing children's writing at different levels of language can localize children's strengths and weaknesses at the word, sentence, and text levels, thus making further instruction and intervention more targeted (Wagner et al., 2011).

A large number of studies in alphabetic languages have focused on the generation component and measured children's writing at different levels of language (Whitaker et al., 1994; Berninger et al., 2002; Abbott et al., 2010; Kim et al., 2011; Wagner et al., 2011; Williams and Larkin, 2013; Drijbooms et al., 2015). Recent studies have investigated the development of writing abilities among primary school children at different levels of writing (Puranik et al., 2008; Wagner et al., 2011; Koutsoftas, 2018). Koutsoftas (2018) measured 4th and 6th graders' writing at the word level and sentence level. Results showed that there was a significant difference at the sentence level, while no significant difference was found at the word level between 4th and 6th graders. In another study, researchers found that there were significant differences between 3rd and 5th graders' writing at both the word and sentence levels (Puranik et al., 2008). Regarding the text level of writing, a previous study reported no significant difference among 4th, 5th, and 6th graders (Whitaker et al., 1994). These studies showed various developmental characteristics of the writing at different levels of language.

In Chinese, the basic units of writing are characters, which are more visually complex than alphabetic letters and represent word or morpheme rather than having a grapheme-phoneme correspondence (Lui et al., 2010). Compared with alphabetic language, Chinese has much more homophones (Shu et al., 2003). Consequently, a large number of characters refer to the same syllable. In addition, the grammar and syntax in Chinese are sometimes more ambiguous and difficult to comprehend, because of the free-flowing punctuation and the frequent omission of major sentence components (Yan et al., 2012). Due to those properties, the literacy development in Chinese relies heavily on character learning (e.g., the learning of visual form and the arbitrary connection between visual form and pronunciation) and semantics learning (e.g., the learning of vocabulary and world knowledge) in surrounding context. These learning modalities emerge at home and gradually extend to family activities in other places when parents try to provide a favorable and rich learning environment for their children. Therefore, HLE may play an indispensable role in Chinese children's literacy development (Shu et al., 2002; Su et al., 2017).

According to educational practices, the development of Chinese primary school children's writing has been divided into three periods: transforming oral language into writing period (Grade 1, 2), transition period (Grade 3, 4), and preliminary writing period (Grade 5, 6) (Zhu, 1990). The teaching emphasis of the first period is the transcription skills and basic rules of writing. From 3rd grade on, children develop their narrative writing by text reading (Yan et al., 2012; Guan et al., 2014). The teaching emphasis turn out to be improving writing through reading practices (Zhu, 1990). Given the uniqueness of the Chinese writing system, the developmental pattern of Chinese writing has important implications for the formulation of universal theories on writing development across different orthographies.

Compared with ample studies in alphabetic languages, studies in Chinese writing were relatively few and limited to the transcription component (handwriting and spelling) of writing (Tan et al., 2005; Guan et al., 2011). Studies investigating text generation component in Chinese were rare and they did not assess writing according to the levels of language (Guan et al., 2014; Yeung et al., 2017). For instance, Guan et al. (2014) measured Chinese children's narrative writing in Grades 4, 5, and 6. Children's response was scored by two research assistants according to three aspects, including expression, content, and commentary. There were significant grade differences among 4th, 5th, and 6th graders, while no significant grade difference was found between 3rd and 5th graders in another study of narrative writing, in which writing of the children were rated according to four aspects consisting of content, vocabulary, sentence structure, and organization (Yeung et al., 2017). The inconsistency of previous studies may be due to different measures used to assess the writing or the differences in the grade levels of the participants. Moreover, in the previous Chinese studies, a general score of the narrative writing was given to each child. However, a general score could not reflect the specific property of writing. It is essential to explore the developmental characteristic of Chinese writing, using more specific writing indices, such as indices for different levels (word, sentence, and text) of writing.

More recently, theories of writing have emphasized that writing is a communicative act that the individual interacts with the external environment to accomplish challenging writing tasks in the learning environment (Singer and Bashir, 2004; Berninger and Winn, 2006; Berninger and Chanquoy, 2012). As the foundation of writing, emergent literacy development is rooted in communication between people and their environments, which first emerge at home and gradually expand to social context (Vygotsky, 1978; Teale and Sulzby, 1986). Therefore, HLE may play an important role in writing development. To describe the nature of the HLE, Sénéchal and LeFevre (2002) proposed the home literacy model. According to this model, there are two types of home literacy experiences; namely, formal and informal literacy experiences. Formal literacy experience (code-related) engages children directly with print through activities such as parent teaching of reading or spelling. In contrast, informal literacy experience (meaning-related) exposes children to print incidentally through activities such as shared book reading or visit of library (Sénéchal and LeFevre, 2002).

Several studies have found the effects of formal literacy experiences on children's reading development (Burgess et al., 2002; Manolitsis et al., 2013; Su et al., 2017; Silinskas et al., 2020). For instance, formal literacy experiences indexed by the onset age of parent teaching of reading has been found to be associated with children's reading in both alphabetic and Chinese languages (Sénéchal et al., 1996; Burgess et al., 2002; Su et al., 2017). In a 11-year longitudinal study, researchers reported that the onset age of parent teaching characters was a significant predictor for reading fluency and reading comprehension for fifth graders (Su et al., 2017). In a recent neuroimaging study, researchers also found that the onset age of parent teaching was related to the property of the left arcuate fasciculus (important brain structure supporting language and reading), even statistically controlling for socioeconomic status (SES), access to print and long-term vocabulary development (Su et al., 2020). Studies from both behavioral and brain levels highlight the essential role of the onset age of parent teaching in the literacy development. Moreover, previous studies have found that the onset age of parent teaching of reading, which attempt to get a cumulative amount of print exposure, were predictive of developmental outcomes than questions that are designed to assess current shared reading practices (DeBaryshe, 1995; Sénéchal et al., 1996; Burgess, 1997). However, until now, the relationship between this variable and writing composition is unclear. Therefore, in the present study, we chose the onset age of parent teaching characters as a representative for the formal literacy experience measure and investigated its association with writing composition.

Regarding informal literacy experience, studies have reported that there is an association between shared-book reading and children's emergent literacy development (e.g., Manolitsis et al., 2013; Khanolainen et al., 2020) and that the educational outings (i.e., visit of various educational locations) are correlated with primary school children's academic achievement, including reading, math and science (Coley et al., 2020). As children enter primary school, they gradually acquire the independent reading skill, the frequency of shared-book reading or literacy games may decrease compared with preschool children (Sénéchal and LeFevre, 2014; Inoue et al., 2018). Indeed, researchers did not find any correlation between shared book reading and primary school children's reading from Grade 1 to Grade 4 (Georgiou et al., 2021). In a recent study, researchers found that the visit of various educational locations (e.g., science center, library, bookstore, art gallery, aquarium, museum, and tourist attraction) was correlated with primary school children's reading performance (Coley et al., 2020). This study highlights the importance of the educational outings for the primary school children, which extends the informal literacy experience to broad settings outside the home and school. Therefore, we followed Coley et al.'s (2020) study and selected the visiting frequency of various educational locations as items for the informal literacy experience. These visiting experiences may promote children's vocabulary and world knowledge development by joyous exploration, which may further improve children's writing development (Dunsmuir and Blatchford, 2004; Kim et al., 2011; Wang, 2017).

Studies have found close relationship between the three levels of writing and reading abilities. For instance, single word reading ability was primarily linked to writing at word level (e.g., writing fluency and spelling), while reading comprehension skills were related to writing at both the word level and the compositional level (e.g., the quality of written content, Berninger et al., 2002; Abbott et al., 2010; Kim et al., 2011; Williams and Larkin, 2013). Considering the tight relationship between reading and writing (Tan et al., 2005; Williams and Larkin, 2013), the connections between HLE and reading could transfer to writing, which may deepen our understanding on the relationship between reading and writing.

However, compared with the abundant evidence on the importance of HLE in reading development, studies exploring the relationship between HLE and writing development were relatively scarce and limited to relatively lower-level skill such as spelling (Sénéchal, 2006; Niklas and Schneider, 2013). For example, Niklas and Schneider (2013) found that HLE (a combination of formal and informal HLE) predicted children's spelling ability at the end of first grade. Sénéchal (2006) reported that formal literacy experience (indexed by parent teaching of reading) had an indirect effect on children's spelling ability in the first grade (*via* phonological awareness) and fourth grade (*via* word reading). Until now, little is known about the association between HLE and the writing composition.

In summary, to contribute to expanding knowledge of writing beyond alphabetic languages, the present study investigates on written compositions provided by students in China. Specific research questions were as follows:

1. Assessing Chinese children's narrative writing according to different levels of language (word, sentence, and text) and investigating the developmental characteristics of Chinese writing in intermediate grade writers (3rd grade vs. 5th grade).
2. Investigating the influence of different aspects of HLE (formal vs. informal) on the three levels (word, sentence, and text) of Chinese writing and comparing the grade difference of the associations between 3rd grade and 5th grade.

We expected that there were significant differences between 3rd and 5th graders on the word, sentence and text levels of narrative writing. Specifically, 5th graders performed better than the 3rd graders on each level of writing (Guan et al., 2014). Furthermore, the roles of formal and informal literacy experience for writing may be different in grades 3 and 5. Specifically, formal literacy experience indexed by parent teaching might play more important role in the word level of writing in the lower graders, while informal literacy experience indexed by various visiting experiences might play more important role in the higher level of writing in the upper graders (McCutchen, 1986; Sénéchal, 2006; Su et al., 2017).

Previous studies have also found that females outperformed males on the narrative writing tasks (U.S. Department of Education, 2008; Troia et al., 2013), but potential differences between females and males in different levels of writing (word level, sentence level, and text level) for the 3rd and 5th graders have not been investigated. Thus, we added sex as a variable of interest in the present study. Moreover, as SES is closely related to HLE in a variety of literacy-related studies (e.g., Sénéchal, 2006; Su et al., 2017), we control this variable in the subsequent regression analyses. Finally, studies have found tight relationship between the three levels of writing and reading abilities (Berninger et al., 2002; Abbott et al., 2010; Kim et al., 2011; Williams and Larkin, 2013). In order to examine the specific association between HLE and writing composition, we added a reading efficiency task (a combination of word reading and reading comprehension) as a control variable in the present study.

Materials and methods

Participants

Two hundred and fifty Chinese children participated in this study. They came from three primary schools of Haidian District in Beijing. In each school, we randomly selected two classes (one from third grade and one from fifth grade). Finally, 146 third graders (M_{age} = 9.1 years, SD = 0.5) and 104 fifth graders (M_{age} = 11.1 years, SD = 0.3) participated in this study. The sex ratio (boys/girls) for the third graders and fifth graders were 71/75 and 53/51 respectively. There were no significant differences in the sex percentage between the two groups of children (all $ps > 0.05$). The participants were all native Mandarin speakers with a wide range of reading skills (see **Table 1**, scores on the reading efficiency task). As they were from the same district, there were nearby opportunities for outside-of-home and school visits (libraries, museums etc.) for all participants. They had normal or corrected-to-normal vision with no history of neurological abnormalities, head injury, or intellectual disability. Family SES was collected by the index of parental education. The overall parent education of the present study was in an upper-middle level (M_{edu} = 5.5, $Range$ = 1–8). Therefore, the sampling of the present study may reflect the situation of upper-middle-class families of China. Informed written consent of the present study was obtained from both the parents and their children.

Data sources and variables

Writing composition task

The written samples were collected in class following the instructions from previous writing studies (Wagner et al., 2011; Yan et al., 2012). Children were instructed to write a narrative entitled "An unforgettable day." Children were expected to write continuously within 10 min, focusing and keeping writing the whole time. For the word the children did not know how to write, they could simply use pinyin to replace it. If the children made a mistake, they could simply cross out the mistaken word and keep writing. If they stopped writing before the 10 min was up, the experimenters encouraged them to continue writing. This task was tested at the whole class level. The written samples were then coded by two raters according to the measurement indices of writing described below.

We used word-level, sentence-level, and text-level measurement indices to evaluate the quality of writing. The word-level measurements were word token and word type, representing the number and density of word in the composition (Wagner et al., 2011). Word token was the total number of words for the writing composition. Word type was the total number of non-repetitive words for the writing composition (Nation, 2001). Word token indicates the fluency, while word type measures the variety of using word to write (Wang, 2017). For example, wǒ xiǎngniàn wǒ de gǒu (我想念我的狗。I miss my dog), there are five types and six tokens in this sentence. For the sentence-level measurement, we used number of premodifiers and mean length of premodifiers as indices of syntactic maturity because language learners use more complex noun phrases when their language levels improve, and these indices are manifested effectively in measuring learners' syntactic development (Nation, 2001; Biber et al., 2011; Wang, 2017; Wu, 2019). For example, nàgè piàoliɑng de niánqīng nǚshì (那个漂亮的年轻女士, the beautiful young lady), there are three premodifiers before the noun "nǚshì" (lady), which are "nàgè" (the), "piàoliɑng de" (beautiful), and "niánqīng" (young). Mean length of premodifiers were calculated by the mean number of Chinese characters in premodifiers. For the text-level measurement, we used the text content quality as an index. The rating scale of the text content quality was adapted from Kuiken and Vedder (2017)'s functional adequacy scale that composed of five items, including content, task requirements, comprehensibility, coherence, and cohesion. The experimenter was required to rate children's writing on the five aspects, with the highest score of 6 and the lowest score of 1 for each item. The sum of the scores on the five items was the text content quality of the child. All of the writing indices were rated by two trained experimenters with high inter-rater reliability ranging from 0.768 to 0.999 (**Table 1**). The criterion-related validity for the content quality measure was 0.744. The averages of the two experimenters were calculated as the measurement indices of writing. As the basic unit of Chinese writing, the total number of characters of the composition was also counted.

Reading efficiency task

In order to test the specific relationship between HLE and the writing skills, we included reading efficiency as a control variable. The reading efficiency task followed the procedures of previous studies in alphabetic language (Moll et al., 2009; Wagner et al., 2010). This task consisted of 100 sentences with gradually increasing length. In this task, children were required to silently read 100 sentences and rapidly indicate whether the sentence "makes sense" in 3 min. One example of the reading sentence is "世界上所有的花都是红色的" (All the flowers in the world are red). The total number of characters in correct sentences per minute was calculated as child's reading fluency score. Therefore, the reading efficiency task used in the present study is scored for reading efficiency, including speed and accuracy. This task was tested at the whole class level. This reading efficiency task has been found to be correlated with both word reading and reading comprehension in previous Chinese studies and it has been suggested to be a reliable proxy with good validity (r = 0.746) for reading efficiency in Chinese children (Xue et al., 2013; Su et al., 2017).

Home literacy environment questionnaire

Formal literacy experience was measured by an item about the onset age of parent teaching of characters. Specifically, the parents were asked about the age at which they started teaching their child to read characters at home. The choices were 1 = never; 2 = after age 4; 3 = at 3–4 years old; 4 = at 2–3 years

TABLE 1 Scores on the writing, reading, and home literacy environment (HLE) between the two grades.

Measures	Mean (S.D.)	Skewness	Kurtosis	Reliability	Grade 3	Grade 5	Comparisons		
					Mean (S.D.)	Mean (S.D.)	t	P	Cohen's d
Writing composition									
Word token (WL-1)*	99.2 (38.8)	0.14	−0.143	0.999	86.6 (31.2)	116.8 (41.6)	−6.254	<0.001	0.821
Word type (WL-2)	62.2 (23.2)	0.212	−0.038	0.998	54.4 (17.6)	73.2 (25.7)	−6.472	<0.001	0.854
Sentence premodifier number (SL-1)	7.9 (5.2)	1.03	1.613	0.999	7.0 (4.2)	9.3 (6.1)	−3.346	0.001	0.439
Sentence premodifier mean length (SL-2)	3.2 (1.2)	0.252	0.829	0.99	3.1 (1.2)	3.2 (1.2)	−0.743	0.458	0.083
Text content quality (TL)	13.6 (4.4)	−0.239	−0.122	0.768	13.3 (3.8)	14.0 (5.0)	−1.211	0.227	0.158
Reading efficiency									
Sentence reading efficiency (Reading)	314.5 (149.6)	0.777	0.589	0.97	267.2 (144.4)	381.0 (130.9)	−6.38	<0.001	0.826
Home literacy environment									
Onset age of parent teaching (Formal)	4.2 (1.3)	−0.357	−0.703	-	4.1 (1.3)	4.4 (1.3)	−1.735	0.084	0.231
Visiting frequency of places (Informal)	3.4 (1.1)	−0.058	−0.194	0.81	3.3 (1.0)	3.5 (1.1)	−1.472	0.142	0.19

*Content in the parentheses is the abbreviation for further analyses. WL, word level; SL, sentence level; TL, text level.

old; 5 = at 1–2 years old; and 6 = from 0 to 1 years old. This item has been widely used as a proxy for child's formal literacy experience in previous studies (Burgess et al., 2002; Su et al., 2017).

Informal literacy experience was measured by seven items about the visiting frequency of various educational locations (science center, art gallery, library, bookstore, aquarium, museum, and tourist attraction). For example, the parents were asked about the frequency they took their children to visit the science center. The choices were 1 = never; 2 = only once; 3 = once every year; 4 = several times every year; 5 = once every month; 6 = once every week, and 7 = several times every week. The average of the seven items was calculated as the index for informal literacy experience. Cronbach's alpha reliability of the seven items in our sample was 0.80.

The HLE questionnaire was sent to the parents (*via* the children) by the teacher at the same time as children's behavioral test. Parents were required to finish the questionnaire in 1 day. On the second day, the teacher collected the parent questionnaire at class.

Analytical method

Statistical analysis was performed in statistical product and service solutions (SPSS) Statistics v.20 (international business machines (IBM) Corporation, Somers, NY, United States). Firstly, descriptive analyses were performed for the writing, reading and HLE measure. Secondly, we compared children's performance in the five writing measurements and reading efficiency between 3rd graders and 5th graders through independent-sample *t*-tests, effect size of the *t*-tests was calculated by *Cohen's d*. Thirdly, we performed partial correlations among formal and informal literacy experiences, narrative writing scores and reading efficiency score with the age and sex controlled for 3rd graders and 5th graders respectively. Results of the correlation analyses were corrected for multiple comparisons using the False Discovery Rate (FDR) correction (Benjamini and Hochberg, 1995). In the Results section, we report uncorrected *p*-values and then compare them to the FDR-corrected alpha threshold *q*-value.

The main aim of this study was to assess the predictive pattern of formal and informal literacy experiences for different levels of writing (word, sentence, and text) in Grade 3 and Grade 5. Thus, our main analytical approach was hierarchical linear regression model. As previous studies showed significant association between age, sex, and SES with writing, all analyses were adjusted for the age, sex, and SES variables. Therefore, for each grade, we established a series of hierarchical regression models with age, sex, and SES controlled in the first step, and the formal and informal literacy experiences in the second step. Different indices of writing at each level (i.e., token and type for word level, number of premodifiers and mean length of premodifiers for sentence level, sum of five content quality scores for text level) were looked at separately as dependent variables. In order to highlight the unique contribution of HLE to the writing skills, in the second series of regression models, we included the reading efficiency as a control variable. For each grade, we tested a series of hierarchical regression models with age, sex, and SES controlled in the first step, the reading efficiency in the second step, and the formal and informal literacy experiences in the third step. The dependent variables were narrative writing scores in word, sentence, and text levels.

Results

In **Table 1**, *Means*, *standard deviation,* and other descriptive statistic measures of narrative writing, reading, and HLE are reported. Generally, all the measures followed a normal distribution with reasonable skewness and kurtosis. No ceiling effect was found for the writing and reading measures. Considering the grade differences, the numbers of word token [$M_{grade\ 3}$ = 86.6, $M_{grade\ 5}$ = 116.8; $t(248) = -6.254$, $p < 0.001$, *Cohens'd* = 0.821], word type [$M_{grade\ 3}$ = 54.4, $M_{grade\ 5}$ = 73.2; $t(248) = -6.472$, $p < 0.001$, *Cohens'd* = 0.854], and sentence premodifier [$M_{grade\ 3}$ = 7.0, $M_{grade\ 5}$ = 9.3; $t(248) = -3.346$, $p = 0.001$, *Cohens'd* = 0.439] for writing were significant larger in Grade 5 than those in Grade 3. Fifth graders also performed better than 3rd graders on the reading efficiency task [$M_{grade\ 3}$ = 267.2, $M_{grade\ 5}$ = 381.0; $t(248) = -6.380$, $p < 0.001$, *Cohens'd* = 0.826]. No significant difference was found in the sentence premodifier mean length [$t(248) = -0.743$, $p = 0.458$, *Cohens'd* = 0.083] and text content quality [$t(248) = -1.211$, $p = 0.227$, *Cohens'd* = 0.158]. Finally, there were no significant differences in the two HLE variables [formal: $t(248) = -1.735$, $p = 0.084$, *Cohens'd* = 0.231; informal: $t(248) = -1.472$, $p = 0.142$, *Cohens'd* = 0.190].

When sex and age were controlled, we found formal literacy experience was correlated with the number of word types ($r = 0.208$, $p = 0.012 <$ FDR-corrected $q = 0.025$) and sentence premodifiers ($r = 0.250$, $p = 0.003 <$ FDR-corrected $q = 0.025$) for writing in Grade 3, whereas informal literacy experience was correlated with the number of tokens ($r = 0.369$, $p < 0.001 <$ FDR-corrected $q = 0.027$), types ($r = 0.438$, $p < 0.001 <$ FDR-corrected $q = 0.027$), mean length of premodifiers ($r = 0.246$, $p = 0.013 <$ FDR-corrected $q = 0.027$), and content quality ($r = 0.393$, $p < 0.001 <$ FDR-corrected $q = 0.027$) for writing in Grade 5 (**Table 2**). Writing measures were correlated with each other in 3rd grade and 5th grade, except for the correlation between word-level

TABLE 2 Partial correlations among home literacy environment (HLE), writing, and reading measures controlling for age and sex.

	Formal	Informal	Writing-WL1	Writing-WL2	Writing-SL1	Writing-SL2	Writing-TL	Reading
Formal	–	0.173*	0.165*	**0.208***	**0.250****	0.117	0.127	0.077
Informal	0.195*	–	−0.094	−0.034	−0.055	−0.008	−0.009	0.135
Writing-WL1	0.178	**0.369*****	–	**0.929*****	**0.559*****	0.147	**0.536*****	**0.199***
Writing-WL2	0.188	**0.438*****	**0.843*****	–	**0.559*****	0.156	**0.537*****	**0.253****
Writing-SL1	−0.021	0.191	**0.456*****	**0.494*****	–	**0.307*****	**0.325*****	**0.194***
Writing-SL2	0.058	**0.246***	**0.299****	**0.462*****	**0.543*****	–	**0.246****	0.172*
Writing-TL	0.197*	**0.393*****	**0.608*****	**0.711*****	**0.401*****	**0.480*****	–	**0.251****
Reading	0.173	0.171	0.213*	**0.296****	0.021	0.029	0.173	–

Values above the diagonal are correlations of 3rd graders; values below the diagonal are correlations of 5th graders. Formal = onset age of parent teaching, informal = visiting frequency of places, WL1 = word token, WL2 = word type, SL1 = sentence premodifier number, SL2 = sentence premodifier mean length, TL = text content quality. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, r values surviving False Discovery Rate (FDR) correction are in bold.

measures and mean length of premodifiers in Grade 3 (token: $r = 0.147$, $p = 0.078$; type: $r = 0.156$, $p = 0.063$). Reading efficiency was correlated with writing measures in Grade 3 (token: $r = 0.199$, $p = 0.017 <$ FDR-corrected $q = 0.025$; type: $r = 0.253$, $p = 0.002 <$ FDR-corrected $q = 0.025$; premodifier: $r = 0.194$, $p = 0.020 <$ FDR-corrected $q = 0.025$; and content quality: $r = 0.251$, $p = 0.002 <$ FDR-corrected $q = 0.025$) and was correlated with word-level writing measure in Grade 5 (type: $r = 0.296$, $p = 0.002 <$ FDR-corrected $q = 0.027$).

To investigate the influence of formal and informal literacy experiences on the writing skills in word level (token and type), sentence level (number of premodifiers and mean length of premodifiers), and text level (quality of writing content), we performed hierarchical regression analyses for each dependent variable, controlling for sex, age, and SES. R^2 change and standardized β coefficients for each variable are reported in Table 3. We found that girls produced a larger number of word type in Grade 3 (β = 0.165, $p = 0.045$) and Grade 5 (β = 0.284, $p = 0.001$). Girls also produced a larger number of premodifiers relative to boys in Grade 5 (β = 0.211, $p = 0.036$). The formal literacy experience was a significant predictor for the number of token (β = 0.180, $p = 0.032$), type (β = 0.214, $p = 0.011$), and premodifier (β = 0.261, $p = 0.002$) in Grade 3, whereas the informal literacy experience was a significant predictor for the number of token (β = 0.304, $p = 0.003$), type (β = 0.339, $p < 0.001$), premodifier (β = 0.220, $p = 0.040$), mean length of premodifier (β = 0.227, $p = 0.036$), and content quality (β = 0.301, $p = 0.003$) in Grade 5.

In an extended model, we performed hierarchical regression analyses controlling the influence of reading on writing. In the model, we entered reading efficiency variable before the HLE variables. R^2 change and standardized β coefficients for each variable are reported in Table 4. We found that girls produced a larger number of word types and sentence premodifiers relative to boys in Grade 5 (β = 0.280, $p = 0.001$; β = 0.211, $p = 0.037$). The reading efficiency predicted the number of word token (β = 0.219, $p = 0.008$), word type (β = 0.267, $p = 0.001$), sentence premodifier (β = 0.202, $p = 0.014$), mean length of premodifier (β = 0.180, $p = 0.035$), and text content quality (β = 0.240, $p = 0.004$) in Grade 3. The effect of HLE on the writing skills remained after controlling the influence of reading efficiency on writing. Specifically, the formal literacy experience was a significant predictor for the number of word token (β = 0.168, $p = 0.042$), word type (β = 0.199, $p = 0.014$), and sentence premodifier (β = 0.250, $p = 0.002$) in Grade 3, whereas informal literacy experience was a significant predictor for the number of word token (β = 0.282, $p = 0.005$), word type (β = 0.315, $p = 0.001$), sentence premodifier (β = 0.224, $p = 0.039$), mean length of premodifier (β = 0.236, $p = 0.031$), and text content quality (β = 0.294, $p = 0.004$) in Grade 5.

Discussion

The present study aims to assess Chinese children's writing development according to different levels of language (word, sentence, and text) and investigate the influence of HLE on children's writing development. Results showed that children's writing abilities differed between Grade 3 and Grade 5 on the word and sentence levels, while no significant difference was found in the writing of text level. Different aspects of HLE played different roles in the development of writing. More specifically, formal literacy experience indexed by the onset age of parent teaching predicted the writing performance (word and sentence levels) in Grade 3, while informal literacy experience indexed by visit of various educational locations predicted the writing performance (word, sentence, and text levels) in Grade 5. After controlling the effect of age, sex, SES, and reading efficiency on the writing skills, the prediction pattern of HLE on writing performance remained, indicating the unique effect of HLE on writing composition.

TABLE 3 Hierarchical regression analyses of writing measures using home literacy environment (HLE) as predictors.

			Word level				Sentence level				Text level	
			Token		Type		Premodifier number		Premodifier mean		Content quality	
Grade	Steps	Measures	Δ R^2	β	Δ R^2	β	Δ R^2	β	Δ R^2	β	Δ R^2	β
3	1	Control variables	0.044		0.042		0.036		0.023		0.036	
		Age		−0.051		−0.041		−0.076		−0.066		0.017
		Sex		0.147		0.165*		0.109		0.125		0.159
		SES		−0.106		−0.082		−0.110		−0.029		0.120
	2	Home literacy environment	0.032*		0.044*		0.065*		0.014		0.021	
		Formal		0.180*		0.214*		0.261**		0.120		0.137
		Informal		−0.077		−0.033		−0.051		−0.015		−0.086
5	1	Control variables	0.100*		0.192***		0.041		0.022		0.126**	
		Age		0.001		−0.002		0.030		0.025		−0.049
		Sex		0.184		0.284**		0.211*		0.021		0.122
		SES		0.114		0.186		−0.059		0.054		0.194
	2	Home literacy environment	0.091**		0.107***		0.041		0.044		0.090***	
		Formal		0.090		0.071		−0.050		0.001		0.092
		Informal		0.304**		0.339***		0.220*		0.227*		0.301**

Formal = onset age of parent teaching, informal = visiting frequency of places. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

TABLE 4 Hierarchical regression analyses of writing measures using reading efficiency and home literacy environment (HLE) as predictors.

			Word level				Sentence level				Text level	
			Token		Type		Premodifier number		Premodifier mean		Content quality	
Grade	Steps	Measures	Δ R^2	β	Δ R^2	β	Δ R^2	β	Δ R^2	β	Δ R^2	β
3	1	Control variables	0.044		0.042		0.036		0.023		0.036	
		Age		−0.060		−0.052		−0.085		−0.074		0.007
		Sex		0.121		0.133		0.085		0.104		0.131
		SES		−0.139		−0.123		−0.140		−0.056		0.084
	2	Reading efficiency	0.048**		0.073**		0.044*		0.033		0.056**	
		Sentence reading efficiency		0.219**		0.267**		0.202*		0.180*		0.240**
	3	Home literacy environment	0.030**		0.038**		0.060**		0.011		0.019*	
		Formal		0.168*		0.199*		0.250**		0.109		0.123
		Informal		−0.092		−0.052		−0.065		−0.028		−0.103
5	1	Control variables	0.100*		0.192***		0.041		0.022		0.126**	
		Age		−0.008		−0.012		0.032		0.029		−0.051
		Sex		0.180		0.280**		0.211*		0.023		0.120
		SES		0.116		0.189*		−0.059		0.053		0.195
	2	Reading efficiency	0.043**		0.049***		< 0.001		0.001		0.010**	
		Sentence reading efficiency		0.162		0.174*		−0.033		−0.067		0.050
	3	Home literacy environment	0.073**		0.087***		0.042		0.047		0.082***	
		Formal		0.068		0.047		−0.045		0.010		0.085
		Informal		0.282**		0.315**		0.224*		0.236*		0.294**

Formal = onset age of parent teaching, informal = visiting frequency of places. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

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Compared with ample studies in alphabetic languages, studies in Chinese writing development were relatively few and limited to the handwriting and spelling of writing (Tan et al., 2005; Guan et al., 2011). The present study investigated the developmental characteristics of Chinese writing composition on different levels of language. In line with previous studies in alphabetic languages (Whitaker et al., 1994; Puranik et al., 2008; Koutsoftas, 2018), the present study found various developmental characteristics of the writing at different levels of language. On the word and sentence levels of writing, 5th graders performed better than the 3rd graders, which was consistent with findings in a previous study of alphabetic language (Puranik et al., 2008). Regarding the writing of text level, no significant difference was found between 3rd and 5th graders, which was also similar with a previous study reporting no differences on the text level of writing among 4th, 5th, and 6th graders (Whitaker et al., 1994). The similar developmental pattern between Chinese and alphabetic languages may indicate the universal property of writing development across different orthographies. Considering the educational implications of these findings, absent development on the text level of writing may suggest that the emphasis of writing instruction in intermediate grades should be focused on the text level of writing. For instance, the measures (content, task requirements, comprehensibility, coherence, and cohesion) assessed writing quality on the text level in the present study may be important teaching directions for the educators.

Previous studies have found the relationship between HLE and reading development (Levy et al., 2006; Inoue et al., 2018; Georgiou et al., 2021). The present study found the association between HLE and writing narratives, which verify the tight relationship between reading and writing and extend the home literacy model to the writing composition process. In the present study, we found that formal literacy experience indexed by the onset age of parent teaching predicted the writing in word level (number of word) and sentence level (number of premodifiers) in Grade 3. More specifically, the earlier the children learned character, the larger number of word and premodifiers they produced in the writing process. Early access to Chinese characters promoted the development of early linguistic skills, like orthographic, phonological, morphological, and vocabulary skills (Su et al., 2017). These skills may subsequently enhance children's literacy skills like recognizing and writing more word, especially including the word used as premodifiers in better expressing the sentence. The educational implication of this finding may be the importance of early parent teaching, especially on the characters teaching of Chinese language.

Another interesting finding of the present study is that the informal literacy experience indexed by visit of various educational locations (science center, art gallery, bookstore, aquarium, museum, and tourist attraction) is related to all levels of writing performance in Grade 5. One superordinate knowledge important for writing is domain knowledge about content, which includes what is often referred to as "world knowledge" (the knowledge a reader brings to a text) (Fitzgerald and Shanahan, 2000). The increased vocabularies of place names, activities, and terminologies due to visit might explain the richness of words used in composition and increased world knowledge due to various visiting experience might explain the increased content quality of writing (Dunsmuir and Blatchford, 2004; Kim et al., 2011; Wang, 2017). The present study showed that children's visit to various places such as a museum, library, or bookstore with parents benefits their writing development in upper grade. However, as children grow up, family members seem to lose much of their out-home visit due to increasing work and excessive use of electronic products (e.g., smartphone and tablet computer). Therefore, educators should advocate the importance of visiting outside home on the writing process, especially for parents of upper graders.

Finally, the work presented here had several limitations. Firstly, although we selected the onset age of parent teaching as the variable for formal literacy experience and visiting frequency of various places as the variable for informal literacy experience, more concrete formal (e.g., actual frequency and time of children's literacy-related behavior at home, duration of the parent teaching behavior) and informal literacy experiences (e.g., quantity and quality of parent-child literacy-related activity during visiting outside home) should be explored. Secondly, there may be mediators between HLE and writing skills. For instance, vocabulary and word knowledge may be important in explaining the relationship between HLE and writing. However, we did not explicitly measure children's vocabulary and word knowledge in the current study. Further study should measure them explicitly and explore the relationship between HLE, vocabulary, word knowledge and writing. Finally, this study was a cross-sectional study with only 3rd and 5th graders, future research should combine longitudinal methodology with careful examination on the effect of literacy experience at home, school and social situation in children's composition writing.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the College of Elementary Education, School of Psychology, Capital Normal University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

MS, YF, and BQ performed material preparation, data collection, and analysis. MS and WZ wrote the first draft of the manuscript. JW and WZ commented on previous versions of the manuscript. All authors contributed to the study conception and design, and read and approved the final manuscript.

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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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Higher-achieving children are better at estimating the number of books at home: Evidence and implications

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The number of books at home is commonly used as a proxy for socioeconomic status in educational studies. While both parents' and students' reports of the number of books at home are relatively strong predictors of student achievement, they often disagree with each other. When interpreting findings of analyses that measure socioeconomic status using books at home, it is important to understand how findings may be biased by the imperfect reliability of the data. For example, it was recently suggested that especially low-achieving students tend to underestimate the number of books at home, so that use of such data would lead researchers to overestimate the association between books at home and achievement. Here we take a closer look at how students' and parents' reports of the number of books at home relate to literacy among fourth grade students, by analyzing data from more than 250,000 students in 47 countries participating in 2011 PIRLS. Contrary to prior claims, we find more downward bias in estimates of books at home among high-achieving students than among low-achieving students, but unsystematic errors appear to be larger among low-achieving students. This holds within almost every country. It also holds between countries, that is, errors in estimates of books at home are larger in low-achieving countries. This has implications for studies of the association between books at home and achievement: the strength of the association will generally be underestimated, and this problem is exacerbated in low-achieving countries and among low-achieving students.

KEYWORDS

estimation skills, socioeconomic status, achievement gaps, differential reliability, human development

Introduction

Students with a socioeconomically more advantaged family background tend to achieve better in school (White, 1980; Sirin, 2005; Harwell et al., 2017). This socioeconomic achievement gap is observed across various operationalizations of SES, such as parental education and occupation and wealth possessions (Mullis et al., 2009; Marks and O'Connell, 2021). In the present study we focus on the number of books at home, which has been considered an attractive measure of SES for several reasons, including relatively high correlations with parents' income and education (Beaton et al., 1996), high response rates (Wiberg and Rolfsman, 2021), and that no laborious coding of the data is required (Heppt et al., 2022). The number of books at home variable is therefore commonly used in studies of the socioeconomic achievement gap (Eriksson et al., 2020) or to control for SES when gauging the relationship between achievement and other important educational factors such as learning opportunities (Yang Hansen and Strietholt, 2018; Rolfe et al., 2021). The number of books at home is also frequently used to complement other socioeconomic measures. For example, the socioeconomic index in the OECD Programme for International Student Assessment (PISA) is based on several indicators, including the number of books at home (Avvisati, 2020).

Many authors have noted that the number of books at home is a particularly strong predictor of student achievement (e.g., Hanushek and Woessmann, 2011; Brese and Mirazchiyski, 2013). One interpretation is that the number of books at home is an indicator of a family interest in reading, which is considered a factor that promotes achievement (Ammermueller and Pischke, 2009).

Because of the wide usage of the books at home variable, it is important that researchers examine the reliability of the variable. Prior studies, using datasets that include both students' and their parents' reports of the number of books at home have indicated that the reliability is not very good, because the correlation between student-reported and parent-reported data is often quite low and never very high (Rutkowski and Rutkowski, 2010, 2018; Jerrim and Micklewright, 2014). While reporting errors are likely found among both students and parents, it is commonly assumed that reliability is a greater concern for student reports (Engzell, 2021). The topic of the present paper is how data reliability may systematically vary with students' achievement level.

A hypothesis about variation in reliability

From a cognitive perspective, estimation of the number of books at home is a non-trivial numerical task. We expect the accuracy of estimates of books at home to depend on how skilled the person is at numerical estimation tasks in general. Numerical estimation skills are counted among mathematical skills that are tested in international large-scale assessment (Schleicher et al., 2009). Hence, we expect estimates of books at home to be more reliable among high-achievers than low-achievers in mathematics. Moreover, high-achievers in math also tend to be high-achievers in reading literacy (Ding and Homer, 2020). Thus, literacy scores should be useful as a proxy for estimation skills. Our hypothesis is therefore that estimates of the number of books at home are less reliable among low-achievers than high-achievers in school, regardless of whether achievement is measured in math or reading.

This hypothesis seems not to have been stated before. However, a prior study found higher literacy scores among students who reported the same number of books at home as their parents did than among students whose estimates deviated from their parents' (Jerrim and Micklewright, 2014). While this result is what we would expect from our hypothesis on how reliability varies with achievement, it is not the correct comparison to make to properly test our hypothesis. For example, it could be that high-achievers seldom make errors but that any errors they do make tend to be large, in which case their reliability could still be poorer than among low-achievers. Testing the hypothesis requires an explicit comparison of reliability between low-achievers and high-achievers.

A hypothesis about variation in bias

Errors may be random or systematic, also known as bias. A recent study claimed that estimates are biased downward especially among low-achieving students (Engzell, 2021), based on the finding that low-achieving students report having fewer books than high-achieving students do when the number of books at home reported by parents is held fixed. However, this finding can be explained without any downward bias among low-achieving students. It is sufficient that low-achieving students truly tend to have fewer books than high-achieving students, because this basic association will be observed also when parents' estimates of books at home are held constant as the true numbers will still vary (due to the presence of unsystematic errors among parents).

There is in fact reason to expect the opposite to Engzell's claim, that is, we expect that estimates are biased downward especially among *high-achieving* students. The reason is that estimates of books at home are made on a scale with a lowest step (0–10 books) and a highest step (more than 200 books). If the true number of books at home is at the lowest step, the only possible error in data is to make an overestimation. Because of the basic association between the true number of books at home and achievement, the true number of books at home is more often at the lowest step for low-achievers than for high-achievers. Thus, the existence of a lowest step of the response scale should cause more overestimation among low-achievers than high-achievers. Similarly, when the true number of books is at the highest step, which will happen more often for high-achievers than low-achievers, the only possible error in data is to make an underestimation. For these reasons, we expect more downward bias among high-achievers than low-achievers.

Estimating the association between books at home and achievement

Many scholars are interested in how the association between socioeconomic status and student achievement varies across countries (e.g., Van de Werfhorst and Mijs, 2010; OECD, 2018;

Kim et al., 2019; Strietholt et al., 2019). Surprisingly, results may strongly depend on how socioeconomic status is operationalized. For example, a recent study found that the association between wealth and achievement is stronger in *less* developed societies, whereas the association between books at home and achievement is stronger in *more* developed societies (Eriksson et al., 2021). Here we propose that this paradoxical finding may partly be due to how the reliability of books at home data varies across countries. To see why, consider the following points:

1. In a global comparison, low-developed countries tend to have more low-achieving students (e.g., Mullis et al., 2012; Stoet and Geary, 2013; Eriksson et al., 2020).
2. Earlier we hypothesized that students' achievement level serves as a proxy for their numerical estimation skills and hence that more low-achieving students will produce less reliable estimates of books at home. In countries with lower achievement levels, we would therefore expect generally lower reliability in data on books at home.
3. Low reliability will attenuate the association between books at home and achievement, that is, make it look weaker than it really is.

Consequently, we expect underestimation of the association between books at home and achievement to be exacerbated in low-achieving countries. The association between books at home and student achievement is therefore expected to be weaker in low-developed countries simply due to less reliable data. This pathway is illustrated in Figure 1.

An assumed relation between students' and parents' reliability

Absent data on the true number of books at home, we cannot say what the error is in individual estimates. Instead, we will assess the reliability at group level. Specifically, we use the strength of the correlation between students' estimates and their parents' estimates in a given group (e.g., the group of low-achieving students in a certain country). Our working assumption is that the estimation skills of students and parents are correlated, due to their shared genes and shared environment. Thus, when comparing reliabilities across groups, we take the correlation between students' and parents' estimates of books at home in a group as a proxy not only for the reliability of student data but also for the reliability of parent data. In other words, a relatively low correlation in a group is assumed to mean that both students and parents in this group make relatively unreliable estimates.

Outline of study

As explained above, we use the correlation between students' and parents' estimates in each group as a measure of the reliability of their estimates of books at home. Using these measures, we test our hypotheses (1) that data reliability is lower among low-achieving students than among high-achieving students in the same country, and (2) that data reliability is lower in low-achieving countries than in high-achieving countries. We further use mediation analyses to examine whether the latter hypothesis can also explain why the association between achievement and books at home is weaker in less developed countries.

We then address the question of whether there is a difference in bias between the estimates of high- and low-achieving students within countries by examining whether the two groups of students differ in how their estimates deviate from their parents'. Here we assume that the bias of *parents* of high- and low-achieving students differs less than the bias of the students themselves, which seems very reasonable as errors are generally assumed to be generally smaller among parents than students (Engzell, 2021).

Finally, given its reliability issues, one may question whether it is worthwhile to study the books-at-home variable at all. To demonstrate that this variable taps into something important, we show that parent-reported data on books at home predict literacy above and beyond parents' education and occupation.

Materials and methods

Following Engzell (2021), we test our hypotheses using publicly available data from the 2011 wave of PIRLS.[1] The details of this assessment are described elsewhere (Mullis et al., 2009).

Countries

We include data from 47 participating countries and country-like entities in the 2011 wave of PIRLS: Australia, Austria, Azerbaijan, Belgium, Botswana, Bulgaria, Canada, Colombia, Croatia, Czech Republic, Denmark, Finland, France, Georgia, Germany, Honduras, Hong Kong, Hungary, Indonesia, Iran, Ireland, Israel, Italy, Kuwait, Lithuania, Malta, Morocco, Netherlands, New Zealand, Northern Ireland, Norway, Oman, Poland, Portugal, Qatar, Romania, Russia, Saudi Arabia, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Taiwan, Trinidad and Tobago, United Arab Emirates.

Samples

The PIRLS target population is the grade that represents 4 years of schooling. The average age of students is typically between 10 and 11 years. Representative samples of students are drawn in each country. All participating students from the 47 countries are

1 https://timssandpirls.bc.edu

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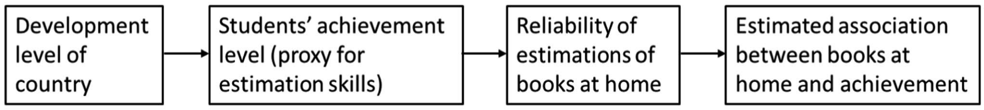

FIGURE 1
An explanation for why the estimated association between books at home and achievement is stronger in more developed countries.

included in our study. The number of participating students per country ranged from 3,349 in Hong Kong to 18,245 in Canada. The total number of participants is 307,747. In line with the representativity of the samples, the gender distribution is almost perfectly even: 50.5% boys and 49.5% girls. The sampling scheme and country samples are described in more detail elsewhere (Mullis et al., 2009, 2012).

Measures

To measure reading literacy, PIRLS ask students to read certain texts and answer questions about them. A rotated booklet design is used whereby every student reads only a few of the full set of texts. PIRLS then imputes a set of plausible values for the student's score on the full test. IEA provides software for analysis that accounts for the additional uncertainty added by this design,[2] as well as sampling weights, etc. We use this software to calculate all the measures used in the further analysis: average achievement scores per country, reliability measures, and the association between books at home and achievement.

The questionnaire to students participating in PIRLS includes the question "About how many books are there in your home? (Do not count magazines, newspapers, or your school books.)" There are five response options: None or very few (0–10 books); Enough to fill one shelf (11–25 books); Enough to fill one bookcase (26–100 books); Enough to fill two bookcases (101–200 books); Enough to fill three or more bookcases (more than 200). These options are coded from 1 to 5. A similar question, but excluding children's books, is included in the questionnaire to parents of participating students: "About how many books are there in your home? (Do not count ebooks, magazines, newspapers, or children's books.)" The five response options are the same intervals as in the question to students, that is, 0–10, 11–25, 26–100, 101–200, and more than 200. These options are coded from 1 to 5. From the questionnaire to parents, we also obtain data on parents' highest levels of education and occupation.

Finally, the development level of a country is operationalized by the Human Development Index (HDI), available from the United Nations Development Programme[3] for 45 countries in our study. We use HDI values obtained from other sources for Taiwan[4] and Northern Ireland.[5]

Data analysis

The first analysis concerns within-country differences in reliability. We perform a median split of the student sample in each country, based on their literacy score (operationalized as the average of the plausible values available for the student). In each half of the sample, we use the Pearson correlation between students' and parents' data on books at home as a measure of the reliability of the data in that group. This yields two reliability measures per country: one measure for below-median achievers and one measure for above-median achievers. We then compare these measures using a paired *t*-test.

The second analysis section concerns between-country differences in reliability and other variables involved in the pathway depicted in Figure 1. We use the Human Development Index as a measure of the development level of each country. We use the mean literacy score in each country as a measure of the achievement level in that country. We use the Pearson correlation between students' and parents' data on books at home, calculated separately in each country, as a measure of the reliability of the data in that country. We further use the Pearson correlation between students' literacy scores and their estimates of the number of books at home, calculated separately in each country, as a measure of the strength of the association between literacy and books at home data from students, and similarly for parents' data. We calculate pairwise correlations between these country-level measures to examine the links of the pathway in Figure 1. We then perform a formal mediation analysis.

A third analysis concerns how the bias in students' estimates of the number of books at home varies their literacy within countries. In analogy with the first analysis above, we perform a median split of the student sample in each country based on literacy scores. In each group, we use the mean difference between students' and parents' estimates as a measure of the bias in students' data. This yields two bias measures per country, one measure for below-median achievers and one measure for above-median achievers, which we compare using a paired *t*-test.

2 https://www.iea.nl/data-tools/tools
3 http://hdr.undp.org/
4 https://www.dgbas.gov.tw
5 https://globaldatalab.org

In a final analysis section, we examine how parent-reported books at home fare as a predictor of literacy compared to the other parent-reported socioeconomic variables in PIRLS: parents' highest education and parents' highest occupation. We first compare how different socioeconomic variables correlate with literacy scores. We then use multiple linear regression to examine whether the number of books at home predicts student literacy above and beyond parents' education and occupation.

Results

The reliability of students' estimates varies with their achievement level

Across 47 countries, reliability measures were lower for the groups of below-median achievers, $M = 0.38$ ($SD = 0.12$), than for the groups of above-median achievers, $M = 0.50$ ($SD = 0.08$), a difference of 0.12, 95% CI [0.09, 0.14], $t(46) = 9.02$, $p < 0.001$, paired *t*-test. Thus, the hypothesis that lower-achieving students make larger unsystematic estimation errors was supported.

A consequence of this hypothesis is that a large difference between the estimates of student and parent indicates that the student is probably a low achiever. To illustrate this phenomenon,

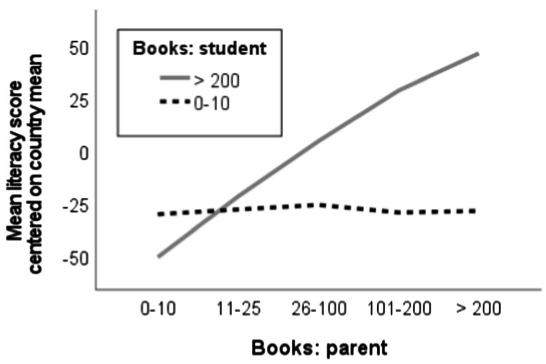

FIGURE 2
How mean literacy scores (centered on the mean in each country) among students who reported the lowest number of books at home (0–10, dashed line) or the highest number of books at home (> 200, solid line) vary across different values of books at home as reported by parents.

Figure 2 shows what the association between literacy scores and parent-reported books at home looks like among students who themselves report either the lowest (0–10) or the highest (> 200) number of books at home. In these groups of students, their estimation error will tend to have very different relations to the number of books reported by parents. Namely, the more books at home that parents report, the more inaccurate we expect the lowest student estimates to be, and the less inaccurate we expect the highest student estimates to be. Among students who report the lowest number of books, the graph in Figure 2 is flat, consistent with a negative association between literacy and estimation inaccuracy that offsets the positive association between literacy and books at home. Among students who report the highest number of books, by contrast, the graph starts very low and increases very steeply, consistent with estimation inaccuracy now changing in the opposite direction so that the two associations reinforce each other.

Tests of the country-level hypotheses

Correlations between country-level variables are reported in Table 1. These correlations support all the links of the pathway depicted in Figure 1. First, the development level of countries is strongly correlated with their achievement level. Second, the achievement level is strongly correlated with the reliability of books at home data. Third, the reliability of books at home data is strongly correlated with the strength of the association between literacy and books at home, whether estimated by students or parents.

For sequential mediation analysis we use Model 6 of the PROCESS macro for SPSS (Hayes, 2017) to calculate 95% confidence intervals for indirect effects using 5,000 bootstrap samples. The results, in Table 2, indicate that the path *via* a country's mean literacy level and reliability level indeed produces a considerable indirect effect of the development level on the association between literacy and books at home, whether estimated using data from students or parents. The effects of other paths were not statistically significant, that is, their confidence intervals include zero. Thus, the hypothesis illustrated in Figure 1 was supported.

The mediation analysis reported in Table 2 is based on a series of linear regressions. We report these underlying analyses in the

TABLE 1 Country-level correlations.

	1	2	3	4	5
1. Human Development Index	–				
2. Mean literacy score	0.74 [0.56,0.84]	–			
3. Reliability of books at home data	0.32 [0.03,0.55]	0.60 [0.37,0.76]	–		
4. Association btw. Literacy and books at home data from students	0.42 [0.15,0.63]	0.65 [0.44,0.79]	0.79 [0.65,0.88]	–	
5. Same for data from parents	0.28 [−0.01,0.52]	0.42 [0.14,0.62]	0.76 [0.60,0.86]	0.80 [0.66,0.88]	–

Based on $n = 47$ countries. 95% confidence intervals based on Fisher's r-to-z transformation with bias adjustment.

TABLE 2 Results of sequential mediation analysis of the effect of HDI on the strength of the association between students' literacy scores and estimates of their number of books at home.

Path	Effect, student data	Effect, parent data
HDI → Mean literacy → Reliability → Association	0.50 [0.24, 0.93]	0.50 [0.26, 0.88]
HDI → Mean literacy → Association	0.21 [−0.16, 0.57]	−0.16 [−0.50, 0.12]
HDI → Reliability → Association	−0.23 [−0.64, 0.07]	−0.23 [−0.65, 0.06]
Direct effect	0.08 [−0.27, 0.42]	0.18 [−0.13, 0.48]
Total indirect effect	0.47 [0.08, 0.91]	0.11 [−0.29, 0.46]

Based on $n = 47$ countries. 95% confidence intervals based on 5,000 bootstrap samples. To obtain more convenient numbers, literacy scores were scaled down by a factor of 1,000 in this analysis.

TABLE 3 Mean values of within-country correlations.

	Literacy	Books at home	Parents' education
Books at home	0.31 [0.28, 0.33]		
Parents' education	0.36 [0.34, 0.39]	0.42 [0.39, 0.45]	
Parents' occupation	0.30 [0.28, 0.33]	0.36 [0.33, 0.39]	0.56 [0.53, 0.58]

Based on $n = 47$ countries. 95% confidence intervals within brackets.

case of student data. First, mean literacy is regressed on HDI, yielding a positive effect estimate $B = 0.53$, 95% CI [0.38, 0.67], $p < 0.001$. This is the first arrow in Figure 1. Second, reliability is regressed on both mean literacy and HDI, yielding a positive effect of mean literacy, $B = 1.42$ [0.80, 2.03], $p < 0.001$, but no significant direct effect of HDI, $B = -0.35$, [−0.79, 0.09], $p = 0.12$. This means that the effect of HDI on reliability follows the path formed by the first two arrows in Figure 1. Third, the association between literacy and student-reported books at home is regressed on reliability, mean literacy, and HDI, yielding a positive effect of reliability, $B = 0.67$ [0.43, 0.90], $p < 0.001$, but no significant direct effect of mean literacy, $B = 0.40$ [−0.17, 0.99], $p = 0.17$, or of HDI, $B = 0.08$, [−0.27, 0.42], $p = 0.65$. This means that the effect of HDI on the strength of the association follows the path formed by the three arrows in Figure 1.

Downward bias in books at home data is stronger among high-achievers

Across the 47 countries, there was stronger downward bias in students' estimates of books at home in the groups of above-median achievers $M = -0.16$ ($SD = 0.21$), than in the groups of below-median achievers, $M = -0.06$ ($SD = 0.23$), a difference of −0.10, 95% CI [−0.13, −0.06], $t(46) = 5.66$, $p < 0.001$, paired t-test. Thus, the hypothesis that downward bias in books at home data is stronger among high-achieving students than low-achieving students was supported.

The number of books at home predicts students' literacy above and beyond other socioeconomic measures

From the results in Table 2, we conclude that the association between books at home and literacy is attenuated, due to poor reliability, even when books at home data are reported by parents. Despite the attenuation, the strength of the association between literacy and parent-reported books at home is comparable with the strength of the associations between literacy and parents' highest education and occupation (reported by the parents themselves). In the average country, the correlations with literacy are between 0.30 and 0.36 for the three socioeconomic variables, see Table 3.

Which of the three socioeconomic variables had the strongest correlation with literacy varied across countries. In some countries it was books at home (12 countries), but most often it was parents' education (34 countries). However, recall that the correlation with books at home is attenuated by low reliability, which also varies across countries. This is illustrated by a scatter plot in Figure 3. The x-axis shows our measure of the reliability of books at home data in each country. The y-axis shows the relative predictive strength of books at home, measured by the difference in strength between the literacy-books at home correlation and the literacy-education correlation. Note that there are 12 countries above the reference line at zero. The plot shows a strong positive correlation between the reliability of books at home and its relative predictive strength, $r = 0.59$, 95% CI [0.36, 75], $p < 0.001$. This finding suggests that if books at home could be measured more reliably, it is likely that it would more generally be the strongest socioeconomic predictor of literacy.

To drive home the point that the number of books at home predicts literacy above and beyond other socioeconomic variables, we also report multiple regression analyses with parents' books at home data, parents' highest level of education, and parents' highest occupation as simultaneous predictors of student literacy. As shown in Table 3, these variables are intercorrelated, but not so strongly that multicollinearity is a problem. Multiple regression analyses, performed separately in each country, yielded three standardized coefficients per country: β_{books}, $\beta_{education}$, and $\beta_{occupation}$. These coefficients were generally positive and statistically significant at the $p < 0.05$ level; exceptions were one country in which β_{books} was not significantly positive, and eight countries in which $\beta_{occupation}$ was not significantly positive. The average country had $\beta_{books} = 0.16$, 95% CI [0.15, 0.17], $\beta_{education} = 0.21$, 95% CI [0.19, 0.22], and $\beta_{occupation} = 0.11$, 95% CI [0.09, 0.12]. We conclude that the number of books at home in general has a considerable effect on literacy above and beyond parents' education and occupation, even when attenuated by low reliability.

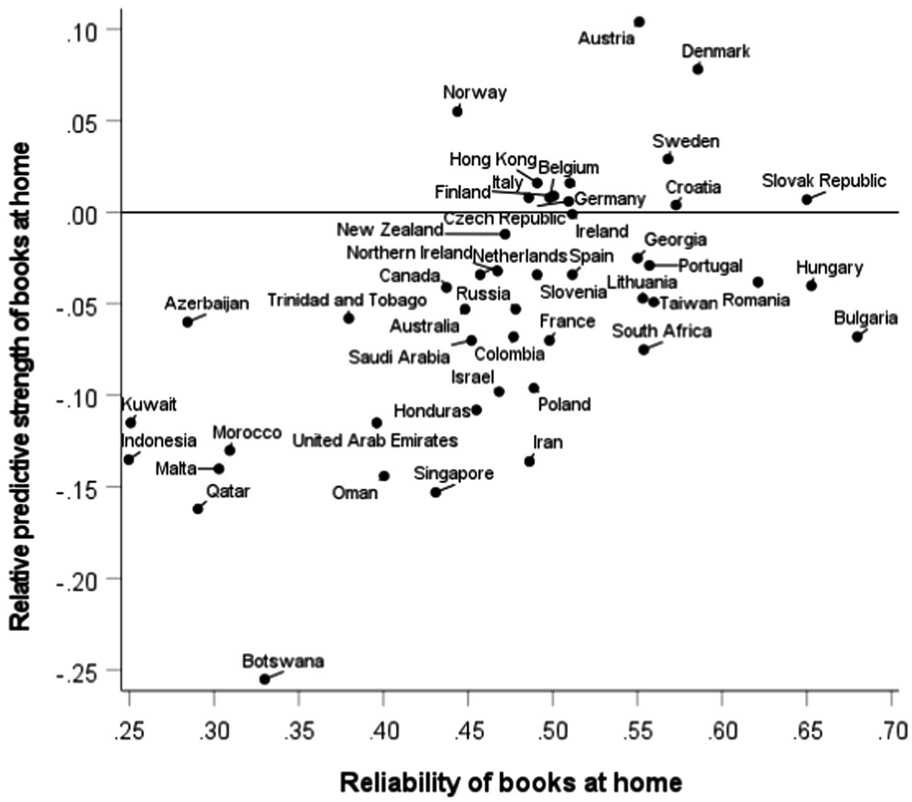

FIGURE 3
Country variation in the reliability of books at home data (x-axis) and the relative predictive strength of books at home (y-axis), operationalized as the difference between the literacy-books at home correlation and the literacy-parents' education correlation. Above the reference line at zero are 12 countries where student literacy was better predicted by books at home than by parent's education.

Discussion

Why study books at home?

The number of books at home is a commonly used proxy of students' socioeconomic status in educational studies. One reason is that this variable is present in all international large-scale studies, which makes it easy to compare results across data sources (Blömeke et al., 2016). On the other hand, several studies have pointed out issues with the reliability of books at home data (Rutkowski and Rutkowski, 2010, 2018; Jerrim and Micklewright, 2014; Engzell, 2021). Should the variable therefore be abandoned? We do not think so, because the number of books appears to tap into an especially important aspect of students' family background that goes beyond other common socioeconomic variables such as parents' education and occupation (Eriksson et al., 2021). In support of this notion, many authors have noted that the number of books at home is a particularly strong predictor of student achievement (e.g., Hanushek and Woessmann, 2011; Brese and Mirazchiyski, 2013). However, Engzell (2021) pointed out a problem with this interpretation and argued that the strength of the association between student-reported books at home and achievement is an artifact of reverse causality in the form of a tendency among high-achieving students to acquire more books (Engzell, 2021).

To shed more light on this question, we studied the association with parent-reported books at home. Parents are asked to exclude children's books in their estimates so their data should not suffer from the reverse causality problem. In our analysis, we nonetheless found that the number of books at home that parents report predicts their children's literacy score above and beyond parents' education and occupation. Our conclusion is that the true number of books at home has an important and unique association with the literacy of fourth grade students. One interpretation is that parents' interest in reading is transferred to students, either socially or *via* genetic transfer, and that interest in reading is beneficial for academic achievement (Ammermueller and Pischke, 2009; Eriksson et al., 2021). We believe that more research needs to be devoted to testing this explanation, and other possible explanations, for the association between books at home and achievement. For this reason, we believe researchers should not refrain from making use of available estimates of books at home, despite their reliability issues. Our recommendation is instead that researchers be careful about taking reliability issues into account when interpreting results.

Taking the relation between reliability and achievement into account

The main aim of the current study was to draw attention to the issue that the reliability of books at home data varies systematically across achievement levels. We find that data reliability is lower among lower-achieving students as well as in lower-achieving countries. A plausible explanation is that students who achieve better in school tend to have better numerical estimation skills. This issue has implications for studies that use the number of books at home to control for family background when studying the effect of another variable on student achievement (e.g., Blömeke et al., 2016; Eriksson et al., 2019; Karadavut et al., 2019; Wennström, 2020). Poor reliability implies that the true number of books is not fully controlled for in such studies, and the problem of insufficient control will be especially bad in low-achievement countries and among low-achieving students.

There are also implications for studies that use the number of books at home to measure the size of the socioeconomic achievement gap. In a recent meta-analysis, Harwell et al. (2017) called these gaps "surprisingly modest." However, low reliability of data typically means that the size of achievement gaps will be underestimated. This underestimation of achievement gaps will be most pronounced in low-achievement countries. Lack of awareness of this phenomenon may lead researchers to unnecessarily look for other explanations. For example, several prior studies have observed a stronger association between books at home and academic achievement in more developed countries, and they have proposed explanations in terms of the use of books or the access to books (Chiu, 2010; Eriksson et al., 2021). Our study indicates that the real explanation why the association is stronger in more developed countries is that in these countries we should expect estimation skills to be higher. Hence, books-at-home data will be more reliable and yield stronger associations with achievement in more developed countries.

Our finding also means that studies of achievement gaps in different groups within a country will tend to underestimate gaps especially in lower-achieving groups. For example, consider prior findings of a weaker association between student achievement and books at home among students with immigrant background than among non-immigrant students in England and Sweden (Elmeroth, 2006; Hansson and Gustafsson, 2013; Lenkeit et al., 2015). Such findings may be artifacts of differences in the reliability of books at home data, as it is likely that immigrants also tend to have overall lower achievement levels and hence provide data of lower reliability.

Does bias in estimates of books at home vary with the achievement level?

Another possible issue with estimates of books at home is that they may be biased in some direction. Engzell (2021) claimed that estimates are biased downward among low-achieving students, but this finding appears to have been an artifact of the analysis method that was used. In our analysis, comparing students' and parents' estimates, we found more downward bias among high-achievers than low-achievers.

Limitations

A limitation of our study (and of all studies in this area) is that, lacking data on the true number of books at home, we cannot tease apart errors in students' estimates from errors in parents' estimates. To get around this problem, we focused on group level comparisons. We assumed that the estimation skills of parents and students are correlated, especially at group level (e.g., countries with weaker school systems are expected to have lower estimation skills both in the parents' generation and the children's generation). To measure the overall reliability of estimates in a group, we used the correlation between students' and parents' estimates. If our assumption is correct, this measure of overall reliability will, across groups, simultaneously capture variation in the reliability of students' and parents' estimates. Consistent with our assumption, we found that the reliability measure in a country is a very strong predictor of the strength of the association between literacy and books at home, whether estimated by parents or students.

In this paper we do not present any equations; our hypotheses were motivated by verbal arguments. The same hypotheses could alternatively be derived in a more formal way, that is, we could formulate a formal model of estimation errors that depend on achievement, fit this model to existing data, and show that simulated data from the fitted model support the same hypotheses.

Conclusion

The number of books at home is a valuable variable for researchers seeking to understand how family background influences children's literacy—but this variable has specific reliability issues that researchers need to be aware of to avoid incorrect interpretations of data. It is not possible to quantify how researchers should adjust findings obtained using data on the number of books at home. Qualitatively, though, researchers should expect that observed associations between books at home and achievement (or any other variable) are weaker than the true associations, especially in lower-achieving group of students.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: Data from the 2011 wave of PIRLS are available at: https://timssandpirls.bc.edu. The Human Development Index is available from the United Nations Development Programme (http://hdr.undp.org/) for 45 countries in our study; we use HDI values obtained from other sources for Taiwan (https://www.dgbas.gov.tw) and Northern Ireland (https://globaldatalab.org).

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 from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

KE conceived of the study, performed the analysis, and wrote the paper. JL, OH, and AR contributed to the survey of the literature and to the discussion, and provided critical 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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With a little help from our pediatrician: An intervention to promote mathematics-related home activities through regular well-child visits

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Introduction: Children's involvement in mathematics-related activities in the home environment is associated with the development of their early numeracy over the preschool years. Intervention studies to promote parents' awareness and provision of mathematics-related home activities are however scant. In this study we developed and tested the effectiveness of a non-intensive intervention program delivered by community pediatricians to promote mathematics-related activities in the home environment.

Methods: Parents of 204 Italian children were invited to report on the frequency of mathematics-related home activities when children attended the first preschool year (3 years, 8 months of age on average) and, subsequently, the third preschool year (5 years, 6 months of age on average). At both waves, children were also assessed on their early numeracy. In occasion of the routine well-child visit at age 5, parents who were randomly allocated to the intervention condition (vs. a business-as-usual control condition) received guidance on age-appropriate home mathematics-related practices to sustain children's numerical development.

Results: Results revealed that parents in the intervention group improved their provision of home mathematics-related activities at the post-intervention assessment (relative to baseline) to a greater extent than parents in the control condition. No effect was observed on children's early numeracy.

Discussion: Overall, results are promising in suggesting that community pediatricians may be a resource to promote home mathematics-related activities though non-intensive low-cost interventions.

KEYWORDS

home mathematics environment, early numeracy, preschool, parent–child activities, intervention, pediatricians

Introduction

People need to build up solid competencies in mathematics to cope with a host of challenges in everyday life. Beyond undermining future academic achievement (Geary, 2011) and employment opportunities (Gross et al., 2009; Martin, 2018), shortage of mathematical skills also prevents people from using math knowledge and procedures to solve basic daily life problems (Jansen et al., 2016). Adults with poor mathematical skills, for example, may struggle with numerical information implied in health risks comprehension (Rolison et al., 2020) and basic medical practices, such as calculation of dose and timing of drug self-administration (Moore et al., 2011), with evident risks to health (Reyna et al., 2009; Peters, 2012). Efforts to improve mathematical competencies from the earliest life years should therefore be seen as a goal not only for the educational systems, but also for professionals and services involved in the promotion of individuals' health and wellbeing at large. In this work, we evaluated the impact of a non-intensive intervention delivered by community pediatricians in the context of ordinary well-child visits. The goal of the intervention was to increase the frequency of mathematics-related activities in the home environment among parents of preschool-aged children, and to promote children's early numeracy in the preschool years.

The development of early mathematical skills

Mathematical competencies emerge early in life and undergo substantial development before children encounter formal teaching at school. Several milestones of numerical knowledge are typically acquired between age 2 and 6, such as the number-word sequence, the ability to map numerical symbols onto related quantities, the cardinality and ordinality principles, and basic arithmetical skills (e.g., simple additions and subtractions; LeFevre et al., 2010a; Siegler and Braithwaite, 2017; Litkowski et al., 2020). Numerical competencies acquired in the preschool years are among the strongest predictors of later academic achievement throughout primary and secondary school (Duncan et al., 2007; Watts et al., 2014; Geary et al., 2018; Davis-Kean et al., 2021).

Before attending school, the family environment is a crucial context in which children learn and practice their emerging mathematical competencies. Shared mathematics-related activities in the home – commonly referred to as "home numeracy" (Skwarchuk et al., 2014) – include direct numerical teaching, such as helping children practice counting or retrieving simple sums, and indirect experiences, such as when parents use numbers in their conversations with children, play number games, use measurement and numerals during cooking activities, and read storybooks with numerical content. Although it is plausible that children with greater numerical skills may elicit more number-related activities from their parents, longitudinal studies suggest that the frequency of home mathematics-related activities (Susperreguy et al., 2021; Authors, submitted) and the use of numerical language in parent–child conversations (Gibson et al., 2020) prospectively predict the growth of preschoolers' numerical competencies over time, even after controlling for children's numerical skills at baseline (see Mutaf Yıldız et al., 2020, for a review).

Provision of home numeracy activities is nonetheless highly variable across families, and not all children have equal opportunity to receive adequate support for their early numeracy development. Socio-demographic factors (e.g., parents' instruction, child's gender; see Saxe et al., 1987; Vandermaas-Peeler et al., 2012b), as well as beliefs and attitudes toward math may shape parents' engagement in number-related activities (LeFevre et al., 2010b; Skwarchuk et al., 2014). Parents with positive attitudes toward mathematics tend to attribute more importance to math achievement (i.e., valuing of math; Eccles and Wigfield, 2002) and report more frequent engagement with home numeracy (Del Río et al., 2017; Susperreguy et al., 2018). This may be of special concern in countries, such as Italy, in which attitudes toward science, technology, and the STEMs in general are generally less favorable at the population level (European Commission, 2021), and the reported frequency for use of numerical skills and engagement in numeracy practices in everyday life is lower than in other industrialized countries (Jonas, 2018). Attempts should therefore be made to improve parental knowledge and attitudes toward early mathematics-related home activities, and support parents in providing richer home numeracy environments for their children (Niklas et al., 2016; Purpura et al., 2019).

Interventions to promote mathematics-related home activities

Despite the spread of research on home numeracy over the last decade (Mutaf Yıldız et al., 2020), interventions to promote number-related practices in the home environment are still rare. In a meta-analysis of home-based interventions to improve literacy and numeracy outcomes among preschool-aged children, only 10 studies focused on mathematics-related outcomes were retained, as compared to 28 studies focused on literacy (Cahoon et al., 2022). Evidence however exists that the frequency of number-related activities and games, as well as the use of numerals in daily conversations, can be successfully improved. Increased involvement in shared mathematics-related activities with parents and higher mathematical skills were observed among children whose parents received structured, intensive programs with repeated sessions of information, guided play with children, and instruction on mathematics-related activities to be conducted at home (Starkey and Klein, 2000; Niklas et al., 2016; Dulay et al., 2019). Leyva et al. (2018), for example, invited parents of kindergartners from low-income Latino backgrounds to take part in an intensive 4-week training program in which participants were instructed to incorporate mathematical strategies (e.g., counting, matching quantities with numerical symbols) into daily cooking routines. Results revealed that children of parents who participated in the intervention showed improved numeracy skills. The intervention was especially effective for children who had lower numerical competencies at baseline, thus supporting the idea that parents can be effectively encouraged to include more mathematics-related activities in their children's home environment.

Other studies showed that even non-intensive interventions, in which parents are provided with only minimal instruction, may also be effective. In a study with parents of preschoolers (Vandermaas-Peeler et al., 2012a), parent–child dyads were observed during a board game play session. In addition to the board game, half of the parents were given a list of suggested numeracy activities to incorporate into the game at their own discretion, but with no further instruction on how and when to do that. Results revealed that parents in the intervention condition not only performed more numerical activities, as prompted by the experimenter's suggestions, but also provided more feedback on children's number-related responses. In turn, children's mathematics achievement improved following the intervention. Similarly, parents of four-year-old children increased their mathematics-related support when they were invited to incorporate number-related talk and activities (e.g., counting, comparing quantities, or doing basic operations) into ordinary cooking activities at home, without receiving any further specific training (Vandermaas-Peeler et al., 2012b).

In some cases, non-intensive interventions were effective in fostering mathematics-related activities in ordinary contexts outside the household, such as visits at museum exhibits (Vandermaas-Peeler et al., 2016; Braham et al., 2018) or shopping (e.g., Hanner et al., 2019). For example, Hanner et al. (2019) placed signs in grocery stores encouraging parents to interact with their children and pose them questions. In a numerical intervention condition, signs invited parents to engage in number-related talk (e.g., "Try asking … How many eggs are in a cartoon"?). In an active control condition, signs simply prompted parents to pose generic questions (e.g., "Try asking … What animal lays eggs?"), whereas in a neutral control condition no tip was provided. Observations of parents' interactions with children revealed that in the numerical intervention condition, number-related talk was twice as frequent as in both the control conditions.

Overall, these findings suggest that even non-intensive interventions may be sufficient to raise parental awareness of numerous opportunities to include mathematics-related practice in their daily interactions with preschool-aged children.

Promoting home numeracy through community pediatricians

In most industrialized countries, children and their parents access primary health consultation and pediatric check-ups on a regular basis, especially in the preschool years (Larson et al., 2016). In Italy, primary and preventive pediatric care – including routine well-child visits – is provided free of charge by the National Health System and parents are generally highly satisfied with the community pediatricians as the primary child health care providers (Corsello et al., 2016). Scheduled well-child visits thus provide community pediatricians with a unique opportunity to inform parents about a variety of issues pertaining to healthy child development.

Current guidelines for children's primary healthcare already prompt pediatricians to carry out periodic screenings and provide guidance for parents on language acquisition (Council on Children With Disabilities et al., 2006; Committee on Practice and Ambulatory Medicine and Bright Futures Periodicity Schedule Workgroup, 2020). Initiatives such as the Reach Out and Read (ROR) program in the US demonstrate that interventions carried out by pediatricians during ordinary well-child consultations are effective in increasing shared reading and literacy-focused activities among parents of preschoolers (for a review, see Klass et al., 2009). Similar programs (*Nati per Leggere*; litt.: Born-to-Read) have also been implemented in Italy.[1] The *Nati per Leggere* program, for instance, has helped the promotion of shared storybook reading and other literacy-focused activities at age 0–6 years, and has currently become routine advice during well-child consultations (Toffol et al., 2011).

Ordinary well-child visits may therefore be a valid setting for also presenting parents with guidance on developmentally appropriate activities to foster children's emerging mathematical skills (Purpura et al., 2019). To the best of our knowledge, however, no systematic initiative has been taken to date to include guidance to home numeracy activities as a part of pediatric consultations to parents of preschool-aged children.

The present study

The primary aim of the current work was to investigate whether parents' involvement in a non-intensive intervention delivered by community pediatricians during scheduled well-child consultations at age 5 was associated with subsequent parents' engagement in shared mathematics-related activities at home, as well as with children's early numeracy development. To this end, the *Nati per Contare* (litt.: Born-to-Count) program was developed in cooperation between the local health authority of the district of XXXX, the Universities of YYYY and ZZZZ (blinded for review purposes), and an Italian professional association of pediatricians (Associazione Culturale Pediatri Romagna – ACPR). Community pediatricians involved in the Born-to-Count program were trained to provide parents with advice on the importance of early numerical competencies, and guidance on home mathematics-related activities that could be easily implemented in daily family routines (e.g., cooking activities, board games,

1 https://www.natiperleggere.it

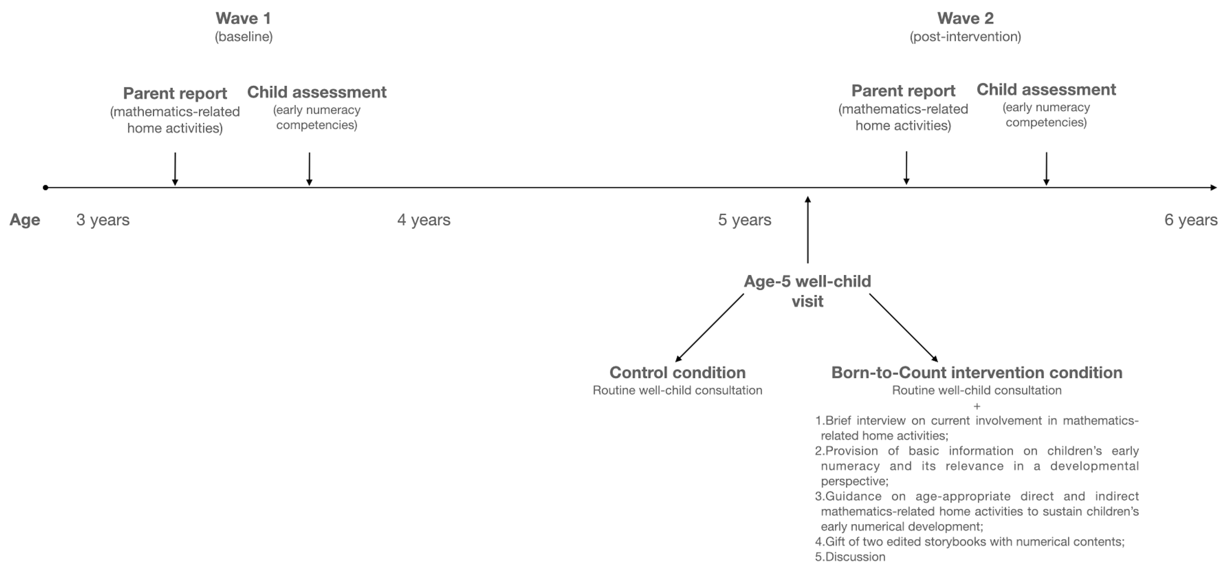

FIGURE 1
Timeline of data collection waves in the Born-to-Count study.

shared reading of storybooks with numerical contents). The primary expected outcome was a steeper increase in the provision of mathematics-related activities, as compared to a baseline assessment conducted during the first preschool year, at age 3, among parents who received the Born-to-Count intervention, relative to those in a business-as-usual control condition who did not receive any numeracy-related advice during well-child consultations. The secondary expected outcome was an improvement in children's performance on a standardized assessment of early numeracy from baseline to the end of the third preschool year. Feasibility and acceptability of the Born-to-Count intervention were also assessed.

Materials and methods

Participants and procedure

Participants were 204 parents of children (111 boys, 93 girls) attending to 11 public and private childcare centers. All the children were patients of 24 community pediatricians in the district of XXX, Italy, a local area that is characterized by generally favorable economic indicators (see: https://www.istat.it/storage/urbes2015/cesena.pdf). Attendance at scheduled well-child visits at 5 years in the district of XXX is 88% (Regione Emilia-Romagna, 2020).

Participants were part of a larger sample of parents and children involved in a multi-center longitudinal study on factors promoting early numerical development ($N = 256$) which was conducted in the district of XXX and in other districts in Northern Italy (see Authors, 2022, for details). Beyond focusing on early numerical development and parental provision of mathematics-related activities, the larger study also included measures that were not taken into consideration in the current research (e.g., parental provision of literacy-focused activities). Only participants resident in the district of XXX, where the Born-to-Count program was implemented, were recruited for the present study. Children's diagnosis of neurodevelopmental disorders and parents' being non-Italian speaking were criteria for exclusion.

Recruitment took place through childcare centers when children were attending the first preschool year. Parents who provided informed consent to take part in the study were asked to complete a questionnaire to report their mathematics-related practices and other relevant study variables when children were in their first preschool year (Wave 1; children's $M_{age} = 45.78$ months, $SD = 3.21$; range: 39–51 months). One-to-two months after scheduled attendance at the well-child visit at 5 years of age, parents were asked to complete the same questionnaire again (Wave 2). Parents choose whether to complete questionnaires in paper-and-pencil or in electronic format. The completion format was unrelated to the outcomes. Children's assessments were conducted at the onset of the Study (Wave 1), and then repeated when children were attending the third and last preschool year (Wave 2; $M_{age} = 67.75$ months, $SD = 3.17$; range: 62–73 months). Wave 2 data collection with children occurred on average 6 months after the scheduled 5-year-old well-child visit. The study timeline is reported in Figure 1. Both parents and children were invited to participate in data collections at Wave 2 regardless of their participation in Wave 1.

One hundred and seventy-two parents and 195 children took part in the study at Wave 1, and 174 parents and 190 children participated at Wave 2. One hundred and sixty-one children and 150 parents participated in the study at both waves. Most of both mothers ($n = 152$, 74.5%) and fathers ($n = 160$, 78.4%) were born in Italy; 21 mothers (11.8%) and 13 fathers (6.4%) were born in other countries (predominantly Europe and Northern Africa). Information regarding nationality was missing for 31 mothers (15.2%) and 31 fathers (15.2%). As regards education levels, 21 mothers (10.3%) and 43 fathers (21.1%) had a middle school diploma or lower, 64 mothers (31.4%) and 70 fathers (34.3%) had a high school education, 88 mothers (43.1%) and 55 fathers (27.0%) had a bachelor's degree or higher. Information regarding education levels was not provided for 31 mothers (15.2%) and 36 fathers (17.6%). Thus, most families were middle-class and both parents and children were born in Italy. As in most questionnaire studies, mothers responded to the questionnaire.

The study protocol was approved by Ethical Committee of the University of YYYY and by the Ethical Board of the Local Health Authority of WWWW.

Intervention

Assignment of participants to the Born-to-Count intervention versus a business-as-usual control condition was determined at the pediatrician level (i.e., cluster randomization). Specifically, all parents whose children were patients of a community pediatrician selected to deliver the Born-to-Count were allocated to the intervention condition, whereas parents of children in charge to all other pediatricians were included in the control condition. The decision to follow a cluster randomization procedure was intended to avoid treatment disparities among patients of the same clinician. A person from the Local Health Authority who was not involved in the study divided community pediatricians into two groups in order to have approximately the same number of children in each group. One of the two groups (which included seven pediatricians) was then randomly assigned to the Born-to-Count intervention condition. The other 17 pediatricians were assigned to the control condition. Pediatricians in the control condition conducted regular well-child visits according to the standard protocol adopted by the Local health Authority in XXXX and received no instruction with regard to the promotion of mathematics-related home activities.

Pediatricians in the intervention condition received a 3-h training session led by three of the authors (CT, FC, and GB) to illustrate the purpose, procedures, and materials in Born-to-Count program. The intervention was designed as a single session to be delivered by the pediatrician to the parents at the routine well-child visit in the 5th year of age of the child, right after having completed all the scheduled assessments (e.g., growth patterns, dental health, eating habits). In detail, the Born-to-Count intervention protocol was designed as follows:

1. First, pediatricians were invited to briefly interview parents on children's acquisition of emerging numeracy skills (e.g., "Did you notice whether your child uses fingers to count?") and their current involvement in mathematics-related activities in the home environment (e.g., "Do you do any activity with your child that involves using numbers? For example, playing dice or card games? Or counting and measuring ingredients when cooking?").
2. Then, pediatricians gave parents and discussed with them a printed booklet edited by the Local Health Authority. The booklet included:

a. basic information on children's numerical development from 0 to 5 years (e.g., the acquisition of the number-word sequence, or the cardinality principle) and its relevance in a developmental perspective;
b. guidance on age-appropriate mathematics-related practices to sustain children's early numerical development (e.g., involvement in daily activities that require measurement, counting, or doing simple sums);
c. suggestions on edited storybooks (e.g., *Inch by Inch* by Leo Lionni) that provide numeracy content (these were available at the local public library) and board games with developmentally-appropriate numerical content.

As guidance to shared home numeracy activities, the pediatricians were instructed to provide detailed examples of activities described in the above-mentioned booklet, pertaining to:

a. direct mathematics-related activities, such as drawing attention to numerical symbols in the child's environment (e.g., road signs, timetables), helping the child counting objects, and doing simple operations;
b. indirect mathematics-related activities, including playing board games, or doing measurements during cooking activities;
c. non-numerical activities that are related to numerical development, such as visuo-spatial activities (e.g., building blocks).

Finally, pediatricians gifted two storybooks with numerical contents to parents. Before concluding the well-child visit, pediatricians asked parents for any clarification or further information, if needed, and encouraged them to incorporate the mathematics-related activities into their daily home routines.

Measures

Outcomes

Mathematics-related activities

The frequency of parent-reported mathematics-related activities was assessed through 20 items drawn from a widely used home numeracy questionnaire by Skwarchuk et al. (2014). Parents were asked to report how frequently they engaged in a list of activities (e.g., "I help my child to recite numbers in order,"

TABLE 1 Raw scores of parent-reported frequency of mathematics-related home activities and children's early numeracy at Wave 1 (baseline) and Wave 2 (post-intervention).

	Wave 1 (baseline)		Wave 2 (post-intervention)	
	Mean	***SD***	**Mean**	***SD***
Mathematics-related activities				
We talk about time with clocks and calendars	2.49	1.474	2.89	1.408
I encourage my child to do math in his or her head	1.73	1.141	2.41	1.299
We sing counting songs (e.g., "Five Little Monkeys")	3.07	1.389	2.77	1,327
We play games that involve counting, adding or subtracting	2.12	1.301	2.79	1.187
We time how fast an activity can be completed	1.69	1.152	2.20	1.289
I help my child to recite numbers in order	3.49	1.287	3.41	1.263
We play board games or cards	2.65	1.243	3.09	1.231
I ask about quantities (e.g., how many spoons?)	3.34	1.278	3.59	1.238
I encourage collecting (e.g., cards, stamps, rocks)	1.67	1.105	2.02	1.329
I encourage use of fingers to indicate 'how many'	3.65	1.343	3.52	1.29
I help my child weigh, measure and compare quantities	2.18	1.257	2.40	1.166
I help my child learn simple sums (e.g., 2 + 2)	1.88	1.138	2.70	1.314
We discuss measurement terms (1/2 cup versus 1/4 cup)	1.90	0.882	2.28	0.933
My child adds and mixes what I measure	2.60	0.815	2.67	0.888
My child does most of the measuring, with some help	1.72	0.848	1.97	0.872
My child watches while I measure and stir ingredients	2.48	0.838	2.47	0.924
My child counts (with fingers, aloud) while we are cooking	1.89	0.885	2.2	0.93
My child weight the ingredients	1.56	0.747	1.97	0.935
My child divides or multiplies ingredients	1.12	0.378	1.23	0.540
My child compares quantities and says which ingredients are more present than others (notions "lesser than," "greater than")	1.75	0.874	1.98	0.955
My child can recognize different kinds of ingredients but with the same quantity (notion "as large as")	1.53	0.756	1.81	0.884
Children's early numeracy				
BAS-3	12.04	6.17	22.69	4.85

N = 204. BAS-3: British Ability Scales (Early Number Concepts sub-test). Range for parent-reported mathematics related activities: 1 (never) – 5 (almost daily). Range for BAS-3 scores at Wave 1: 0–28 (observed range: 0–26). Range for BAS-3 scores at Wave 2: 0–29 (observed range: 2–29). Higher BAS-3 scores indicate better performance.

"We play games that involve counting, adding, or subtracting," or "My child adds and stirs ingredients that I measure"; see details in Table 1). Response scale ranged from 1 (never) to 5 (almost daily).

Children's early numeracy

The Early Number Concepts sub-test from the British Ability Scales (BAS-3; Elliot and Smith, 2011) was used to assess different aspects of children's early numeracy (i.e., quantity understanding, number concepts, symbol-quantity mapping, counting, ordinality, cardinality, and simple arithmetic). One point is assigned for each correct answer, and testing terminates once a child produced five consecutive errors. Performance raw score is calculated as the sum of correct responses. The scale is validated for use with children between 3 and 7 years of age.

Feasibility and acceptability of intervention

Feasibility was assessed by collecting data from pediatricians and parents in the Born-to-Count intervention condition. Pediatricians in the Born-to-Count intervention group were individually interviewed to determine whether (a) the intervention was compatible with the timing of a regular well-child visit, and (b) parents reported positive or negative comments on the intervention. To evaluate acceptability, parents in the Born-to-Count intervention condition were asked to complete a supplementary section in the Wave 2 parents' questionnaire with 11 items regarding satisfaction and enjoyment with the pediatrician's advice (e.g., "The pediatrician's recommendations were easy to implement") and the contents of the Born-to-Count intervention booklet (e.g., "The Born-to-Count booklet was clearly written"), as well as the appropriateness of the received guidance for the child's age and needs (e.g., "Activities suggested in the Born-to-Count booklet were too easy for my child's age"). Response scale ranged from 1 (completely disagree) to 4 (completely agree).

Data analyses

The software program IBM SPSS 27 was used to carry out analyses. Descriptive statistics are expressed as frequencies for categorical data, and as mean scores, standard deviation (*SD*), range (i.e., minimum and maximum observed scores), skewness, and kurtosis for all continuous outcomes. Single-group *t*-tests against the scale mid-point were used to analyze parents' responses to items assessing feasibility and acceptability of the Born-to-Count intervention.

For the outcome measures, an intention-to-treat analytical approach was adopted, and linear mixed-effects (LME) models were used to assess change over time and group differences between participants in the Born-to-Count intervention and in the control condition for mathematics-related home activities and children's early numeracy. LME models offer several advantages over traditional analytical approaches to longitudinal data analysis in intervention trials, especially in presence of unbalanced designs (i.e., with unequal number of participants within each level of a grouping variable), incomplete data (e.g., with missing observations at one time point), and non-independence among observations (e.g., with multiple observations for each participant, or with participants nested within contexts; Westfall et al., 2014). An additional advantage of LME models is that they handle each observation at a time point as a unit of analysis (instead of each individual participant), thus allowing to account for variability not only across participants, but also across indicators of the study constructs (i.e., survey items) over time.

In detail, we estimated two random-intercept LME models with mathematics-related home practices and children's early numeracy, respectively, as the outcomes, and wave (within-participants: one and two), condition (between-participants: Born-to-Count intervention vs. control), and wave by condition interaction as the fixed factors. Two random intercept factors were also included in the LME models to account for participant-specific and pediatrician-specific variability in the outcome measures. In the case of the LME model on mathematics-related home practices, an additional random factor was included to account for item-specific variability. In presence of significant fixed interaction effects, post-hoc simple slope models were computed to detect specific trends over time in the outcome variable among participants in the Born-to-Count intervention and in the control condition, respectively, after accounting for participant-specific, pediatrician-specific, and item-specific random variability.

Results

Descriptive statistics for study variables are reported in Table 1. Preliminary analyses revealed that participants in the control vs. Born-to Count intervention conditions did not differ at baseline (Wave 1) on any demographic characteristics or study measures (details are reported in Supplementary Table A1).

Feasibility and acceptability of intervention

As regards feasibility, pediatricians in the intervention condition ($N = 7$) reported that the Born-to-Count intervention required on average 15 additional minutes relative to the usual duration of well-child visits at age 5. All the pediatricians also reported that the Born-to-Count intervention was fully compatible with the ordinary management of well-child visits. Five out of seven pediatricians reported that parents were apparently "very interested" in the contents of the Born-to-Count intervention, and two reported that parents were on average "quite interested."

As regards parents, 90% of participants in the Born-to-Count intervention condition reported having received specific information and advice on children's numerical development from the pediatrician. It is worth noting that 25% of parents in the control condition also reported having received advice on children's early numeracy, even though numerical development is not included in the protocol of routine well-child visit at age 5. In addition, 79.3% of parents in the intervention condition reported having read the Born-to-Count booklet after the well-child visit.

As regards acceptability, between 88.3% and 98.5% of parents in the Born-to-Count intervention condition reported positive or very positive evaluations of the advice from the pediatrician and the contents of the informative booklet (e.g., interesting, easy to understand, helpful). Between 7.7% and 9.7% of parents in the Born-to-Count intervention condition reported that the Born-to-Count guidance was slightly or too difficult to implement. At the same time, 23.9% of parents rated the proposed activities as slightly or definitely too easy for the age of the child. Overall, single-group *t*-tests against the scale mid-point revealed that all positively-worded items displayed average scores that were significantly above the scale mid-points (all $t_{(0)}s > 10.420$, all $ps < 0.001$), thus indicating a general appreciation of the pediatrician's advice in support of home mathematics-related activities. Similarly, all negatively worded items displayed average scores that were significantly below the scale mid-point (all $t_{(0)}s > 6.258$, all $ps < 0.001$), indicating that the pediatrician's advice and the suggested mathematics-related activities were mostly deemed as appropriate to the children's age and developmental needs. Details are reported in supplemental materials (Supplementary Table A2).

Outcomes

Mathematics-related activities

Results from the LME model for the parents' reports of mathematics-related activities are presented in Table 2.

Estimates for the fixed components of the model reveal that the main effect of wave was significant, thus indicating that the overall frequency of mathematics-related home activities increased significantly from Wave 1 to Wave 2. The main effect of condition was not significant. However, a significant interaction

TABLE 2 Estimates from Linear Mixed Effects (LME) models on parent-reported frequency of mathematics-related home activities and children's early numeracy.

	Mathematics-related home activities		Children's early numeracy	
	Estimate (*SE*)	**Value of *p***	**Estimate (*SE*)**	**Value of *p***
Fixed components				
Intercept	2.333 (0.143)	<0.001*	17.517 (0.422)	<0.001*
Wave	0.140 (0.011)	<0.001*	5.388 (0.237)	<0.001*
Condition	0.001 (0.037)	0.991	0.672 (0.422)	0.140
Wave * Condition	0.029 (0.013)	0.023*	0.123 (0.237)	0.605
Random components				
Participant	0.183		9.717	
Item	0.401		–	
Pediatrician	<0.001		0.894	
Residual	1.050		19.572	

$N = 204$. Estimates for random components represent variances (σ2). $*p < 0.05$.

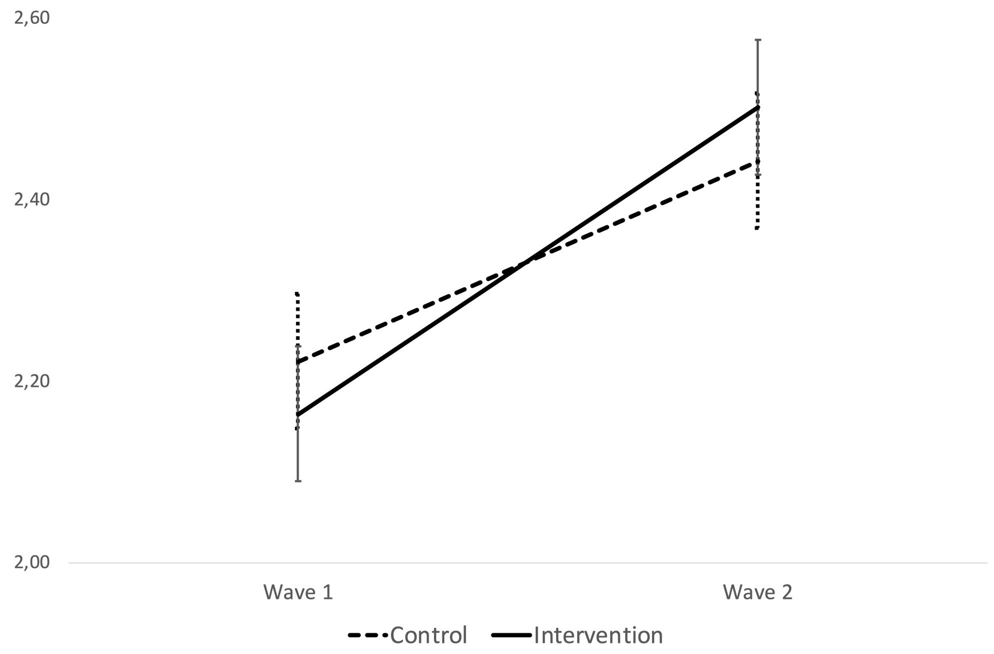

FIGURE 2
Trends in frequency of home mathematics-related activities from baseline to post-intervention for participants in the Born-to-Count intervention versus control condition. Error bars represent Standard Errors.

between condition and wave emerged ($\beta = 0.029$, $SE = 0.013$, $p = 0.023$), indicating – as predicted – that change in the frequency of reported mathematics-related activities from baseline to post-intervention assessment was different in size between participants in the intervention and those in the control condition. Estimated trends in frequency of mathematics-related activities over time are depicted in Figure 2.

As it is evident from Figure 2, the difference in point estimates for the frequency of mathematics-related home activities between participants in the control and in the intervention condition was not significant neither at Wave 1 ($M_{control} = 2.222$, $SE_{control} = 0.150$; $M_{intervention} = 2.164$, $SE_{intervention} = 0.148$; $F_{(1,197)} = 0.550$, $p = 0.459$) nor at Wave 2 ($M_{control} = 2.443$, $SE_{control} = 0.150$; $M_{intervention} = 2.502$, $SE_{intervention} = 0.147$; $F_{(1,195)} = 0.586$, $p = 0.446$). However, the slope representing the increase in the frequency of mathematics-related home activities between Wave 1 and Wave 2 was significantly steeper for participants exposed to the Born-to-Count intervention ($\beta = 0.169$, $SE = 0.17$, $p < 0.001$), as compared to participants in the control condition ($\beta = 0.111$, $SE = 0.19$, $p < 0.001$).

Estimates for the random part of the model reveal that variability across participants and variability across items represent approximately the 26% and the 11%, respectively, of the observed variability that is not accounted for by the fixed part of the model, whereas variability due to participants' nesting within pediatricians is close to zero.

Children's early numeracy

Results from the LME model for the analysis of children's early numeracy are presented in Table 2. A significant main effect of wave emerged, indicating that children's early numeracy improved from Wave 1 to Wave 2, as expected. In contrast, neither the main effect of condition nor the wave by condition fixed effects were significant, thus indicating that parents' involvement in the Born-to-Count intervention did not produce differential changes over time in children's early numeracy compared to the control condition.[2]

In the random part of the model, estimates reveal that variability across participants amounts to ~32% of the variability that is not accounted for by the model's predictors, whereas variability due to participants' nesting within pediatricians is close to zero (0.03%).

Discussion

The preschool years are a critical age period for the acquisition of foundational skills and prerequisites for subsequent children's mathematical development (LeFevre et al., 2010a; Watts et al., 2014). Parents' provision of shared mathematics-related activities in the home environment is associated with the growth of children's mathematical skills prior to formal schooling (Mutaf Yıldız et al., 2020). The goal of the present study was to examine whether a non-intensive intervention delivered by community pediatricians in the context of ordinary well-child visits would increase the frequency of mathematics-related activities at home and promote the growth of children's early numeracy over the preschool years. Specifically, pediatricians working in community health services were trained to deliver information to parents concerning the emergence and the importance of children's early numerical skills prior to formal schooling, and to provide guidance on developmentally-appropriate shared activities in the home environment that may sustain early numerical development. The contents and the format of the materials developed for the Born-to-Count intervention on mathematics-related home activities were modeled on an existing program used to promote shared literacy-focused activities in the home environment (i.e., the *Nati per Leggere* program; https://www.natiperleggere.it), which is currently a routine protocol of pediatric well-child visits in Italy.

Overall, community pediatricians involved in the study reported that the intervention was feasible and sustainable. Providing advice on numerical development and mathematics-related activities was deemed as highly compatible with the overall context of well-child consultations, in which guidance is routinely provided to parents over several other aspects of child development (e.g., nutrition, physical activity, dental health, early literacy). The Born-to-Count intervention was also deemed as highly acceptable by parents, who reported high levels of satisfaction and enjoyment with the guidance provided by the pediatricians, and generally rated the suggested mathematics-related activities as appropriate to their child's age and developmental needs. In sum, pediatricians' and parents' feedback suggests that routine well-child consultations may represent a valid setting for promoting activities to foster children's early mathematical skills (Mazzocco, 2016; Purpura et al., 2019).

Consistent with expectations, parents who received the Born-to-Count intervention reported an increased frequency of mathematics-related activities in the home environment at the post-intervention assessment – relative to baseline – to a greater extent than parents in the control condition, who received a business-as-usual well-child visit. These findings are consistent with those of other intervention studies (Starkey and Klein, 2000; Berkowitz et al., 2015; Niklas et al., 2016; Leyva et al., 2018). However, in most cases, previous studies used more intensive interventions (e.g., repeated encounters with parents over prolonged time periods). Intensive interventions may be more powerful, but they may also limit participation and feasibility, due to features such as self-selection of participants, effort required, and attrition over the course of the intervention. In contrast, the current research adds to the few existing studies showing that even non-intensive interventions that involve minimal engagement from families, can result in positive outcomes, and contribute to the inclusion of mathematics-related activities in the home environment. Moreover, the current intervention can be provided within the context of well-child visits that families would attend anyway. Accordingly, this intervention has no additional cost to the parents. In health systems in which access to primary care is universal and free-of-charge for the whole population, as in Italy (Corsello et al., 2016), well-child consultations administered by community pediatricians are a context in which sensitivity to the importance of children's numerical development, and its crucial impact later in life, can be promoted to all families.

Despite showing that the intervention was successful in influencing parents' reports of the frequency of mathematics-related home activities, the Born-to-Count intervention did not have an impact on the skills of children whose parents received

2 A supplemental analysis was also performed using Generalized Estimation Equation (GEE) in order to determine whether the intervention produced differential outcomes depending on baseline levels of parents' provision of mathematics-related activities or children's early numeracy skills at Wave 1. No interaction emerged between condition (control vs. Born-to-Count intervention) and baseline levels of the outcome variables (both *ps*>0.800).

guidance from pediatricians, relative to those who did not. There was indeed a substantial increase in early numeracy skills for all children between 3 and 5 years of age, but the increase was not significantly different for participants in the intervention condition compared to those in the control condition. In part, these findings confirm the difficulty of influencing children's competencies through parent-based training programs. Meta-analytic findings suggest that the size of positive effects of parent-based interventions that promote mathematics-related competencies in the preschool years are quite small (Cohen's $d = 0.18$; Cahoon et al., 2022).

In the present study, one potential explanation for the null effect of the Born-to-Count intervention on the children's early numeracy is the low intensity of the intervention, which consisted of about 15 min of discussion and delivery of informative materials within the context of a well-child visit. Whereas the low intensity of the intervention supports feasibility and sustainability, it may also limit the potential long-term impact of the intervention itself. Moreover, parental report of mathematics-related home activities occurred only 2–4 months before the assessment of children's' numeracy in the post-intervention phase. We speculate that changes in the parent-reported frequency of mathematics-related activities at home may require more time to reflect in benefits to children's early numeracy. Future research is needed that involves monitoring both parents' mathematics-related practices and children's early numeracy over a more prolonged time span.

Limitations and future directions

The present research is one of the few studies testing the impact of an intervention targeted to parents that was designed to promote mathematics-related activities in the home environment in the preschool years. Moreover, as far as we know, it is the very first study that relied on community pediatricians as a resource to promote the development of children's mathematical skills. Nevertheless, this study has several limitations. First, parents' mathematics-related home activities were indexed through a self-report measure. Although this measure has been widely used in many previous studies in the field (Skwarchuk et al., 2014), and is consistently related to standardized measures of children's numerical competencies (e.g., Napoli and Purpura, 2018; Purpura et al., 2020; Susperreguy et al., 2021), parents' reports may be biased by social desirability concerns. Although more time- and resource-consuming, future studies may benefit from integrating parent-reported measures with observation-based assessment of shared mathematics-related activities.

Second, only two measurement waves were included in the present study. The inclusion of repeated waves of assessment both at the pre- and at the post-intervention phase would allow a more fine-grained modeling of individual trajectories of change over time in the outcome measures and would also allow a considerable increase in statistical power (Toffalini et al., 2021). Moreover, the assessment of children's numeracy skills when children enter school and first encounter formal teaching of mathematics, would provide a stronger test of the persistence of the intervention outcomes. Similarly, delivering the intervention at earlier ages (e.g., in the first or second preschool year) may be important, as this would allow more time for parents to include mathematics-related practices in their home routine before children enter primary school. Longer-term follow up is also important considering the accumulating evidence of fade-out effects for numerous early childhood education programs (Abenavoli, 2019).

Third, the strength of the intervention may have been insufficient. It included several components, such as interviewing of parents concerning their current mathematics-related practices, information on children's early numerical development, guidance on diverse mathematics-related activities to be incorporated in family routines, and delivery of printed materials and storybooks with numerical contents. Although all these elements are associated with positive outcomes in previous intervention studies in the field, the design of the current study does not allow us to disentangle which of these elements affected parents' provision of mathematics-related activities. Because routine well-child visits have time constraints, and parents are simultaneously provided with information regarding several aspects of the child health and development at these visits, focusing attention on only a few critical and most impactful elements may help increase the effectiveness of pediatricians' guidance.

Finally, the frequency of related but non-numerical home activities was not assessed. Parents in the Born-to-Count intervention conditions were also encouraged to engage in practices that may indirectly foster children's numeracy skills, such as visuo-spatial activities and shared reading of storybooks with numerical content. Furthermore, it may be important in future studies to also monitor the possible impact of interventions to promote mathematics-related activities not only on children's numeracy skills, but also on their emerging self-concept in mathematics, or on emotions toward mathematics (e.g., math anxiety).

Conclusion

In conclusion, we found that a non-intensive intervention implemented within the context of routine well-child visits at age 5 was associated with a larger increase in the frequency of parent-reported mathematics-related activities in the home environment, compared to parents who received an ordinary well-child consultation. These findings add to the limited body of research on interventions to promote mathematics-related activities in the home environment in the preschool years and identify, for the first time, community pediatricians and the public primary health care services as an important resource to support parents' engagement in children's early mathematical development.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Bioethics Committee of the University of Bologna, Bologna, Italy, and Ethics Committee IRST and Area Vasta Romagna, Meldola (FC), Italy. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

CT wrote the initial draft of the manuscript and ran the statistical analyses. J-AL, MP, CV, and VG contributed to different versions of the manuscript and were involved in the revision and interpretation of the results. VG contributed to the data collection process and the raw data preparation. CT, J-AL, MP, AB, FC, and GB contributed to the design of the study and the "Born-to-Count" intervention protocol. AB, FC, and GB obtained funding to carry out the study. All authors agreed to all aspects of the study, and approved the final version of the manuscript.

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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

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.1051822/full#supplementary-material

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Cross-lagged relationship between home numeracy practices and early mathematical skills among Chinese young children

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The present study examined the cross-lagged relationship between home numeracy practices (e.g., formal teaching, number games, and number application) and early mathematical skills (basic number processing, and arithmetic skills) among Chinese young children. A total of 155 children (82 boys; mean age=67.49months, SD=3.58months) were assessed with basic number processing and arithmetic skills at three timepoints during the kindergarten year, and their parents reported the frequency of parent–child numeracy activities. Main results from random-intercept cross-lagged panel models showed that, at the within-family level, earlier basic teaching activities uniquely predicted subsequent basic number processing, while both advanced teaching activities and number game activities at earlier timepoints predicted the following arithmetic skills. These results indicated a unidirectional effect from home numeracy practices on early mathematical skills during the early years.

KEYWORDS

home numeracy practices, early mathematical skills, cross-lagged, basic number processing, arithmetic skills

Introduction

The past decade of studies showed that children's learning experience with parents on numeracy, i.e., home numeracy practices, were associated with their mathematics skills (e.g., Huntsinger et al., 2000; Lefevre et al., 2002, 2009, 2010; Kleemans et al., 2012; Manolitsis et al., 2013; Niklas and Schneider, 2014; Skwarchuk et al., 2014; Deng et al., 2015; Huang et al., 2017; Susperreguy et al., 2020; Wei et al., 2020). Most of these studies examined the concurrent relations between home numeracy practices and mathematics skills, and the researchers assumed that home numeracy practices unidirectionally predicted mathematical skills. However, far less was known about the cross-lagged relationship between home numeracy practices and early mathematical skills. Examining their mutual relations may help understand not only the specific role of parent–child numeracy activities in children's early mathematics learning, but also the influence of children's mathematics performance on parental involvement in numeracy activities. Thus, the present study aimed to examine the cross-lagged relationship between different aspects of home numeracy practices (formal teaching, number games, and number application) and early mathematical skills (basic number processing, arithmetic skills) during the kindergarten year.

Previous studies showed that parents may involve in a wide range of mathematics-related activities (Lefevre et al., 2002; Deng et al., 2015), such as teaching their child number knowledge directly, playing number games with their child, and using the number in everyday life. In several studies, home numeracy practices are typically composed of formal and informal numeracy activities based on whether parents use an explicit or implicit way (e.g., Lefevre et al., 2010; Skwarchuk et al., 2014; Deng et al., 2015). In formal numeracy activities, parents directly provide instructions on number knowledge and arithmetic procedure. While in informal numeracy activities, parents engage their children in games related to numbers (such as board games with dice) or talking about numbers in everyday life (such as prices during shopping).

The relationship between home numeracy practices and mathematical skills has been well established in the past decade (e.g., Lefevre et al., 2002, 2010; Silinskas et al., 2010, 2020; Kleemans et al., 2012; Niklas and Schneider, 2014; Skwarchuk et al., 2014; Deng et al., 2015; Huang et al., 2017; Mutaf-Yıldız et al., 2020, for a review; Wei et al., 2020). A recent meta-analysis study by Daucourt et al. (2021) indicated an average correlation of 0.13 between home mathematics environment and children's mathematics. Furthermore, their results showed that the relation between home numeracy practices and mathematical skills during the early year was much higher than that during formal schooling.

In the review of Mutaf Yıldız et al. (2018), most studies with young children examined mathematic skills with comprehensive tests on a group of numeracy knowledge and arithmetic skills, while far fewer studies examined how two types of home numeracy practices were related to specific mathematics skills (e.g., basic number processing, arithmetic skills). Results of these studies (Mutaf Yıldız et al., 2018; Vasilyeva et al., 2018; Susperreguy et al., 2020) showed that numeracy activities were differently related to basic number processing and arithmetic skills. More specifically, both formal and informal numeracy practices were uniquely related to arithmetic skills in most of these studies (e.g., LeFevre et al., 2009; Dearing et al., 2012; Huang et al., 2017; Mutaf Yıldız et al., 2018, for exception; Vasilyeva et al., 2018; Susperreguy et al., 2020), while children's number processing was explained by formal numeracy activities in one study (Susperreguy et al., 2020) but informal numeracy activities in another (Vasilyeva et al., 2018). For example, Susperreguy et al. (2020) found formal numeracy activities (including manipulation of digits or quantities) in prekindergarten years uniquely predicted number processing (non-symbolic and symbolic comparison) 1 year later, while both formal numeracy activities and shared-number games play uniquely predicted arithmetic skills 1 year later.

When explaining their relationship, most researchers (e.g., Skwarchuk et al., 2014; Susperreguy et al., 2020), from the sociocultural learning theory by Vygotsky (1978), claimed that children develop their early mathematical skills through the interactions during parent–child numeracy activities. However, children's mathematical skills may also have influence on parents' activities. According to Rutter (1997), children's characteristics and behaviors may elicit parents' particular responses. To date, three longitudinal studies (e.g., Silinskas et al., 2010, 2020; Deng et al., 2015) found that primary students' earlier performance on mathematics may also predict later home numeracy practices, but negatively. Deng et al. (2015) argued that parents of primary students would give more frequent numeracy practices when they learned about children's poor performance in school from teachers (e.g., the test reports), which, in one recent study by Silinskas et al. (2020), was referred to be *responsive home numeracy* to children's mathematics performance.

Therefore, not only the effects of home numeracy practices on mathematics but also the reverse effects should be examined in longitudinal studies. However, to our knowledge, only three studies (Silinskas et al., 2010, 2020; Deng et al., 2015) had examined their bidirectional relationships, and all three studies examined primary students. Parents of primary students may learn their children's mathematics performance through homework and the feedback from school (e.g., test reports), while parents of kindergarten children may have less ways to know children's mathematics skills due to no test reports and much less homework in kindergarten (Pressman et al., 2015). Therefore, it is unknown whether young children's early mathematical skills predicted future home numeracy practices.

In addition, many previous studies were conducted with western children, and far less was known with Chinese children. Several studies revealed that Chinese children showed better mathematics skills or numerical cognition than their western counterparts as early as preschool years (e.g., Siegler and Mu, 2008; Rodic et al., 2015), which may be partly attributed to family factors (Rodic et al., 2015). Compared with parents in western countries, Chinese parents place high expectations for their children's school achievement, especially for mathematical achievement (Wang, 2004; Luo et al., 2013). In addition, Chinese parents of third-year kindergarten children start to rank academic skills as the most important area among children's developmental outcomes (Chan, 2012; Lau, 2014), and may increase the frequency of academic activities during children's transition to primary school. A handful of studies on Chinese young children showed the relationship between parent–child numeracy activities and early mathematical skills (Huang et al., 2017; Liu et al., 2019; Zhang et al., 2020). Most of them are concurrent design, and only one study (Zhang et al., 2020) showed that number application activities at the beginning of kindergarten predicted the increase in mathematics skills during the kindergarten year. However, to date, no studies examined how earlier early mathematical skills predicted the later home numeracy practices among Chinese young children.

The present study

The aim of this study is to examine the mutual relationship between home numeracy practices (informal and formal numeracy activities) and early mathematics skills (number processing and arithmetic skills) among a group of Chinese young children. Random-interception cross-lagged panel modeling (RI-CLPM; Hamaker et al., 2015) is performed to examine their cross-lagged relationship. Compared with the traditional cross-lagged panel modeling, RI-CLPM examined the cross-lagged relationship between the within-personal individual difference of variables controlling for the between-personal individual difference (Hamaker et al., 2015). Since previous studies had not examined the effects of children's mathematics skills on the home numeracy during the early years, we can only expect that the home numeracy at earlier time points may predict subsequent number processing and arithmetic skills based on the findings of previous studies (e.g., Vasilyeva et al., 2018; Susperreguy et al., 2020).

Materials and methods

Participants

A total of 155 Chinese children (82 boys, 73 girls; mean age = 67.49 months, SD = 3.58 months, range = 56–74 months) were recruited from one urban public kindergarten and two suburb public kindergartens in Shanghai, China (letters of information were initially sent to the parents of about 180 children). All three kindergartens are rated as level-one by the quality rating system at the city level.[1] All children were attending the third year of kindergarten, and none were diagnosed with intellectual, sensory, or behavioral disorders. A total of 13 children withdrew from the study at the second or third wave because of their illness or moving to other kindergartens. The data were missing completely at random (MCAR) according to the results of Little's MCAR test ($\chi^2 = 77.2$, $df = 76$, $p = 0.44$). Across three timepoints, about 60–70% of the questionnaires were completed by mothers, 30–40% by fathers, and less than 5% by grandparents. Most parents had three-year college studies or four-year university studies (63% fathers, 68% mothers), some of the parents had graduate studies (21% fathers, 14% mothers), and the remaining had high school studies or vocational school studies (8% fathers, 11% mothers), or primary or junior high school studies (8% fathers, 7% mothers).

1 Kindergartens in Shanghai are qualified into five levels, i.e., city-level demonstrative, district-level demonstrative, level-one, level-two, and level-three, and more than half are rated as level-one.

Materials

Home numeracy practices

Parents were asked to report how frequently they engaged in 13 numeracy-related activities (based on the original questionnaire of LeFevre et al., 2009; Huang et al., 2017) with their children in the recent month (e.g., 'In the last month, how often did you work with your child on printing numbers?') using a 5-point Likert scale (0 = never to 4 = almost daily). According to the structures in previous studies (e.g., LeFevre et al., 2009; Huang et al., 2017), three-factor models were constructed firstly: formal teaching was assessed with seven items ('teaching counting', 'teaching skip counting', 'comparing size or magnitude', 'teaching compare or counting on computer', 'identifying numbers', 'printing numbers', and 'teaching simple arithmetic'), number games three items ('playing card games', 'playing board games with dice or spinner', and 'playing computer games involving mathematics'), and number application three items ('being timed', 'talking about money', and 'talking about stops on bus or subway').

However, the three-factor model did not fit the data well, and the modification indices suggested that the residual errors of three items, 'identifying numbers', 'printing numbers', and 'teaching simple arithmetic', should be correlated. Therefore, the formal teaching variable was divided into two latent variables. Since three items were related to written numbers, the latent variable was named advanced teaching, and the left four items were named basic teaching. The modified four-factor model has acceptable or excellent fits to the data of three waves (T1: χ^2 (59) = 86.380, $p = 0.012$, CFI = 0.953, TLI = 0.938, RMSEA = 0.054; T2: χ^2 (59) = 102.364, $p = 0.000$, CFI = 0.929, TLI = 0.907, RMSEA = 0.071; T3: $\chi2$ (59) = 77.560, $p = 0.053$, CFI = 0.962, TLI = 0.949, RMSEA = 0.048). Cronbach alpha for the four subscales at three timepoints ranged from 0.69 to 0.81.

Early mathematical skills

Digit Comparison from Nosworthy et al. (2013) was used to assess *Arabic number processing*. Children were presented with a booklet of 56 digit pairs (ranging from 1 to 9; e.g., 4|5, 6|8) and were asked to cross off the larger one as fast as possible in 1 min. The score in each task was the total corrects divided by the time. The Split-reliability in this study was 0.79, 0.74, and 0.84, respectively.

Numerical Operations from Wechsler Individual Achievement Test (WIAT-III; Wechsler, 2009) was used to assess *arithmetic skills*. A total of 60 items on addition, subtraction, multiplication, division, and more advanced arithmetic were arranged in increasing difficulty, and children were asked to write the answers to these items one by one. The test was discontinued after four consecutive errors. The score was the number of correct answers. Cronbach's alpha reliability coefficient at three timepoints in this study was 0.86, 0.91, and 0.89, respectively.

Covariates

Children's executive functions

Behavior Rating Inventory of Executive Function-Preschool version (BRIEF-P; Gioia et al., 2000) was used to assess children's executive functions. In total 63 items on a three-point scale (1 = Never, 2 = Sometimes, and 3 = Often) assessed children's difficulties in daily activities related to five components (inhibition, shift, emotional control, working memory, and plan/organize) of executive functions. The average score of all items, i.e., global executive composite score, was used. The Cronbach's α reliability coefficient was 0.89 in this study.

Parent's education levels

Parents were asked to report on their highest attained education on a 4-point scale ranging from 1 = finished elementary or secondary school to 4 = completed master's or doctoral studies. The average of mother's and father's education scores was used.

Procedure

Parental permission and ethical approval from the affiliation of the authors was obtained before testing. The participants were assessed three times every 4 months approximately, in November/October (T1, the beginning of the school year), February/March (T2), and May/June (T3). The parents completed the questionnaire including items on home numeracy practices, parents' educational levels, and children's executive functions, and the children were individually assessed in a quiet room at school by trained graduate students.

Statistical analyses

RI-CLPM (Hamaker et al., 2015) was performed to examine the cross-lagged relationship between home numeracy practices and early mathematical skills. Separate models were constructed for formal numeracy practices (basic teaching activities, advanced teaching activities) and informal numeracy practices (number games, number application). In both models, children's age, gender (0 = boy, 1 = girl), executive functions, parents' education levels, and kindergarten (0 = urban, 1 = suburb) were added as covariates predicting the intercepts of home numeracy practices and early mathematical skills (Mulder and Hamaker, 2021). Both autoregressive and cross-lagged path estimates (e.g., basic teaching at T1 to Digit Comparison at T2, and basic teaching at T2 to Digit Comparison at T3) were constrained to be equal for each of home numeracy practices, Digit Comparison, and Numerical Operation. The constrained model was then compared to the nested model in which both autoregressive and cross-lagged parameters were freely estimated, and the more parsimonious model (i.e., the constrained model) would be used if the difference (chi-squared test) was non-significant (Bentler and Satorra, 2010). The RI-CLPM analysis was performed using the 'lavaan' package (Rosseel, 2012) for R software, and missing data were handled using Full Information Maximum Likelihood (FIML).

Results

Preliminary data analyses

Table 1 presents descriptive statistics (mean, standardized deviation, skewness, and kurtosis) for the measures of home numeracy practices and mathematics skills along with their Pearson correlations controlling for the covariates. According to the correlation matrix in Table 1, weak to moderate associates were found between four types of home numeracy activities and two early mathematical skills across three timepoints (*r*s ranged from −0.04 to 0.43). More specifically, formal teaching activities (basic and advanced teaching) weakly correlated with concurrent or later early mathematical skills (*r*s ranged from −0.04 to 0.28), and weak to moderate correlations were found between informal activities (number games and number application) and concurrent or later early mathematical skills (*r*s ranged from 0.11 to 0.43). Furthermore, earlier mathematics skills weakly correlated with later home numeracy activities (*r*s ranged from 0.02 to 0.27).

Results of random-interception cross-lagged panel modeling

The results of RI-CLPM were presented in Figures 1, 2, in which the intercepts and the covariates along with the non-significant paths were removed to simplify the models. Figure 1 showed the results for within-family relations among formal numeracy activities and mathematics skills. Insignificant difference was found between the constrained and free-estimated models ($\Delta\chi^2 = 22.66$, $\Delta df = 16$, $p = 0.12$), and thus results of the constrained model were reported. The constrained model fitted the data well ($\chi^2 = 79.87$, df = 62, $p = 0.06$, CFI = 0.98, TLI = 0.96, RMSEA = 0.05). The estimates of the autoregressive parameters showed within-family associations over time for advanced teaching activities and Digit Comparison but not for basic teaching activities or Numerical Operation. It should be noted that the autoregressive effect in RI-CLPM (referred as carry-over effect in Hamaker et al., 2015) is different from that in traditional CLPM, since the rank-order stability of each variable across times in RI-CLPM is captured by the intercept of the variable (Hamaker et al., 2015). The estimates of the cross-lagged parameters showed that basic teaching activities significantly and positively predicted change in Digit Comparison, which in RI-CLPM implied that one child whose parents have more frequent basic teaching activities relative to their expected score (the means of the frequency of basic teaching activities across three timepoints), is likely to have higher performance on Digit Comparison relative to the child's

TABLE 1 Descriptive statistics for the measures of home numeracy and mathematics along with their correlations (controlling for the covariates).

Variable	M ± SD	Skew.	Kurt.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. T1_BA	2.88 ± 0.92	−0.12	−0.72																	
2. T1_AA	3.59 ± 0.94	−0.39	−0.71	0.59**																
3. T1_NG	2.04 ± 0.90	0.92	0.37	0.24**	0.28**															
4. T1_NA	2.80 ± 0.84	0.16	−0.70	0.36**	0.34**	0.31**														
5. T1_DC	0.41 ± 0.09	0.04	−0.48	0.11	0.08	0.18*	0.19*													
6. T1_NO	15.14 ± 4.47	−0.73	1.28	0.23**	0.18	0.22*	0.18*	0.41**												
7. T2_BA	2.92 ± 0.96	0.20	−0.96	0.43**	0.39**	0.23**	0.45**	0.08	0.22*											
8. T2_AA	3.44 ± 1.08	−0.37	−0.66	0.31**	0.48**	0.32**	0.31**	0.14	0.21*	0.56**										
9. T2_NG	2.14 ± 0.84	0.74	−0.01	0.13	0.14	0.52**	0.29**	0.27**	0.26**	0.42**	0.32**									
10. T2_NA	2.82 ± 0.81	−0.12	−0.58	0.29**	0.29**	0.35**	0.40**	0.10	0.22**	0.52**	0.53**	0.40**								
11. T2_DC	0.46 ± 0.12	0.11	−0.21	0.19*	0.16*	0.30**	0.20*	0.70**	0.45**	0.11	0.18*	0.36**	0.12							
12. T2_NO	16.59 ± 4.25	0.04	1.78	0.23*	0.28**	0.43**	0.24**	0.44**	0.60**	0.17	0.20*	0.39**	0.24**	0.42**						
13. T3_BA	2.88 ± 0.89	−0.20	−0.82	0.40**	0.32**	0.11	0.41**	0.06	0.10	0.50**	0.38**	0.25**	0.37**	0.14	0.02					
14. T3_AA	3.49 ± 1.02	−0.27	−0.60	0.32**	0.28**	0.14	0.27**	0.15	0.05	0.47**	0.49**	0.18*	0.33**	0.14	0.02	0.57**				
15. T3_NG	2.26 ± 0.80	0.37	−0.83	0.22**	0.22**	0.38**	0.31**	0.12	0.10	0.29**	0.28**	0.54**	0.29**	0.16	0.18	0.32**	0.31**			
16. T3_NA	2.91 ± 0.80	−0.01	−0.34	0.28**	0.15	0.23*	0.43**	0.11	0.20*	0.43**	0.32**	0.26**	0.47**	0.12	0.09	0.57**	0.45**	0.42**		
17. T3_DC	0.52 ± 0.13	0.42	−0.11	0.09	0.13	0.21*	0.28**	0.57**	0.37**	0.19*	0.27**	0.23**	0.23**	0.66**	0.30**	0.22*	0.19*	0.11	0.21*	
18. T3_NO	17.96 ± 3.80	0.34	0.75	0.26**	0.18	0.34**	0.12	0.44**	0.64**	0.10	0.14	0.33**	0.23**	0.44**	0.77**	−0.03	−0.04	0.13	0.19*	0.25**

M, mean; SD, standard deviation; BA, basic teaching activities; AA, advanced teaching activities; NG, number games; NA, number application; DC, digit comparison; NO, numerical operation; covariates: gender (0, boy; 1, girl), children's age, parents' education levels, kindergarten (0, urban; 1, suburb).

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

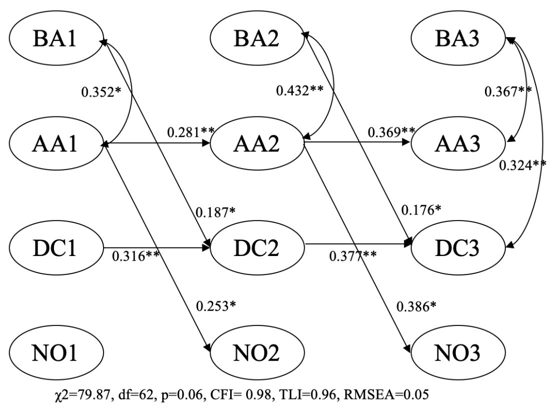

FIGURE 1
BA, basic teaching activities; AA, advanced teaching activities; DC, digit comparison; NO, numerical operation; children's age, gender, executive functions and parents' education were covariates predicting the intercepts of BA, AA, DC, and NO. *$p < 0.05$, **$p < 0.01$.

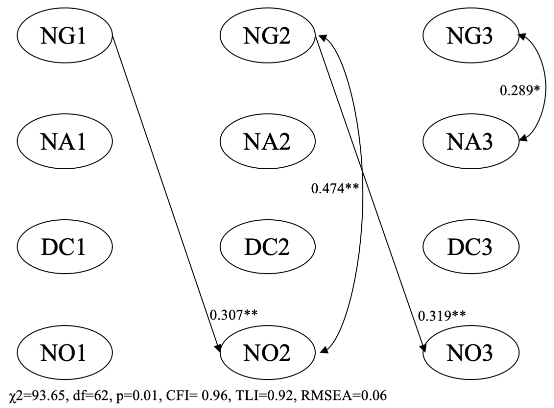

FIGURE 2
NG, number games activities; NA, number application activities; DC, digit comparison; NO, numerical operation; children's age, gender, executive functions and parents' education were covariates predicting the intercepts of NG, NA, DC, and NO. *$p < 0.05$, **$p < 0.01$.

expected score at the next time point as well. The results also showed advanced teaching activities predicted change in Numerical Operation.

Figure 2 showed the results for within-family relations among informal numeracy activities and mathematics skills. Insignificant difference was also found between the constrained and free-estimated models ($\Delta\chi^2 = 19.90$, $\Delta df = 16$, $p = 0.22$), and thus results of the constrained model were reported. The constrained model also fitted the data well ($\chi^2 = 93.65$, $df = 62$, $p = 0.01$, $CFI = 0.96$, $TLI = 0.92$, $RMSEA = 0.06$). The estimates of the cross-lagged parameters showed that number game activities significantly and positively predicted change in Numerical Operation.

Discussion

This study aimed to examine the cross-lagged relationship between home numeracy practices and early mathematical skills during the kindergarten year in young Chinese children. The results showed that earlier basic teaching activities positively and significantly predicted the following number processing, and earlier advanced teaching activities along with earlier number games activities predicted subsequent arithmetic skills.

The different prediction power of basic and advanced teaching activities in early mathematic skills echoed the argument of Mutaf Yıldız et al., 2018. However, Mutaf Yıldız et al., 2018, in their review, claimed that advanced teaching activities instead of basic teaching activities predicted mathematics skills among four-to six-year-old children since they already had basic number knowledge. In comparison, earlier basic teaching activities uniquely predicted subsequent number processing in our study. The reason may be that number processing in our study assesses the efficiency of processing Arabic numbers instead of Arabic number knowledge, and children may also improve their number processing efficiency with repeated exposure to the magnitude in basic teaching activities.

Interestingly, number games in our study uniquely predicted arithmetic skills, which was in line with the findings of previous studies (Siegler and Ramani, 2009; Cheung and McBride, 2016). For example, Siegler and Ramani (2009) found that playing board games promoted low-income children's performance on mathematics tasks (e.g., number identification, magnitude comparison, arithmetic). The study by Cheung and McBride (2016) showed that Chinese parents frequently used counting and addition in the number board game to demonstrate to their children, and thus may help children understand the combination of numbers.

Generally, the main results showed that earlier home numeracy practices unidirectionally predicted subsequent early mathematics skills, and did not replicate the effects of children's mathematics on home numeracy practices in previous studies on primary students (e.g., Silinskas et al., 2010, 2020; Deng et al., 2015). Our results thus did not support the responsive model of home numeracy practices (Silinskas et al., 2020) during the early years. Considering Chinese parents' high expectations for children's academic performance (Luo et al., 2013), the reason cannot be that parents are not sensitive to their children's mathematics skills. One possible reason may be that parents would get less explicit reports of children's mathematics from the kindergarten teachers, and their perceptions of children's mathematics skills may be imprecise. Parents of primary students can learn about the mathematics performance of their children through report cards or homework (Núñez et al., 2017), and thus may provide more frequent numeracy activities to facilitate children's mathematics learning. However, these explicit feedbacks are typically unavailable during the kindergarten year, and thus parents' perception of young children's actual mathematics skills may be imprecise. Some studies compared the mathematics skills reported by parents and the objective performance of children on early mathematics tests, and found their correlation was very low (e.g., Sonnenschein et al., 2014). Moreover, it could be worse under the low frequency of family-kindergarten communication (Rimm-Kaufman and Pianta, 1999). As a result, parents may misestimate their children's mathematics performance (Pezdek et al., 2002), and thus may not provide appropriate numeracy activities scaffolding children's early mathematics learning.

Some limitations should be mentioned. First, the frequency of home numeracy practices was reported by parents in this study, and thus the results may be biased by parents' social desirability (Elliott and Bachman, 2018). Further studies may use more objective measurements such as direct observation or activity checklist. Second, children in our study attended the third year of kindergarten (5–6 years old), and thus the findings may not be generalized to younger preschool children (2–4 years old). Finally, the sample size of this study was relatively small for running RI-CLPM analysis despite the well-fitting results, and future studies may recruit and examine more participants.

Despite these limitations, the strength of this study is using a three-wave longitudinal study examining the bidirectional relationship between home numeracy practices and children's early mathematics skills. The first implication is that parents may provide both formal and informal numeracy activities to promote children's early mathematics development, considering the predictive power of both types of home numeracy practices. The second implication is that parents may observe and monitor their children's mathematics progress through more reliable approaches, such as collaborating with kindergarten teachers.

Data availability statement

The raw data and the R scripts supporting the conclusions of this article are available from the first author, WW (wwei@shnu.edu.cn), upon reasonable request.

Ethics statement

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

Author contributions

WW and YL: research design. WW, Q-YW, and QL: data collection. WW, Q-YW, and YL: data analysis. 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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Parents' understanding of early writing development and ways to promote it: Relations with their own children's early writing

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The study examined how parents' understanding of early writing development was reflected in how they analyzed anonymous preschool children's writings and the support they offered to promote these children's writing. It also assessed how this general knowledge related to their own children's early writing development. The participants were 274 parents and one of their children (M = 5.4 years old). During home visits, the parents were shown vignettes with three writing samples of invitations to a party written by anonymous 5½-6-year-old preschoolers. The sample represented initial, intermediate, and advanced early writing levels. The parents were asked to relate to each of these vignettes and write what the child who wrote the invitation knows about writing and how they would recommend promoting the child. Additionally, the participating parents' children's early writing was assessed. We studied the parents' references to the following literacy aspects: Letters, orthography (e.g., final letters, vowel letters), phonology, and the writing system (e.g., the direction of writing, the separation between words) when relating to the vignettes and when recommending ways to support the children's writing development. The study's analyses revealed that parents distinguished between the writing levels of these anonymous children and suggested providing writing support recommendations in line with the various levels. Parents mainly referred to the letters when describing and suggesting support for the initial writing level. They referred more to the writing system when giving their opinion and suggesting support for the writing at an advanced level. The more parents referred to different aspects of literacy when analyzing the writing vignettes, the more aspects of writing support they suggested in their writing support recommendations. Parents who related to more literacy aspects in their writing support recommendations to anonymous children had children with higher writing levels. The study indicates that parents' general knowledge and understanding of literacy development has a role in fostering their own children's literacy skills.

KEYWORDS
parents' perceptions, parents' early literacy knowledge, early writing, writing support, understanding of the writing system, writing mediation, early literacy

1. Introduction

As a creation of culture, a writing system is passed on from generation to generation (Olson, 1984). Writing of preschool children before they formally learn to read and write represents their understanding of the writing system and is a good predictor of future literacy achievements (e.g., National Early Literacy Panel, 2008; Kessler et al., 2013; Kim et al., 2015). The overarching framework of our study is that writing development, like development in general, is embedded in the socio-cultural context, in which the child's home generates the closest and most meaningful system to the child's development. This line of thinking is associated with the socio-cultural school of Vygotsky (1978), neo-Vygotskians like Rogoff (1990), cultural psychologists like Bruner (1996), and contextual ecological models of development like that of Bronfenbrenner (1979). Vygotskian theory encourages thinking about children's development in light of their experiences and the meaningful support they get from others (Winsler, 2003). At home, parents' support can promote children's development within their Zone of Proximal Development (ZPD). Adequate support helps the child independently complete tasks previously completed with the adult's help (Vygotsky, 1978).

Indeed, parents play a key role in the development of their children's early literacy (Lonigan and Shanahan, 2009). One way that they do so is by engaging in writing activities with their children (e.g., Neumann et al., 2009; Puranik and Lonigan, 2011). The frequency of these activities and the nature of their writing support are meaningful to their children's literacy development (e.g., Aram et al., 2013; Skibbe et al., 2013; Inoue et al., 2018; Puranik et al., 2018). To be able to give a child meaningful support, adults must be aware of the children's ZPD – the distance between what the child can do independently and what s/he can do with assistance, as well as possible ways to join the child's knowledge and scaffold within the specific realm of development (Winsler, 2003). Yet, little is known about parents' knowledge and understanding of preschoolers' writing development and of the possible importance of this knowledge.

This study aimed to begin filling this gap by exploring how parents understand writing development, as reflected in how they relate to anonymous preschoolers' writing vignettes and the scaffolding they offer to promote these children. It also examined how parents' general writing development knowledge relates to their own children's writing skills. The study's results may help in planning effective guidance to parents, focusing on writing activities and appropriate writing support.

1.1. Emergent literacy and early writing

Children's emergent literacy skills are chief predictors of their later academic success (Bossaert et al., 2011; Costa et al., 2013). Emergent literacy refers to children's knowledge regarding spoken and written language prior to formal schooling. It includes knowledge and skills that are precursors to conventional forms of reading and writing. Researchers agree that the major components that comprise emergent literacy are oral language skills, phonological awareness, print awareness, and early writing (Whitehurst and Lonigan, 1998).

Preschoolers are interested in writing using different tools (pencils, crayons, or digital tools) and attempt to write before they understand that written symbols represent sounds and create words that transmit messages (e.g., Neumann et al., 2009; Zhang and Quinn, 2020). Knowing how to write (beyond one's own name) shows increased knowledge about the writing system (Puranik and Lonigan, 2011). Indeed, in alphabetic languages, a young child's writing level provides evidence of their understanding of the alphabet system (Ritchey, 2008) and relates to other early literacy skills as well as literacy achievements in school (e.g., Caravolas et al., 2001; Mäki et al., 2001; National Early Literacy Panel, 2008; Kessler et al., 2013; Kim et al., 2015).

Studies show that children's writing unfolds in a fairly predictable pattern. They first produce marks that capture the general features of writing, such as segmentation into units and linearity. Next, the marks that children use have the shapes of letters in their writing system, in random order, and are unrelated to the sounds of the target words (invented spelling). They subsequently refine their written output using language-specific features. When children begin to understand the written code, they start to represent the sounds within words with phonetically relevant letters, not necessarily the right spelling. Writing continues to progress and includes both correct phonological spelling and invented spelling until the children become fully phonological spellers (e.g., Levin et al., 1996; Bowman and Treiman, 2002; Levin and Bus, 2003; Tolchinsky, 2008; Puranik and Lonigan, 2011).

To portray a full picture of children's writing knowledge, researchers analyze the components of children's early writing (Puranik et al., 2014). Tortorelli et al. (2022) divided this into three major skills: *Composition*, the ability to compose ideas to write; *Transcription*, the skills to express ideas on paper (including both handwriting and spelling); and *Writing concept* understanding, the knowledge of print conventions like print direction according to the orthography.

In our study, we focused on emergent transcription skills. Specifically, we studied parents' knowledge of young children's conceptual knowledge of the basics of the Hebrew writing system. That is children's letter knowledge, letter-sound connections, and print conventions (Pinto et al., 2016). We studied how parents refer to these writing aspects when viewing vignettes, including samples of different writing levels, and their reference to these aspects in the writing support they offer the children at different writing levels.

1.2. Parent–child writing interactions

Children's understanding of the writing system develops along with their age and their growing exposure to writing and the writing system. They first learn about writing through their interactions with significant adults in their lives (Tolchinsky, 2003, 2008; Wasik and Herrmann, 2004). The home literacy environment captures parent–child literacy practices, such as joint book reading, teaching the alphabet, guiding them in spelling their names and words and supporting their phonological awareness *via* rhyming games. These home literacy practices are meaningful to children's early literacy development (e.g., Puranik et al., 2018) and later academic skills (e.g., Tamis-LeMonda et al., 2019).

Parents sometimes initiate joint writing (e.g., writing a greeting card) and, at other times, respond to their children's requests to write. While explicit instruction is required for children to master writing (Hall et al., 2015), parents teach their young children about the writing system (e.g., letter names and sounds), and this teaching is meaningful to their early literacy (Puranik et al., 2018) and later literacy skills (e.g., Inoue et al., 2018). Writing activities with young children are important since they allow the practice and integration of literacy skills such as phonological awareness, letter knowledge, and basic orthography understanding (Bindman et al., 2014). Effective parental support includes scaffolding at a challenging but not frustrating level and sensitivity to the child's competence (Vygotsky, 1978).

Studies that assessed the nature of parents' writing support focused on parents' references to the conventions of the writing system (e.g., writing in lines, presenting words separate from each other), phonological segmentation of words, the connection of word segments (phonemes) to letters that represent them, graphic production of the letters, and orthography-specific rules (e.g., in Hebrew, writing from right to left, using final letters; e.g., Aram and Besser-Biron, 2017).

Studies on parental writing support in different languages showed that the nature of parents' writing support, mainly the way that a parent helps the child to independently segment the words that the child wants to write, find the correct letters to write, and print them in a readable manner in line with their orthography, relates to their children's early literacy (e.g., Lin et al., 2012; Levin et al., 2013; Skibbe et al., 2013; Bindman et al., 2014; Aram et al., 2016; Cho and McBride, 2018) as well as reading and writing acquisition in first grade (e.g., Aram et al., 2013; Kalindi et al., 2018). Parental writing support is meaningful because it scaffolds the child's understanding of the writing system and gives the child the tools to observe writing and learn the rules for more conventional writing. Yet, what is parents' knowledge about early writing development? What do parents think about young children's writing products?

1.3. Parent knowledge of children's writing development

There is relatively limited research on parents' knowledge of child development (e.g., September et al., 2016; Sonnenschein and Sun, 2017). Studies on parents' general knowledge of milestones in child development showed that it related to infants' early cognitive development (Keels and Raver, 2009), reading and math skills in kindergarten (Sonnenschein and Sun, 2017) as well as pleasure in parenting (Dias and Lima, 2018). These studies explored parents' general child development knowledge (e.g., "All infants need the same amount of sleep"), but what about specific knowledge about writing development and support?

We did not find studies on parents' knowledge and understanding of writing development, but there are a few studies related to teachers' knowledge of literacy development. Cash et al. (2015) studied teachers' beliefs and knowledge regarding children's early literacy. They found that teachers' ability to categorize young children's behaviors into and within language skills (e.g., vocabulary, narrative skills) and literacy skills (e.g., phonological awareness, alphabet knowledge), but not their beliefs, predicted children's language and early literacy skills. Knowledge within the literacy domain predicted children's gains in print knowledge, while language knowledge predicted expressive vocabulary gains. In a recent study, Bingham et al. (2022) revealed that teachers' knowledge about writing development related to their practices in class. Teachers who showed elaborated knowledge about writing development when describing children's writing development, based on three writing vignettes of children that showed different writing levels, offered the children in their class higher writing support. The more knowledgeable teachers had a wider, more complex view of writing development, and they related to more writing components (i.e., print concepts, handwriting, spelling, and composing). These studies raise questions regarding parents' writing development knowledge.

As to parents, they are generally familiar with their own children's early literacy skills; they are aware of their children's letter knowledge, phonological awareness, and early writing abilities with mild over or under estimation (e.g., Aram and Levin, 2016). Studies have not yet investigated parents' general knowledge regarding early writing development or how to support and scaffold children at different writing levels. However, recently, Segal et al. (2021) studied parents' reading-related knowledge (parents' phoneme segmentation, syllable segmentation, and syllable-pattern identification) and explored its relation to parents' writing support. Parents were presented with one child's (Maddie) writing vignette and were asked to give her feedback on her writing. They were also asked to help their own preschool child write a thank-you note. The researchers found that parents with higher reading-related knowledge gave more positive feedback to Maddie and better supported their own children. Like their previous studies (Segal and Martin-Chang, 2018, 2019), the researchers found that parents with higher reading-related knowledge had children with more advanced spelling skills.

In sum, preschoolers' writing is an excellent measure of their understanding of the written language and a good predictor of future literacy achievements. To the best of our knowledge, no research addressed questions regarding parents' understanding of early writing development and ways to scaffold and promote children's writing. It is interesting to learn about the importance of this knowledge.

1.4. The present study

This study aimed to start filling these gaps. The study explored how parents' understanding of emergent writing development is reflected in how they relate to anonymous preschoolers' writing vignettes representing different writing levels and the support they offered to promote the children. It also explored how parents' early writing understanding relates to their own children's early writing development.

Given the lack of previous research on these issues, most of our research questions remained open. We asked:

1. When talking about the early writing development of anonymous preschoolers', to what extent do parents distinguish between initial, intermediate, and advanced levels of children's early writing?
2. To what extent do parents' ideas of writing support differ when relating to vignettes of early writing outcomes that represent initial, intermediate, and advanced levels of early writing?
3. When analyzing parents' responses, can we create profiles for parents that reflect the complexity of their understanding of writing development and of early writing support?
   a. We hypothesized that parents who referred to more aspects of writing and writing support when talking about one writing vignette would also do it when talking about the other two vignettes.
4. How does the complexity (breadth of parents' reference to the different early writing aspects) of parents' understanding of writing development relate to the complexity of their writing support recommendations?
5. What are the connections between the complexity of parents' references to anonymous children's writing development and the breadth of their writing support recommendations, and the level of their own child's early writing?

2. Materials and methods

2.1. Participants

Participants were 274 parents (248 mothers) aged 28–55 years ($M = 38.01$; $SD = 4.93$) and one of their children (138 boys and 136 girls). The children's mean age was 5.4 years ($M = 64.71$ months, $SD = 6.72$). Most of the parents were married (89.80%), and the rest were single (5.80%), divorced (4%), or widowed (0.4%). The parents in our sample were mostly educated. About 10% of the parents had a high school diploma, 16% had a post high school diploma; 40% held a bachelor's degree, 33% held a Master's degree; and 1% had a Ph.D. In Israel, 50.1% of adults have academic degrees (OECD, 2021). Participating families had an average of 2.51 children ($SD = 0.86$), in line with the birthrate in Israel (OECD, 2016).

Hebrew was the spoken language in all the participating families. The Hebrew writing system is a Semitic abjad writing system. It consists of 27 letters (22 regular and five final letters) that are written from right to left, and their basic function is to represent consonants. Four of the letters serve the dual function of representing consonants and vowels. Hebrew's syllable structure is mainly Consonant-Vowel and Consonant-Vowel-Consonant. Hebrew does not include single-phoneme words. It is characterized by derivational morphology, and words consist of around 3–5 letters.

All the participating children learned in preschools, with 94% in public preschools and the rest in private settings (e.g., Montessori preschools), which are also supervised by the Ministry of Education. Preschools in Israel are physically and pedagogically detached from elementary schools. In each class, the staff includes a certified early education teacher, usually holding a degree equivalent to a minimum Bachelor's degree, and a paraprofessional assistant. Formal reading and writing instruction begin in first grade. The preschool's early literacy curriculum refers to oral language, communication skills, book immersion, and alphabetic skills (Levin et al., 2007). The curriculum emphasizes teachers' autonomy in selecting the instruction methods and the specific goals that they want to emphasize in their classes. Teachers tend to focus on language skills (including rhyming games), communication, shared-book reading, and the alphabet. They rarely engage children in writing activities (Sverdlov et al., 2014).

2.2. Procedure

The study received ethics approval of the Tel-Aviv University ethics committee. Participants were recruited through a snowball method. Flyers inviting parents to participate in a study that explores literacy development and parents' thoughts about literacy development were distributed *via* preschool teachers and online parent groups. Parents who expressed interest signed a consent form prior to beginning the study. M.A. students in education collected the data within children's homes during a 30-min session in the middle of the school year. They presented three writing vignettes to the parents on separate pages. Their order of appearance was: First vignette (intermediate level), second vignette (initial level), and third vignette (advanced level). We presented them in this order to avoid a pattern of advanced to initial or initial to advanced. We thought that this order would encourage parents to think about each writing sample. On each page, the message the child intended to write was printed at the top of the page, and the child's writing was presented below it (see Figure 1). We asked the parents two questions regarding each vignette: (1) What does this child (same gender as their own child) know about writing; and (2) If you were asked to sit next to the child for 5–10 min and guide him/her in writing - how would you promote him/her? How would you help him/her to understand the idea of writing better and write better in practice? The parents wrote their answers to each question independently (we allocated four lines for writing after each question). During this time, the researcher assessed the children's early writing.

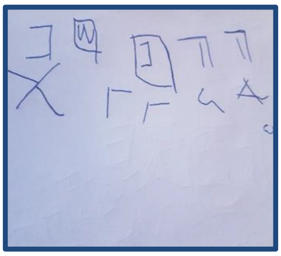
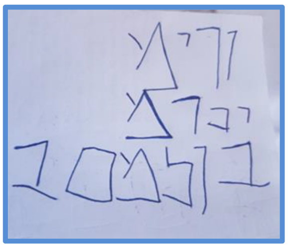
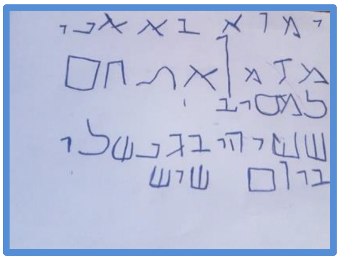
1: Initial level	2: Intermediate level	3: Advanced level
אני מזמין את ההורים למסיבה בגן	הורים יקרים בואו למסיבה	אמא ואבא אני מזמין אתכם למסיבה שתהיה בגן שלנו ביום ששי
		
"I invite the parents to a party in the preschool"	"Dear parents come to the party"	"Mom and Dad I invite you to a party on Friday in my preschool"

FIGURE 1
The writing vignettes.

2.3. Measures and coding

2.3.1. Parents' understanding of early writing development and ways to promote it

Our measurement was based on the Early Writing Knowledge Assessment (EWKA; Bingham et al., 2022). Parents were presented with three writing vignettes written by anonymous Israeli preschoolers (age 5½ to 6 years old) from a preschool that serves children from middle socio-economic backgrounds. In that preschool, children were asked to invite their parents to a party in the preschool. We chose three writing vignettes demonstrating three levels of writing development that suit Israeli children in the age range of our sample (see Figure 1).

The three invitations presented three writing levels:

1. The initial level example represents the beginning writing of letters. The child knows a few letters and creates a mixture of writing systems (letters from Hebrew, English, and non-letter signs). The child writes some letters in mirror writing. There is a beginning of a tendency to write in a line, but we do not see a separation of print into words. Also, there is no connection between the child's verbal description of the writing ("I invite the parents to a party in the preschool") and the actual written product.
2. In the intermediate level example, the child uses clearly identifiable Hebrew letters and writes in a line from right to left (in line with the Hebrew orthography). The child partially understands how to split ideas into words and leave space between words, how to divide a word into its sounds, knows the letters, relates the sound to the phonetically appropriate letter, and writes two vowel letters. Still, the child does not spell correctly, omits letters (mainly vowel letters), and does not use final letters. The written text is somewhat readable.
3. In the advanced level example, the child uses Hebrew letters (consonants and vowels). The child knows to write in a line from right to left, break a word into its segments and relate each segment (sound) to the letter that suits it. There is an (unstable) separation between the words in the sentence. The child uses some vowel letters. There is a clear connection between the content the child was asked to write and the writing product; the sentence is long and clear.

The parents were asked to relate to each of these vignettes and write what the child who wrote the invitation knows about writing, and how they would recommend promoting the child.

2.3.2. Parents' references to the writing vignettes: Coding

When analyzing parents' responses to each of the writing vignettes, we focused on their references to letter knowledge, phonological awareness, unique characters of the Hebrew orthography, and general aspects of the writing system (writing in lines, the direction of writing, etc.). First, we summed parents' references to each writing aspect and then created a more general score that referred to the complexity of their perception, as detailed below.

2.3.2.1. Sum of references to each writing aspect

For each vignette we counted parents' references to each of the following four aspects: (1) Letters: References to letter recognition, use of non-letter symbols, correct letter writing, the forming of the letters, etc. (e.g., "she knows the letters," "Here she invented letters," "He knows how to write B correctly," "It's the right letter," "She recognizes the letters"); (2) Orthography: References to specificities in the Hebrew orthography like final letters, vowel letters, and homophonic letters (e.g., "Missing final letters," "She is not aware of the *'silent letters'*", "He is confusing between H and A," "He missed the H at the end of the word because we do not hear it"; Ravid and Shalom, 2012); (3) Phonology: References to word segmentation, awareness of syllables/sub-syllables/phonemes (e.g., "She understands how to split a word," "She listens to the sounds in the word," "He writes what he hears," "He did not notice the last sound of the word"); and (4) The writing system: References to writing in a line, the direction of writing, separation between words or sentences (e.g., "She separates the lines in writing," "She knows that we write from right to left," "Writes the letters in order in the same size," "Does not understand that a sentence has to be split into words with spaces"). For examples of the scoring of parents' responses please see Appendix.

The sum of the references in each of the four categories constituted the summary score in that index. Reliability between two judges (graduate students in the Department of Special Education and Educational Counseling) regarding 15% of the products showed 80, 97, 91, and 79% absolute agreement for the categories *letters, orthography, phonology*, and *writing system,* respectively. Beyond that, there was usually partial agreement in cases of lack of agreement, and the two judges discussed these cases to reach an agreement.

2.3.2.2. Writing perception complexity score

We assumed that a parent who referred to more aspects when talking about each writing vignette is a parent whose writing vision is broader and more complex (Bingham et al., 2022). A parent who refers several times only to one aspect (e.g., letters or phonology) perceives children's early writing in a narrower way. We summed the aspects parents referred to when describing the child's knowledge. We referred to the four aspects (letters, orthography, phonology, and writing system), and the possible range was zero to four.

2.3.3. Parents' recommendations for writing support: Coding

When analyzing the parents' support recommendations, we refer to the same four writing aspects (letter, orthography, phonology, and the writing system). We also referred to two general recommendations: not to teach the child and give the child a model to copy (Segal et al., 2021) as detailed below.

2.3.3.1. Sum of support recommendations for each writing aspect

For each vignette we counted parents' writing support recommendations that referred to each of these four aspects: (1) Letters: References to writing support that addresses the letters (e.g., "I would work on letters," "teach letter recognition," "teach her more letters," "play games with letters," "practice writing letters"); (2) Orthography: Recommendations for teaching specific aspects of the Hebrew orthography like final or vowel letters (e.g., teach him about H (ה) at the end of the word, "show final M (מ/ם)," "talk about letters that sound the same like ק/כ"; (3) Phonology: References that relate to sound awareness support (e.g., "you have to teach him their sounds," "I will emphasize each letter according to its sound," "I will correct her when she misses a sound," "I will split words into their specific sounds"); and (4) The writing system: Recommendations to draw the child's attention to the regularities of the writing system (e.g., "teach her to write from right to left," "emphasize spaces between words," "sit with him with booklets and teach him how the words should be written," "I would teach him that every word is made up of several letters together"). We also counted their general recommendations not to teach the child (e.g., "I would not promote my child," "I would say well done," "I would leave him," "I would not promote him at all") and their recommendation to give the child a model to copy (e.g., "I would write the word and ask her to copy," "ask him if he wants me to show him how to write," "show her how to write each word separately"; Segal et al., 2021).

The sum of the references in each of the first four categories constituted their summary score for that category. As to the last two categories, the reference to them was binary. We marked whether or not the parent referred to each of these categories. Reliability between two judges (graduate students in the Department of Special Education and Educational Counseling) regarding 15% of the products showed 80, 89, 87, 75, 91, and 94% absolute agreement for the categories of *letters, orthography, phonology*, *writing system, no support*, and a *model to copy*, respectively. Beyond that, there was usually partial agreement in cases of lack of agreement, and the two judges discussed these cases to reach an agreement. For examples of the scoring of parents' recommendations please see Appendix.

2.3.3.2. Writing support complexity score

We summed the aspects parents referred to when describing possible writing support recommendations. We referred to letters, orthography, phonology, and writing system. The range was zero to four. For example, if a parent referred to letters twice and to phonology once, her complexity score was two (letters and phonology). We did not include the parent's recommendation not to support writing or present the child with a model because they are more general.

2.3.4. Children's early writing

Each child was asked to write their name and four other words that represent known nouns: "plate" ZLXT; "faucet" BRZ; "peach" APRSK; and "rain" GSM. These words include 14 out of the 22 letters in the Hebrew alphabet. The letters represent consonants, as all letters stand for consonants in Hebrew (an abjad alphabetic system), but four letters can also represent vowels (Ravid, 2012). In writing Hebrew, children first represent consonants and then include some letters for vowels (Levin et al., 1996).

The words were presented through pictures on cards. The child was given a card with the drawing and was asked: "Please write the word X below the drawing however you can." The writing of their name was intended to make the child feel comfortable, and it was not analyzed since the vast majority of the children wrote their name in standard writing.

The writing products were analyzed on a six-point scale (Levin and Bus, 2003): (1) signs that are not letters, such as lines, circles, or unidentified signs; (2) random letters – invented spelling in which the child writes letters that are not phonologically related to the word; (3) basic use of consonants - the child uses one appropriate consonant with the necessary sound value not randomly (homophonic or phonological substitution are accepted as appropriate); (4) the child uses more than one of the consonants of the word (homophonic or phonological replacements are accepted) but not all of them. The child may add letters to the corresponding consonants; (5) full consonant writing with additions or disruptions (homophonic replacement); and (6) standard writing. The average score across the four words constituted the writing level score ($\alpha = 0.93$). Inter-judge reliability by two MA educational counseling students on 15% of participants showed 86% agreement (*Kappa* = 0.81).

2.4. Data analysis

First, we present the statistics relating to the sum of parents' references to the different aspects in their description of the children's knowledge about early writing (means and ranges). To learn about the extent that parents distinguish between different levels of children's writing, we present a General Estimating Equation (GEE) analysis with repeated measures that compares the three writing levels (three vignettes). Second, we present the statistics relating to the sum of parents' recommendations for writing promotion (means and ranges). To learn about the extent that parents' ideas of writing support differ when relating to different levels of writing, we present a General Estimating Equation (GEE) analysis with repeated measures that compares the three writing levels (three vignettes). Third, to learn about parents' profiles of understanding writing development and writing support recommendations, we present parents' complexity scores – the sum of aspects in parents' descriptions of the children's writing knowledge and their support recommendations at each writing level, as well as the correlations between them. We then present two cluster analyses of parents who referred to many/few aspects in their references to children's writing and parents who gave many/few writing support recommendations. We ran a Crosstabs analysis to learn how these clusters relate to each other. Last, to learn about the connections between the scope of parents' references to anonymous children's writing and their writing support recommendations with the level of their own child's early writing, we present an ANOVA that explored the differences between the writing levels of children whose parents belong to each of the clusters.

3. Results

3.1. Three writing levels: Differences in the sum of parents' references to the children's knowledge and writing support recommendations

First, we present the number of the parents' references to letters, orthography, phonology, and the writing system when describing the child's knowledge ("what the child knows about writing") in the three vignettes. We ran a GEE analysis with repeated measures to compare the sum of parents' references to these vignettes in each of the assessed aspects (see Table 1).

Table 1 shows that overall, parents' references to the writing samples were fairly brief and that they varied widely in their knowledge, with differences emerging across the writing levels. Parents referred frequently to the *letters* and paid relatively little attention to *phonology* and *orthography*. They also acknowledged children's awareness of the rules of the *writing system* (e.g., lack of space between words).

Parents clearly differentiated between the three writing levels across the four writing aspects. *Post hoc* Bonferroni tests showed that parents referred significantly more to *letters* at the initial writing level compared to the intermediate level and more at the intermediate level compared to the advanced writing level. Parents referred to both *orthography* and *phonology* significantly more at the intermediate writing level compared to the advanced level and more at the advanced writing level compared to the initial level. Lastly, Bonferroni tests showed that parents referred significantly more to the *writing system* at the advanced writing level compared to the intermediate and initial writing levels. No significant difference was found between the number of parents' references to the *writing system* between the intermediate and the initial writing levels.

Next, we present the sum of parents' writing support recommendations for each vignette ("how will you promote him/her") along with a GEE analysis with repeated measures to study the differences in the number of parents' writing support recommendations for the three writing levels across the assessed aspects (see Table 2).

Table 2 shows that parents gave few recommendations overall and there were significant differences in the number of parents'

TABLE 1 Differences in the sum of parents' references to the different writing levels (N =274).

Aspect	Writing's level	Range	*M (SE)*	Waldχ^2	Bonferroni comparisons
Letter	Initial	0–4	0.96 (0.04)	73.50***	I[1] > IN > A
	Intermediate	0–3	0.68 (0.03)		
	Advanced	0–3	0.54 (0.03)		
Orthography	Initial	0–1	0.05 (0.01)	67.11***	IN > A > I
	Intermediate	0–3	0.47 (0.04)		
	Advanced	0–3	0.32 (0.03)		
Phonology	Initial	0–2	0.23 (0.03)	61.03***	IN > A > I
	Intermediate	0–3	0.58 (0.04)		
	Advanced	0–2	0.38 (0.03)		
Writing system	Initial	0–5	0.80 (0.05)	38.05**	A > IN, I
	Intermediate	0–4	0.88 (0.05)		
	Advanced	0–5	1.20 (0.06)		

**p < 0.05; ***p < 0.001. [1] I, initial; IN, intermediate; A, advanced.

TABLE 2 Differences in the sum of parents' writing support recommendations for the different writing levels (N =274).

Aspects	Writing level	Range	*M (SE)*	Waldχ^2	Bonferroni comparisons
Letter	Initial	0–4	0.94 (0.05)	202.18***	I[1] > IN > A
	Intermediate	0–2	0.32 (0.03)		
	Advanced	0–3	0.20 (0.02)		
Orthography	Initial	0–1	0.01 (0.00)	71.09***	IN > A > I
	Intermediate	0–3	0.65 (0.05)		
	Advanced	0–3	0.37 (0.04)		
Phonology	Initial	0–5	0.55 (0.05)	40.08***	I, IN > A
	Intermediate	0–3	0.55 (0.05)		
	Advanced	0–3	0.23 (0.03)		
Writing system	Initial	0–4	0.64 (0.05)	10.93***	A > IN, I
	Intermediate	0–4	0.68 (0.05)		
	Advanced	0–3	0.83 (0.05)		
I will not teach[2]	Initial	0–1	0.07 (0.01)	37.97***	A > IN > I
	Intermediate	0–1	0.11 (0.02)		
	Advanced	0–1	0.21 (0.02)		
A model to copy[2]	Initial	0–1	0.20 (0.02)	9.21**	I, IN > A
	Intermediate	0–1	0.18 (0.02)		
	Advanced	0–1	0.11 (0.02)		

**p < 0.01; ***p < 0.001. [1] I, initial; IN, intermediate; A, advanced; [2] These metrics are binary.

support recommendations across the studied aspects. Again, parents mainly referred to *letters*. They said that they would teach the children the Hebrew alphabet, show the children what the letters look like, teach them to print letters, etc. They also related to the rules of the *writing system*, saying that they will teach the child where a word ends and another begins, draw attention to the correct writing direction, etc.

Post hoc Bonferroni tests indicated the source of the differences. Parents gave significantly more recommendations concerning *letters* at the initial writing level compared to the intermediate level and more at the intermediate level compared to the advanced writing level. The number of recommendations to promote *orthography* at the intermediate writing level was significantly greater than at the advanced level and at the advanced

TABLE 3 Complexity: Number of aspects in parents' description of the writings and in their writing support recommendations at the different writing levels (*N* =274).

	Writing's level	*M*	*SD*	Range
Initial writing level	Writing description	1.57	0.81	0–4
	Writing support	1.61	0.87	0–3
Intermediate writing level	Writing description	2.03	1.01	0–4
	Writing support	1.68	0.93	0–4
Advanced writing level	Writing description	1.78	1.04	0–4
	Writing support	1.28	0.92	0–4

level more than at the initial writing level. The number of recommendations to promote *phonology* at the intermediate and initial writing levels was significantly greater than at the advanced writing level, with no differences between initial and intermediate writing levels. Parents recommended promoting the children's understanding of the *writing system* significantly more at the advanced writing level compared to the intermediate and initial writing levels (with no significant differences between these two levels). Significantly more parents recommended "no teaching" at the advanced writing level compared to the intermediate level and more at the intermediate level compared to the initial level. Significantly more parents suggested giving the child a model to copy at the intermediate and initial writing levels than at the advanced writing level, with no differences between initial and intermediate writing levels.

3.2. Complexity of parents' writing perception: Breadth of parents' view

Table 3 presents a description of the sum of aspects that parents referred to when describing children's knowledge and when suggesting writing support. It presents parents' references to the three vignettes separately: initial, intermediate, and advanced writing levels.

Table 3 shows variation between the parents. Some parents did not relate to the writing aspects we studied, and some referred to all four aspects in each writing level (except for support recommendations at the intermediate level). The median score referenced two aspects for writing description and writing support across the writing levels.

We studied the correlations (Spearman) between the number of aspects the parents referred to when discussing the child's writing and the number of aspects that they referred to in their support recommendations and found significant low to medium correlations: $r = 0.18$, $p < 0.01$; $r = 0.28$, $p < 0.001$; and $r = 0.26$, $p < 0.001$ at the initial, intermediate and advanced writing levels, respectively. In other words, the more categories the parent included in her reference to the child's writing knowledge, the more categories she referred to in her writing support recommendations.

To deepen our understanding, we used a K Cluster Analysis to map the number of aspects in parents' references to the three writing levels when relating to children's writing knowledge (letters, orthography, phonology, and the writing system) and the parallel aspects in their writing support recommendations. The best grouping of the references to writing at the three levels (writing development knowledge) was into two clusters: (1) Broad view of writing development: Parents who referred to many writing aspects ($n = 145$) and (2) Narrow view of writing development: Parents who referred to few writing aspects ($n = 129$). Similarly, the best grouping of the parents' writing support recommendations was into two clusters: (1) Broad writing support: Parents who referred to many aspects ($n = 153$) and (2) Narrow writing support: Parents who referred to few aspects ($n = 121$). Table 4 and Figure 2 present the clusters.

To learn how these groups of parents who refer to many/few aspects in their references to children's writing relate to the groups of parents who referred to many/few aspects in their writing support recommendations, we ran a Crosstabs analysis. We found that parents who had a broad view of writing development and referred to more writing aspects in their references to the writing vignettes (writing development knowledge) also referred to more aspects in their writing support recommendations $X^2 = 16.72$, $p < 0.001$. Of the parents, 67% showed a broad view of both writing development and writing support, 57% showed a narrow view of both writing development and writing support, 32% showed a broad view of writing development and a narrow view of writing support, and 43% showed a narrow view of writing development and a broad view of writing support.

3.3. Parents' writing perception and their own children's writing level

The children's mean writing level was 3.52 ($SD = 1.54$). This indicates that when writing words, children used mainly basic consonantal spelling (e.g., when asked to write the word "peach" APRSK; a child wrote "ABLM," using only the correct consonant "A") or partial consonantal spelling (e.g., when asked to write the word "peach" APRSK; a child wrote "ALGK," using the correct consonants "A" and "K"). Ten children did not agree to write, and instead, they drew the objects. As such, they were excluded from the following analysis.

TABLE 4 Classification of parents' views according to their complexity scores into clusters: Narrow and broad view of writing development and writing support[1] (N =274).

Writing development knowledge	Narrow view of writing development: Few aspects n =129	Broad view of writing development: Many aspects n =145
Initial writing level	1.11	1.99
Intermediate writing level	1.30	2.70
Advanced writing level	0.97	2.50
Writing support recommendation	**Narrow view of writing support: Few aspects n =121**	**Broad view of writing support: Many aspects n =153**
Initial writing level	1.03	2.07
Intermediate writing level	1.09	2.16
Advanced writing level	0.67	1.76

[1]Possible range: Zero to four aspects.

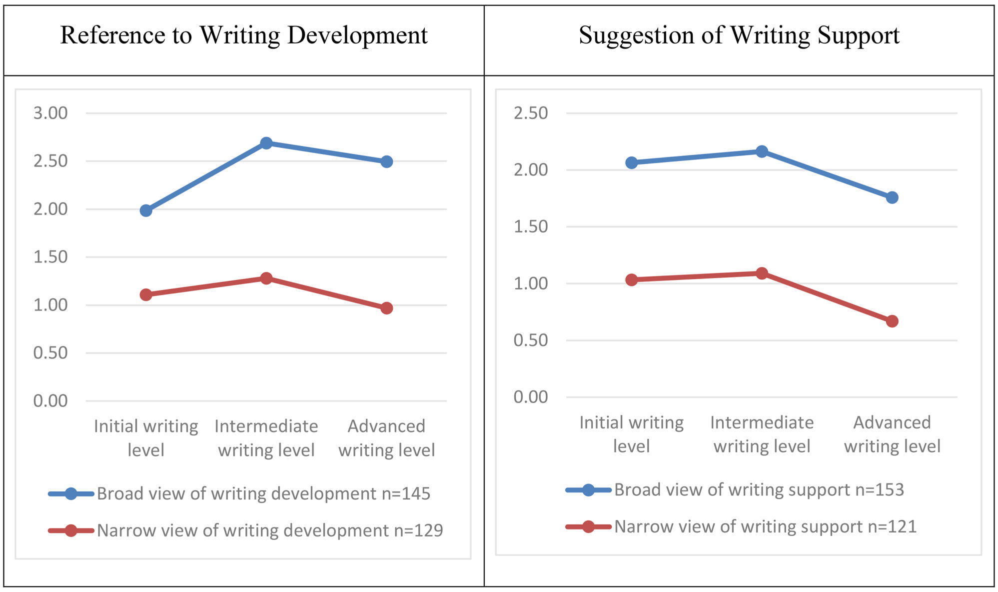


FIGURE 2
The clusters.

To learn about the differences between the writing level of children of parents with broad/narrow views of writing development and writings support, we ran a two-way ANOVA: Child's writing level × References to the writing vignettes (many/few writing aspects) × Writing support view (many/few writing aspects in their writing support recommendation). We did not find a significant effect for reference to children's writing ($F_{1,262}$ =1.85, p =0.17). There was no difference between the writing levels of children of parents who referred to few or many aspects in their reference to the writing knowledge of the children who wrote the vignettes. We found a significant effect for writing support recommendations ($F_{1,262}$ =4.40, p =0.03). Parents who showed a broad view of writing support and referred to more writing aspects in their writing support suggestions had children who showed more advanced writing levels than parents who showed a narrow view of writing support and referred to few aspects. We did not find a significant interaction between the two ($F_{1,262}$ =0.65, p =0.42).

4. Discussion

Acknowledging parents' central role in their children's literacy development and the scarcity of research on parents' knowledge of early literacy development, this study explored how parents related to the writings of preschoolers at different levels of writing development (initial/intermediate/advanced). An interesting aspect of this study is that we evaluated parents' references to the writing of children who are not their own. Based on Bingham et al. (2022) approach to assessing teachers' early writing knowledge (EWKA), we showed parents vignettes of children's writing and asked them to express their opinion on these vignettes. This assessment revealed trends in parents' writing development knowledge.

The main results showed that of the four aspects of writing that we assessed (letters, orthography, phonology, and the writing system), parents mainly referred to letters and to the principles of the writing system, with orthography and phonology rarely mentioned. Parents distinguished between the different writing levels and adjusted their writing support recommendations accordingly. To assess the complexity of parents' understanding of early writing development, we created an overall score that reflected the number of aspects that parents addressed (e.g., if the parent referred to letters twice and to phonology once, the score was two aspects). We found that parents mainly referred to only two aspects in their writing assessment and in their writing support recommendations. The more aspects the parent addressed in the writing assessment, the more aspects she addressed in her support suggestions. Cluster analysis showed that there are two groups of parents, those who have a narrow view of writing development and referred to fewer writing aspects in their description of children's knowledge and their writing support recommendations at three levels of writing and those who have a broader view and referred to more aspects. It is interesting that parents who saw writing support as a broad process and included different aspects of writing in their suggestions have children with a higher writing level. This relationship was not found regarding parents' references to the children's knowledge.

4.1. Understanding children's writing development and ways to promote it

Parents referred to the four early writing aspects that we assessed when describing the children's writing knowledge and when recommending ways to promote writing. At the same time, they did not elaborate, like in other studies (Leyva, 2019). They referred frequently to letters and to the writing system (e.g., words have to be separated). The centrality of letters as a major aspect of literacy development can be seen in the many letter books, letter games, puzzles, etc. in the stores. When parents read alphabet books to their children, they focus on the name of the letter and pay less attention to the phonology or the structure of the word in which the letter appears (Davis et al., 2010; Bergman Deitcher et al., 2021). In studies on parental writing support, many parents simply dictate letters to their children (Skibbe et al., 2013). Also, when thinking about their writing interaction with their own child, they tend to focus more on letter knowledge and the general writing system and less on phonology, orthography, or letter-sound connection (Aram and Bergman Deitcher, in print).

It was interesting to see that parents paid little attention to phonological or orthographic knowledge. This knowledge is significant and fundamental to the acquisition of reading and writing (Levin and Aram, 2013; Jones, 2015), yet parents seem to be less aware of it. There is similar evidence that preschool teachers pay less attention to phonology (Pelatti et al., 2014; Sverdlov et al., 2014). It may be that parents write automatically, seeing the letters and the finished product in front of their eyes, and not thinking about the process involved in writing such as word segmentation or correct spelling, and thus consider children's writing in a similar way.

The study's results expand our understanding of parents' knowledge of children's writing development. Existing studies provide evidence that parents are familiar with their own children's academic and literacy skills (Korat, 2011; Sonnenschein et al., 2014; Aram and Levin, 2016), and that mothers of preschool-age fraternal twins are sensitive to the differences between their children's writing levels (Aram, 2007). The present study expands this knowledge and reveals that parents differentiate between the writing levels of anonymous children, both in their analysis of the children's knowledge about writing and in their writing support recommendations. Unlike Aram (2007) study, in the present study, parents had no prior information on the children's development beyond the writing vignettes.

When referring to the initial level writing sample, parents frequently referred to letters both in their description of the children's writing knowledge and in their support recommendations. They wrote that the child does not know the letters and how to write them, and he/she had to learn the letters. It seems that parents refer to letters as the building blocks of a written message (Levin and Ehri, 2009), and to letter knowledge as the basis of the acquisition of writing and reading (Robins et al., 2014). When referring to the more advanced writing vignettes, parents referred less to letters. Similarly, Segal et al. (2021) found that parents offered fewer suggestions relating to letters to children with higher spelling skills.

Even though parents generally related less to orthography and phonology, the intermediate level was the one where they did it the most, both in their writing knowledge descriptions and in their support recommendations. Parents understood that the child who wrote the intermediate vignette had a basic understanding of the writing system, but they needed "fine-tuning" of the understanding that each sound has its specific representing letter as well as the specificities of the Hebrew orthography.

At the advanced level, parents referred the most to the writing system (e.g., a separation between words, writing in a line and within the line, separation between lines, reference to a sentence, reference to the direction of letters). From the vignette, the parents probably understood that the child knows how to segment a word into its phonological segments and associate them with letters. The child wrote a long readable message and used some specific features of Hebrew like final letters. Therefore, the parents referred more to aspects of the writing system that are less salient in the vignette such as separating words, maintaining letters within a line, writing the letters in the same size, etc. – aspects that they thought would help the child write a more "organized" message.

Like in Segal et al. (2021), parents were less likely to provide the advanced child with a written model to copy. Interestingly, although the invitations in the intermediate and advanced levels contained many spelling errors, connected words, omitted letters, etc., parents tended to write that there is no need to support the children at the higher levels (especially when relating to the child at advanced writing level). That is, they thought that the knowledge that these children have is sufficient for preschool and that it is better to "leave" them. The thought that these children have enough knowledge and there is no need to promote them represents a line of Israeli parents' thinking about promoting writing. There is a tendency to separate the kindergarten from the school and attribute the kindergarten to play and the school to teaching (Aram et al., 2016). Interestingly, Bingham et al. (2022) found a similar trend among kindergarten teachers in the US who thought that the children who write at a relatively high level did not need to be further promoted.

4.2. Complexity of parents' perception of writing development: Relations to their own child's writing skills

We studied the complexity of parents' views on early writing development, by counting the number of aspects that they refer to (out of four) when discussing children's early writing. The aspects that were assessed in our study relate to children's *transcription skills* and *writing concept* understanding (Tortorelli et al., 2022).

We found that most of the parents referred to two aspects. The more aspects the parent included in the analysis of the child's writing, the more aspects she included in her writing support recommendations. This result is somewhat like that of Bingham et al. (2022) who found that teachers' writing development knowledge complexity was related to the writing practices they implemented in class. Yet, the correlations in our study were low to medium. It is likely that teachers have seen more children's writings and have more academic knowledge about writing compared to parents.

Like in studies that found that mothers have a writing support style across different writing tasks (Aram and Besser-Biron, 2017), parents in our study showed a "style" across the writings. That is, they were classified into two groups: those who had a broader view of writing and referred to more aspects in their description of the children's writing and in their writing support across the three writings, and those who had a narrower view of writing and referred to fewer aspects across the three writing vignettes. Parents who showed a broader view of writing support and related to more aspects in their recommendations for promoting the writing of anonymous children had children with higher writing levels.

The relationship between a broader view of writing support and children's early writing is meaningful. It highlights the centrality of adults' scaffolding and the importance of parents' understanding of effective writing support. Studies showed that the way that parents support their children's writing relates to the children's early literacy skills and reading and writing in the first grades beyond the family's socio-economic background and the child's age and early literacy skills (e.g., Aram et al., 2013; Neumann, 2018). The current study stresses for the first time that parents' knowledge of writing support goes beyond the support of their own child. It is a more general knowledge that probably benefits their children during everyday literacy interactions.

4.3. Limitations and suggestions for future studies

The study has several limitations that prompt ideas for future studies. First, regarding our participants: (a) the participants were mostly well-educated parents, reflecting higher SES. This may weaken the ability to generalize the findings to more diverse populations. There is evidence that children's socio-economic background is related to their early literacy skills (e.g., Lee and Al Otaiba, 2015). We suggest that future studies will study the writing development knowledge of parents from diverse backgrounds; (b) we studied mostly mothers. Future studies should include more fathers, and we suggest also studying the writing development knowledge of older siblings and grandparents because they spend a lot of time with preschoolers (e.g., Sherr et al., 2018; Elias et al., 2019), and can participate in literacy activities with them (Del Boca et al., 2018; Elias et al., 2020), and be early writing supporters; and (c) bilingualism in early childhood is common (e.g., Ducuara and Rozo, 2018). The parents in our sample spoke only Hebrew with their children. We recommend that future studies address this issue. Second, regarding the method, the parents in our study described very briefly the writing knowledge of the children who wrote the vignettes and gave short writing support recommendations. We asked only two open-ended questions and parents wrote their responses within the four lines below each question. We recommend that future studies will add a few guiding questions that will encourage parents to elaborate.

4.4 Implications and conclusion

From a theoretical point of view, our study strengthens the view of child development within the social context and the importance of adults' knowledge of child development and ways to scaffold it (Vygotsky, 1978). Within the realm of early literacy, our study shows that adults need to have knowledge regarding effective scaffolding in general and writing in particular. Preschool children's writing represents their understanding of their writing system and includes reference to various literacy aspects, including letter knowledge, orthographic awareness, phonology, and understanding the principles of the specific writing system. Our study is the first to show that parents distinguish between different levels of early writing. It showed that a broad view of writing support is meaningful. Parents who had a broad view of writing support when thinking about the writing of anonymous children had children with higher literacy skills. We think that it is important to help parents learn about their children's literacy, initiate writing situations in the family, and draw the children's attention to the various aspects of writing. Teaching parents about writing support may advance their understanding of their children's early literacy development and give them tools to support their children's literacy in an effective way. The implications of the research are also true for children with special needs who show difficulties in the development of literacy. It is possible that bringing parents' attention to the development of writing and ways to promote it may give these parents practical tools to assist and advance their children.

The data collection method in the study contributes to the methodology of research on parental behavior in the context of early literacy. In previous studies, researchers videotaped parents supporting their own child's writing (e.g., Bindman et al., 2014). This approach is costly, and it only partly reflects parents' knowledge because parents see and interact solely with their children. Using the vignettes approach enables a broader understanding of parents' writing development knowledge. Moreover, as it is less costly, it allows access to more parents. This methodology can complement studies that deal with parent–child literacy activities.

To sum up, the study verifies that parents understand children's writing development beyond their reference to their own children. It indicates that the complexity of parents' understanding of writing development has a role in fostering their own children's literacy skills. Based on this, there is room to guide parents about writing skills and development.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the Tel Aviv University Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

Author contributions

DA conceived the presented idea and developed the assessment protocol, and wrote the first draft. RY organized and analyzed the transcriptions. DA and RY contributed to the statistical analyses and the interpretation of the results. 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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Appendix

Examples of complete analyses of parents' responses.

A. Examples of parents' responses to each of the writing levels accompanied by their scores:

1. Initial level: "Knows some of the letters, his direction is correct (right to left)." The scoring was: One point for letters (knows letters) and one point for the writing system (writing direction).
2. Intermediate level: "Recognizes the sounds, but there is no differentiation between letters that are similar in sounds. Lacks spacing and correct endings." The scoring was: Two points for orthography (homophonic letters, final letters), two points for phonology (references to sounds), and one point for the writing system (lack of spacing).
3. Advanced level: "Understands what a word is, makes spaces between words. Knows final letters. But has difficulty with the finals and some vowel letters. Manages to make beautiful separations. Knows the letters." The scoring was: One point for letters (knows the letters), two points for orthography (references to final letters and vowel letters), and two points for the writing system (references to the representation of words and to spacing).

B. Examples of parents' writing support recommendations to each of the writing levels accompanied by their scores:

1. Initial level: "In this case, I think there is a need to establish the letters and then words. I would start by writing only letters, cards of letters, and games where you have to choose letters." The scoring was four points for letters.
2. Intermediate level: "I would not teach if that's what he knows how to write. Just divide the last attached two words into two." The scoring was one point for the writing system (spacing between words) and a general recommendation not to teach the child.
3. Advanced level: "I would show him how to write mom and dad, teach final letters, vowels, and final N." The scoring was three points for orthography (vowel and final letters) and a general recommendation to give the child a model to copy.

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The influence of home environmental factors on kindergarten children's addition strategy use

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Young children vary widely in their levels of math knowledge, their abilities to solve math problems, and the strategies they use to solve math problems. As much of later math builds on children's early understanding of basic math facts and problem-solving strategies, understanding influences on children's early problem solving is important. Few studies, however, have examined the home environment in relation to children's strategy use during arithmetic problems. We examined how both structural characteristics of children's home environments, such as socioeconomic status (SES), as well as the learning environment, such as engagement in math and literacy activities at home, related to their use of problem-solving strategies for numerical addition problems. Kindergarten children from diverse backgrounds completed a measure of addition problem solving and strategy use, including simple and complex numerical problems. Strategies were coded based on a combination of accuracy and strategy sophistication, with higher scores indicating problems solved correctly with more sophisticated strategies. Parents completed a home activities questionnaire, reporting the frequency with which they and their child had engaged in math and literacy activities at home over the past month. An exploratory factor analysis identified three components of the home activities - a basic activities factor, an advanced math activities factor, and a literacy activities factor. Findings indicated that SES related to children's strategy sophistication, and frequency of engaging in advanced math and literacy activities at home predicted strategy sophistication, however, engaging in activities at home did not moderate the relations between SES and strategy sophistication. This suggests that family engagement in activities at home may promote early arithmetic skills, and that the role of home environmental characteristics should be considered in children's arithmetic strategy use and performance over development.

KEYWORDS

addition strategy, SES, home learning environment, home literacy, home math environment, arithmetic, early childhood

1. Introduction

From a young age, children vary widely in their levels of math knowledge and their abilities to solve math problems. Early math knowledge is particularly important because it provides a foundation for and is predictive of later math development and academic achievement (Watts et al., 2014). Specifically, much of more complex math concepts build on children's early understanding of basic math facts and problem-solving strategies. Therefore, understanding influences on children's early problem solving is critical. Prior research suggests the importance of the home environment for children's early math knowledge (Mutaf-Yıldız et al., 2020; Daucourt et al., 2021). However, few studies to date have examined the home environment in relation to children's strategy use during arithmetic problems. The goal of the current study was to examine the role of home environmental factors in children's addition strategy use.

The home environment includes both structural characteristics of the home, such as socioeconomic status (SES), as well as the home learning environment, such as engagement in math and literacy activities at home. Each of these aspects of the home environment can contribute to children's early math development. For example, studies have shown that children from lower-income backgrounds may begin school at a lower level than children from higher-income backgrounds (Jordan et al., 2006, 2009). Reasons for this difference may include factors related to the home learning environment, such as access to resources and learning opportunities within the home, including engagement in learning activities at home (Laski et al., 2016; Daucourt et al., 2021).

In considering the home learning environment, studies have examined both the home literacy environment—a measure of families' engagement in literacy activities, interactions, and beliefs at home—as well as the home math environment—a measure of families' engagement in math activities, talk, and attitudes/beliefs at home. For both the home literacy and home math environments, it is theorized that parent attitudes about the subject area (i.e., literacy or math) and frequency of engaging in informal (e.g., games and playful activities) and formal (e.g., direct math or literacy activities, such as counting and reading) activities relate to children's abilities in literacy and math (Skwarchuk et al., 2014). Recent meta-analyses and reviews have shown that the home math environment positively relates to children's math development (Mutaf-Yıldız et al., 2020; Daucourt et al., 2021). For example, the frequency of parent and child engagement in early math activities such as counting on fingers, using number or quantity (e.g., more, less) words, and talking about simple math facts has been shown to relate to children's math abilities in preschool and kindergarten (Blevins-Knabe and Musun-Miller, 1996; Anders et al., 2012; Vandermaas-Peeler and Pittard, 2014). In addition, children's engagement in math games at home as preschoolers and kindergartners has been shown to relate to their concurrent math skills and predict their informal and formal math skills longitudinally through first grade (Niklas and Schneider, 2014; Zhang et al., 2020). Studies have also indicated that the home literacy environment positively relates to children's math development, with the frequency of parent and child engagement in early literacy activities, such as reading books and identifying letters and letter sounds, relating to children's early math and numeracy skills (Anders et al., 2012; Manolitsis et al., 2013). Engaging in literacy activities can support math skills through children's development of vocabulary and language skills as well as through the home learning environment more broadly, as engagement in literacy activities may relate to engagement in numeracy activities (Anders et al., 2012; Manolitsis et al., 2013; Napoli and Purpura, 2018). Overall, these findings suggest that engaging in math and literacy activities at home can play an important role in early math development. Few studies, however, have examined the home environment in relation to children's strategy use during arithmetic problems.

Arithmetic strategies are the types of problem-solving strategies children use when solving arithmetic problems. Strategies for simple addition problems include counting processes like using fingers or speaking out loud, as well as other mental methods for solving problems, such as automatic fact retrieval, guessing, or breaking down the problem into different parts (Geary et al., 2004). Strategies can be broken down into multiple levels of sophistication within finger and verbal counting, with more efficient strategies such as counting up from the largest addend in an addition problem (i.e., min strategy) viewed as more sophisticated than less efficient strategies such as counting up from the smaller addend (i.e., max strategy) or counting both addends (i.e., sum strategy). Even more sophisticated are strategies where children rely more on their memory and knowledge of addition facts. For example, children may use their knowledge of simple sums to break down a problem into smaller parts (i.e., recognizing that 2 + 5 is the same as 2 + 3 + 2). Children may also simply directly retrieve answers to specific problems from memory.

As children develop their arithmetic problem-solving skills, they vary in the strategies they use and tend to use multiple strategies to solve similar problems (Siegler, 1987, 1996). Throughout development, the strategies children use progress from being primarily simple strategies to more complex, memory and retrieval-based strategies (Ashcraft, 1982; Svenson and Sjöberg, 1983; Baroody, 1987; Geary et al., 1991; Paul and Reeve, 2016). This trajectory of development is critical for children's development of increasingly complex math concepts and their problem-solving abilities, as the sophistication of children's strategy choices relates to their later math performance, and becomes increasingly predictive of math performance longitudinally (Geary et al., 2017). In this way, having a strong foundation in early problem-solving abilities and being set on a trajectory of developing increasingly advanced problem-solving strategies is critical for later math development and achievement. However, previous research indicates that children's development and use of strategies can vary based on personal and environmental factors, including children's math abilities (Bailey et al., 2012), working memory abilities (Cragg and Gilmore, 2014), math anxiety (Ramirez et al., 2016), socioeconomic background (Laski et al., 2016), as well as whether problems are solved in an academic or play context (Bjorklund and Rosenblum, 2002; Bjorklund et al., 2004; Casey et al., 2020) and what materials are used for problem solving (Schiffman and Laski, 2018). Understanding the factors that influence this development is important for developing interventions to aid children in their math learning and development of problem-solving skills. The current study specifically focused on the role of home environmental factors to better understand the roles of SES, and the math and literacy activities children engage in at home on the development of children's arithmetic strategies.

Research indicates that children from different socioeconomic backgrounds vary in their ability to solve simple and complex arithmetic problems. For example, Ginsburg and Pappas (2004) found that 4- and 5-year-old children from higher SES backgrounds performed better on addition problems than same-age peers from middle or lower SES backgrounds. Children from higher SES backgrounds were also more likely to use more sophisticated strategies, such as recall strategies, and less likely to use strategies such as touching and counting manipulatives to solve the problems. Similarly, Laski et al. (2016) found that kindergarten and first-grade students from higher-income backgrounds tended to use more sophisticated, efficient strategies, including decomposition, retrieval, and counting on from the larger addend. In contrast, students from lower-income backgrounds tended to use more inefficient strategies, including counting each addend before counting the total of both addends and other strategies. In addition, children from lower-income backgrounds were more likely to use simpler strategies as first graders than children from higher-income backgrounds. Results also indicated that children from higher-income backgrounds were more likely to solve problems accurately, and this relation of income with addition accuracy was mediated by use of sophisticated addition strategies.

These studies indicate that children's SES background can influence their problem-solving strategies from a young age. It is possible that socioeconomic differences in the home environment, resources, and opportunities may contribute to these differences (Ginsburg and Pappas, 2004; Laski et al., 2016). Further understanding these influences on strategy use is important, because early strategy use is important for children's later development of problem-solving and math abilities. The current study examines both overall strategy sophistication and frequency of use of individual strategies in relation to children's SES backgrounds, as well as the role of the home learning environment in the relations between SES and arithmetic strategies.

Multiple studies have shown positive relations of children's home numeracy experiences and their accuracy on addition problems. For example, parental reports of children's engagement in home numeracy activities relate to their children's single-digit addition problem fluency (LeFevre et al., 2009), and performance on symbolic (Dearing et al., 2012) and non-symbolic addition and subtraction (Skwarchuk et al., 2014). Another study indicated that children's accuracy on single-digit non-symbolic arithmetic related to their engagement in math games at home, but did not relate to engagement in other home numeracy activities (Mutaf Yıldız et al., 2018).

Studies of children's home literacy experiences have also shown positive relations of children's home literacy experiences and their math abilities (Anders et al., 2012; Manolitsis et al., 2013; Napoli and Purpura, 2018). These studies suggest that engaging in activities that support language skills can support math development and that relations between engaging in home literacy and home math activities may also explain relations between literacy activities and math development (Anders et al., 2012; Manolitsis et al., 2013; Napoli and Purpura, 2018). However, results are also mixed, such that some studies do not show significant relations between the home literacy environment and children's math abilities (LeFevre et al., 2009; Segers et al., 2015). Further, many studies examining relations between the home literacy environment and math abilities focus on math and numeracy skills more broadly (e.g., using broader measures that include multiple areas of early math skills), rather than examining relations with individual skills, such as arithmetic strategy use, directly.

Overall, these studies highlight the importance of the home learning environment and indicate that children's math development is influenced by factors in their home environments. As these home factors are known to relate to children's math skills in general, it is plausible that these same factors influence children's developing understanding and use of addition strategies. The current study examines this by considering how children's engagement in activities at home influences their addition strategy use.

The goal of the current study was to examine the role of the home environment in children's addition strategy use. Specifically, we examined how both structural characteristics of children's home environment, such as socioeconomic status (SES), as well as the learning environment, such as engagement in math and literacy activities at home, relate to their use of problem-solving strategies for numerical addition problems. The study contributes to the literature by examining the relation of children's home activities to both accuracy and strategy use. Because the sophistication of children's strategy use relates to their later math performance, and becomes increasingly predictive of math performance longitudinally (Geary et al., 2017), understanding factors that may influence children's development and use of addition strategies is critical.

The first aim was to examine structural characteristics of children's home environment in relation to their strategy use during arithmetic problem solving. We examined how SES related to children's use of strategies to solve addition problems. We expected to replicate previous findings that income relates to strategy use, with children from higher-income backgrounds tending to use more efficient, sophisticated strategies, and children from lower-income backgrounds tending to use more inefficient strategies (Laski et al., 2016).

The second aim was to examine children's home learning environment in relation to their addition strategy use. We examined how the frequency of children's engagement in learning activities at home related to their use of strategies when solving addition problems. Engaging in more math activities, and specifically more activities related to mathematical problem solving, could provide children with more practice with basic math facts and enhance children's problem solving, and therefore promote their use of more sophisticated addition strategies. We also examined relations between children's addition strategy use and engagement in literacy activities at home, as these activities have the potential to support children's mathematical skills as well (Anders et al., 2012; Manolitsis et al., 2013).

The third aim was to examine if home activities moderated the relations between socioeconomic status and children's addition strategy use. Based on previous research examining relations of SES with children's arithmetic skills (Laski et al., 2016), math skills, and home environment (Dearing et al., 2012; Galindo and Sonnenschein, 2015; Daucourt et al., 2021), we expected that the relations between SES and addition strategy use would vary based on the frequency of engaging in activities at home. Examining if home activities are a moderator of these relations could provide information for future interventions for promoting children's arithmetic skills.

2. Materials and methods

2.1. Participants

Data were collected as part of two larger studies within a larger project, examining children's math and working memory skills (Ramani et al., 2019). Participants were 403 kindergarten children (mean age = 5.4 years, 51% female) recruited from public elementary and charter schools on the east coast and west coast of the United States.

At the time of consent, parents completed a survey of demographic information. Parents reported children's race and ethnicity, parent education level, family size, annual household income, children's language background, and children's level of bilingualism/trilingualism.

Thirty percent of children were African American or Black, 28% were Caucasian/White, 7% were Biracial/Mixed Race, 3% were Asian or Pacific Islander, 1% were American Indian or Alaska Native, 2% were other, and 29%, did not report race. For ethnicity, 45% of children were Hispanic/Latino, 37% were not Hispanic/Latino, 7% were other, and 11% did not report ethnicity.

Parents also reported the highest level of education for each of the child's parents/guardians. If parents selected multiple levels of education, the highest selected level was used. For mothers, 13% had some high school coursework, 27% had a high school diploma/GED, 25% had some college coursework/vocational training, 8% had a 2-year college degree, 8% had a 4-year college degree, 10% had a postgraduate or professional degree, and 9% did not report mother's education. For children's other parent, 18% had some high school coursework, 38% had a high school diploma/GED, 11% had some college coursework/vocational training, 5% had a 2-year college degree, 7% had a 4-year college degree, 6% had a postgraduate or professional degree, and 15% did not report other parent's education.

Eighty-eight percent of families reported their family size (the number of people typically residing in their household). The average reported family size was 4.42, with a range from 1 to 10.

For annual household income, 19% of families reported an annual household income less than $15,000, 23% reported an annual income of $15,000–$30,000, 13% reported an annual income of $31,000–$45,000, 8% reported an annual income of $46,000–$59,000, 6% reported an annual income of $60,000–$75,000, 5% reported an annual income of $76,000–$100,000, 5% reported an annual income of $101,000–$150,000, and 5% reported an annual income of $151,000 or more. Fifteen percent of families did not report annual household income.

Parents also reported the language children spoke the most at home. Specifically, 68% reported English, 15% reported Spanish, 3% reported English and Spanish, 1% reported Arabic, 1% reported Vietnamese, less than 1% reported Russian, less than 1% reported Turkish, less than 1% reported Albanian, less than 1% reported Japanese, and 10% did not report the language spoken at home.

In addition, parents reported their child's level of bi/trilingualism on a scale of 1 to 5. Thirty-four percent of children were not bi/trilingual (spoke predominantly one language), 11% were weak bi/trilinguals, 10% were non-fluent bi/trilinguals, 6% were practical bi/trilinguals, and 6% were fluent bi/trilinguals. 3% of families reported mixed categories, and 30% of families did not report children's level of bi/trilingualism.

2.2. Procedure

Children completed a measure of addition strategy one-on-one with an experimenter in their classroom or another room at their elementary school. Prior to participating, parents provided informed consent and children provided verbal assent.

2.3. Measures

2.3.1. Addition strategy

The addition strategy items, procedure, and coding were adapted from commonly used measures of addition strategy (e.g., Geary et al., 2004). Children were asked to solve a series of addition problems as quickly as they could without making too many mistakes. They were told they could use whatever way was easiest for them to get an answer. In one study, problems were shown one at a time on a computer screen. In the other study, problems were shown one at a time in a printed flip book. In both

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studies, two sets of problems (i.e., Set A, Set B) were used and were evenly counterbalanced across participants.

Children completed one practice problem (2 + 2) with feedback and 12 test problems with no feedback. Two problems were not included in these analyses as they differed across studies from which data were collected. The remaining 11 problems were administered in both studies. These included one practice problem, six simple problems, and four complex problems (Set A: 2 + 2, 3 + 5, 8 + 4, 16 + 7, 9 + 2, 9 + 15, 6 + 4, 14 + 8, 4 + 9, 3 + 18, 5 + 2; Set B: 2 + 2, 3 + 4, 6 + 2, 9 + 3, 9 + 14, 3 + 19, 7 + 3, 16 + 8, 8 + 5, 15 + 6, 4 + 7). For the simple problems, half of the problems had sums less than or equal to ten, and half had sums greater than ten. Approximately half of each of the simple and complex problems presented the larger addend first.

For each problem, the experimenter read the problem out loud (e.g., "What is 2 plus 2?") and recorded children's responses as well as any observed use of problem-solving strategies. After the children responded, the experimenter asked them how they got their answers. Children's accuracy was coded for each addition problem.

2.3.2. Addition strategy coding

Strategies were coded from experimenter observations and children's explanations of how they got their answer. Experimenters classified children's behaviors while solving the problems as using finger or verbal counting, retrieval, decomposition, or an undetermined strategy. Finger and verbal counting strategies were further classified as Min (starting at the higher number and counting up), Max (starting at the lower number and counting up), Sum (starting at zero and counting the sum of the two numbers), or Not specified (e.g., saying numbers in a random order, random finger movements, inaudible mouth movements). If children used both finger and verbal counting, but different subcategories of counting (e.g., min finger count and max verbal count), the more sophisticated strategy was recorded (e.g., mixed min count).

If children's descriptions of how they got their answers differed from experimenter observations (e.g., the experimenter observed finger counting and the child said they just knew it/retrieval), the experimenter's observations were used as the strategy observed. When no strategies were observed by the experimenter, the child's explanation was used to classify the strategy as retrieval or undetermined. Explanations including retrieval strategies ("I knew it," "Someone told me," "I guessed," "I used my brain") were classified as retrieval, and explanations including other strategies or nonsense answers (e.g., "I think it is," "It is easy") were classified as undetermined.

For the current study, responses were then coded based on a combination of accuracy and strategy sophistication (coding scheme adapted from Chu et al., 2018). Considering scores in this way is particularly useful because this approach takes into account problem-solving accuracy for each individual strategy used and scores values along a continuum, such that higher scores indicate correct answers solved with more sophisticated strategies, and lower scores indicate incorrect answers solved with less sophisticated strategies. The current coding scheme included 10 values, with values representing problems solved incorrectly and problems solved correctly, with increasingly sophisticated strategies (see Table 1 for values and definitions). Children's codes were summed to get total combined strategy and accuracy scores for all problems, for simple problems, and for complex problems. The average score for each problem type was used as an outcome measure.

2.3.3. Socioeconomic status

A composite consisting of household income and parent education was used as a measure of SES. First, an income-to-needs ratio was calculated by dividing the reported annual household income by the Census poverty threshold for the reported family size from the year of data collection (2016 or 2018). Because annual household income was reported on a scale of income intervals (e.g., $15,000 to $30,000), the midpoint of each family's reported income interval (e.g., $22,500 in this example) was used as the family's income for the calculation. Eighty-two percent of participants reported both income and family size, and family income-to-needs for those participants ranged from 0.3 to 7.9 (mean = 1.91). Family income-to-needs was positively correlated with mother's education ($r(304) = 0.691$, $p < 0.001$) and with other parent's education ($r(304) = 0.695$, $p < 0.001$). To create the composite of household income and parent education, the family income-to-needs ratio variable, mother's education variable, and other parent's education variable were each standardized. The range of values for these standardized variables was as follows: income-to-needs −0.96 to 3.56, mother's education −1.33 to 1.97, other parent's education

TABLE 1 Strategy and accuracy coding definitions.

Code	Value	Includes
Missing	0	Missing
Undetermined error	1	Error: Undetermined
Retrieval error	2	Error: Retrieval, Guessing, Count in head, Decomposition
Counting error	3	Error: Any counting strategy
Undetermined	4	Correct: Undetermined
Other count	5	Correct: Other counting
Sum/Max count	6	Correct: Sum/Max counting
Min count	7	Correct: Min counting
Advanced strategy	8	Correct: Count in head, Decomposition
Retrieval	9	Correct: Retrieval, Guessing

TABLE 2 Summary of home activities survey.

Item	Activity	*n*	*M*	*SD*
Item 1	Reading together	362	3.42	1.29
Item 2	Saying/singing the ABCs	347	3.13	1.46
Item 3	Counting out loud	351	3.72	1.26
Item 4	Counting by a number other than 1 (by 2's, by 5's, by 10's)	354	2.47	1.65
Item 5	Noticing letters and words	357	3.89	1.18
Item 6	Counting objects	353	3.89	1.23
Item 7	Labeling letters or words	353	3.38	1.39
Item 8	Talking about how many objects are in a set (e.g., there are 5 toys in the basket)	357	3.38	1.39
Item 9	Memorizing letters/sounds or sight words	363	3.67	1.30
Item 10	Memorizing math facts	354	3.61	1.33
Item 11	Writing numbers	357	3.47	1.31
Item 12	Point to letters/words while reading	354	3.61	1.33
Item 13	Comparing numbers (e.g., "2" is bigger than "1")	354	3.07	1.44
Item 14	Counting down (10, 9, 8, 7...)	351	2.97	1.60
Item 15	Talking about meanings of words	356	3.32	1.39
Item 16	Talking about what letters words start with	357	3.29	1.51
Item 17	Introducing new words and definitions	354	3.14	1.53
Item 18	Counting out money	347	2.30	1.48
Item 19	Asking questions when reading together	351	3.42	1.38
Item 20	Comparing amounts (e.g., 3 cookies is more than 1 cookie)	351	3.06	1.54
Item 21	Talking about letter sounds	353	3.53	1.38
Item 22	Using fingers to indicate how many	352	3.75	1.29
Item 23	Sounding out words	346	3.62	1.47
Item 24	Learning simple sums (e.g., 2+2)	356	3.27	1.51

Activities were rated based on the past month and rated on the following scale: (0) did not occur, (1) 1–3 times per month, (2) once per week, (3) 2–4 times per week, (4) almost daily, (5) daily, or (NA) activity is not relevant to my child.

−1.06 to 2.34. The total of the standardized values was used as the composite (as in prior measures; Hauser, 1994; Levine et al., 2010; Daubert et al., 2019).

2.3.4. Home activities survey

Parents completed a home activities survey at the time of consent. Parents reported the frequency with which they and their child had engaged in 12 literacy and 12 math activities over the past month (adapted from LeFevre et al., 2009; Skwarchuk et al., 2014; see Table 2 for a summary of the items).

3. Results

3.1. Preliminary analyses

Preliminary analyses were conducted in order to create meaningful composite variables from the home activities survey. An exploratory factor analysis was conducted using principal components analysis. Missing data were handled with listwise deletion, leaving a subsample of $n = 269$ participants with complete data on the home activities survey.[1] A Velicer's MAP test for number of components to extract indicated that 3 components should be extracted. Direct oblimin oblique rotation was used to account for overlap among components and to maximize the interpretability.

Three components were identified from this analysis, representing a basic activities factor, an advanced math activities factor, and a literacy activities factor (see Table 3 for loadings). These factors were used in subsequent analyses. As shown in Table 3, the literacy activities factor included 11 activities, such as reading together and talking about the meanings of words. The advanced math activities factor included eight activities such as learning simple sums and memorizing math facts. The basic activities factor included five items such as counting out loud and

1 The subsample of participants with complete data on the home activities survey was used for these preliminary analyses. The full sample of participants was used for all primary analyses.

TABLE 3 Summary of items and factor loadings.

Item	Activity	Advanced math activities	Literacy activities	Basic activities
Item 1	Reading together		−0.838	
Item 2	Saying/singing the ABCs			0.884
Item 3	Counting out loud			0.755
Item 4	Counting by a number other than 1 (by 2's, by 5's, by 10's)	0.659		
Item 5	Noticing letters and words		−0.723	
Item 6	Counting objects			0.513
Item 7	Labeling letters or words		−0.557	
Item 8	Talking about how many objects are in a set (e.g., there are 5 toys in the basket)			0.552
Item 9	Memorizing letters/sounds or sight words		−0.469	
Item 10	Memorizing math facts	0.764		
Item 11	Writing numbers	0.602		
Item 12	Point to letters/words while reading		−0.744	
Item 13	Comparing numbers (e.g., "2" is bigger than "1")	0.631		
Item 14	Counting down (10, 9, 8, 7...)	0.482		
Item 15	Talking about meanings of words		−0.743	
Item 16	Talking about what letters words start with		−0.697	
Item 17	Introducing new words and definitions		−0.737	
Item 18	Counting out money	0.509		
Item 19	Asking questions when reading together		−0.856	
Item 20	Comparing amounts (e.g., 3 cookies is more than 1 cookie)	0.469		
Item 21	Talking about letter sounds		−0.536	
Item 22	Using fingers to indicate how many			0.426
Item 23	Sounding out words		−0.659	
Item 24	Learning simple sums (e.g., 2 + 2)	0.668		

counting objects. This factor also included the saying/singing the ABC's activity, which, while related to literacy, is also a fundamental basic skill in early development, the same way that counting is.

We also conducted preliminary exploratory analyses to examine differences in average strategy use and home activities by potential covariates (gender and level of bilingualism/trilingualism). Results from t-tests indicated that there were no significant differences in strategy use ($t(383) = 1.359$, $p = 0.175$, $d = 0.139$), basic activities ($t(359) = -1.645$, $p = 0.101$, $d = -0.173$), advanced math activities ($t(359) = 0.536$, $p = 0.592$, $d = 0.056$), or literacy activities ($t(360) = -0.581$, $p = 0.561$, $d = -0.061$) as a function of children's gender. To examine the level of bi/trilingualism, children's level of bilingualism/trilingualism was classified into one of three groups: fluent monolingual, fluent bi/trilingual, and non-fluent bi/trilingual. Results from one-way ANOVAs indicated that there were no significant differences in strategy use ($F(1, 268) = 0.645$, $p = 0.423$), basic activities ($F(1, 267) = 0.260$, $p = 0.611$), advanced math activities ($F(1, 267) = 1.39$, $p = 0.240$), or literacy activities ($F(1, 268) = 1.886$, $p = 0.171$) based on children's level of bilingualism. Because there were no significant differences, gender and level of bilingualism/trilingualism were not included as covariates in subsequent analyses.

3.2. Descriptive statistics

Table 4 shows descriptive statistics for addition strategy use, home activities, and SES.

3.3. Primary analyses

3.3.1. Aim 1: Structural characteristics of the home

The first aim was to examine the relations between children's addition strategy use and SES, as a replication of previous research. Correlations between SES and children's average strategy use for simple and complex problems and percent strategy use for the types of strategies are shown in Table 5. SES was significantly positively correlated with children's strategy

TABLE 4 Descriptive statistics for addition strategy, home activities, and SES variables.

	n	Min	Max	*M*	*SD*
Average strategy use (overall)	399	0	7.7	3.21	1.48
Average strategy use (simple problems)	399	0	8.5	3.76	1.80
Average strategy use (complex problems)	399	0	7.25	2.36	1.37
Percent missing (Strategy 0)	401	0	100	3.34	12.80
Percent undetermined error (Strategy 1)	400	0	100	24.63	31.63
Percent retrieval error (Strategy 2)	400	0	100	19.68	25.79
Percent counting error (Strategy 3)	400	0	100	25.90	26.58
Percent undetermined (Strategy 4)	400	0	30	1.20	4.01
Percent other count (Strategy 5)	400	0	90	4.30	11.85
Percent sum/max count (Strategy 6)	400	0	80	8.20	11.92
Percent min count (Strategy 7)	400	0	80	5.57	11.42
Percent advanced strategy (Strategy 8)	400	0	70	3.37	10.01
Percent retrieval (Strategy 9)	400	0	50	4.05	8.32
Basic activities	363	0	5	3.58	1.05
Advanced math activities	363	0	5	2.93	1.16
Literacy activities	364	0	5	3.46	1.08
SES	303	−3.29	7.87	0.11	2.74

use overall and on simple and complex addition problems, such that children from higher SES backgrounds were more likely to solve addition problems accurately using more sophisticated strategies.

We also conducted regression analyses predicting average strategy use from SES. Results indicated that SES was a significant predictor of children's strategy sophistication overall, for simple addition problems, and for complex addition problems (Table 6). Overall, we found that SES accounted for 13% of the variance in children's average strategy use on the addition problems.

As part of Aim 1, we also examined more in-depth differences between lower- and higher-income groups in strategy sophistication. In these analyses, we used income as a measure of SES, to be able to compare with previous research (e.g., Laski et al., 2016). Specifically, to examine lower- and higher-income groups, we used an income-to-needs ratio of 1 as a threshold, comparing less than 1 with greater than or equal to 1 (e.g., Duncan et al., 1994; Dearing et al., 2001).

T-tests were used to compare strategy use for lower ($n = 140$) and higher ($n = 190$) income groups. For average strategy use, results indicated that there were significant differences in strategy use overall ($M_{low} = 2.87$, $M_{high} = 3.53$; $t(324) = -3.92$, $p < 0.001$, $d = -0.439$), on simple problems ($M_{low} = 3.37$, $M_{high} = 4.12$; $t(324) = -3.75$, $p < 0.001$, $d = -0.420$), and on complex problems ($M_{low} = 2.13$, $M_{high} = 2.63$; $t(324) = -3.19$, $p = 0.002$, $d = -0.357$), such that children from higher-income backgrounds were more accurate and used more sophisticated strategies than children from lower-income backgrounds.

We also compared differences in strategy use for use of the coded strategies (Figure 1). For interpretability, strategies are grouped as Error (strategies 1, 2, and 3), Undetermined (strategy 4), Counting (strategies 5 and 6), and Sophisticated (strategies 7, 8, and 9). We found the same pattern of results as average strategy use. Specifically, results indicated that there were significant differences in Error ($M_{low} = 75.18$, $M_{high} = 64.95$; $t(325) = 3.25$, $p = 0.001$, $d = 0.364$), Counting ($M_{low} = 9.06$, $M_{high} = 15.90$; $t(325) = -3.69$, $p < 0.001$, $d = -0.413$), and Sophisticated ($M_{low} = 10.58$, $M_{high} = 15.69$; $t(325) = -2.44$, $p = 0.015$, $d = -0.273$) strategy use, such that children from higher-income backgrounds were more likely to use counting and sophisticated strategies and less likely to have errors. There were no significant differences in Undetermined ($M_{low} = 1.15$, $M_{high} = 1.28$; $t(325) = -0.273$, $p = 0.785$, $d = -0.030$) strategy use, which was infrequently used overall.

3.3.2. Aim 2: Home learning environment

The second aim was to examine how children's engagement in activities at home related to their addition strategy sophistication. Correlations and regressions were used to examine these relations. Table 5 shows correlations between home activities composites and average strategy use for simple and complex problems and percent strategy use for the types of strategies. Overall, basic activities were not significantly correlated with average strategy use, however, advanced math and literacy activities were significantly correlated with average strategy use for both simple and complex arithmetic problems. In examining relations with specific strategy types, we found that basic activities were not significantly related to any individual strategy types. Advanced math activities were significantly negatively related to Undetermined Error and significantly positively related to Counting Error and Min Count. Literacy activities were significantly negatively related to Undetermined Error and significantly positively related to Sum/Max Count and Min Count.

TABLE 5 Correlations between strategy use, home activities, and socioeconomic status.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
1. Average strategy use (overall)	–																
2. Average strategy use (simple problems)	0.956**	–															
3. Average strategy use (complex problems)	0.817**	0.612**	–														
4. Percent missing (Strategy 0)	−0.167**	−0.077	−0.298**	–													
5. Percent undetermined error (Strategy 1)	−0.674**	−0.649**	−0.541**	−0.151**	-												
6. Percent retrieval error (Strategy 2)	−0.240**	−0.235**	−0.185**	−0.109*	−0.197**	–											
7. Percent counting error (Strategy 3)	0.199**	0.163**	0.217**	−0.097	−0.443**	−0.385**	–										
8. Percent undetermined (Strategy 4)	0.101*	0.107*	0.061	0.001	−0.002	−0.083	−0.144**	–									
9. Percent other count (Strategy 5)	0.340**	0.266**	0.394**	−0.045	−0.218**	−0.173**	−0.045	0.086	–								
10. Percent sum/max count (Strategy 6)	0.419**	0.434**	0.277**	−0.024	−0.373**	−0.221**	0.252**	−0.039	−0.071	–							
11. Percent min count (Strategy 7)	0.521**	0.507**	0.410**	−0.045	−0.260**	−0.186**	−0.01	0.018	0.004	0.114*	–						
12. Percent advanced strategy (Strategy 8)	0.516**	0.473**	0.461**	−0.031	−0.201**	−0.083	−0.153**	0.024	0.112*	−0.01	0.067	–					
13. Percent retrieval (Strategy 9)	0.415**	0.458**	0.220**	−0.006	−0.117*	−0.008	−0.208**	0.124*	0.069	−0.126*	0.028	0.103*	–				
14. Basic activities	0.033	0.019	0.051	−0.066	−0.055	0.011	0.077	0.014	0.023	−0.058	0.095	−0.049	−0.006	–			
15. Advanced math activities	0.182**	0.172**	0.154**	−0.06	−0.162**	−0.041	0.109*	0.06	0.075	0.028	0.139**	0.02	0.077	0.760**	–		
16. Literacy activities	0.235**	0.210**	0.222**	−0.139**	−0.169**	−0.044	0.099	0.039	0.071	0.111*	0.197**	0.037	0.045	0.715**	0.771**	–	
17. SES	0.361**	0.308**	0.369**	−0.068	−0.254**	−0.051	−0.007	0.071	0.150**	0.235**	0.227**	0.165**	0.019	−0.065	−0.045	0.304**	–

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

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TABLE 6 Summary of regressions predicting average strategy use from SES.

	Average strategy use (overall)			Average strategy use (simple problems)			Average strategy use (complex problems)		
Variable	β	t	p	β	t	p	β	t	p
SES	0.204	6.681	<0.001***	0.209	5.572	<0.001***	0.196	6.847	<0.001***
	$R^2 = 0.131$			$R^2 = 0.095$			$R^2 = 0.136$		
	$F(1, 297) = 44.630$, $p = <0.001$***			$F(1, 297) = 31.051$, $p = <0.001$***			$F(1, 297) = 46.876$, $p = <0.001$***		

***$p < 0.001$.

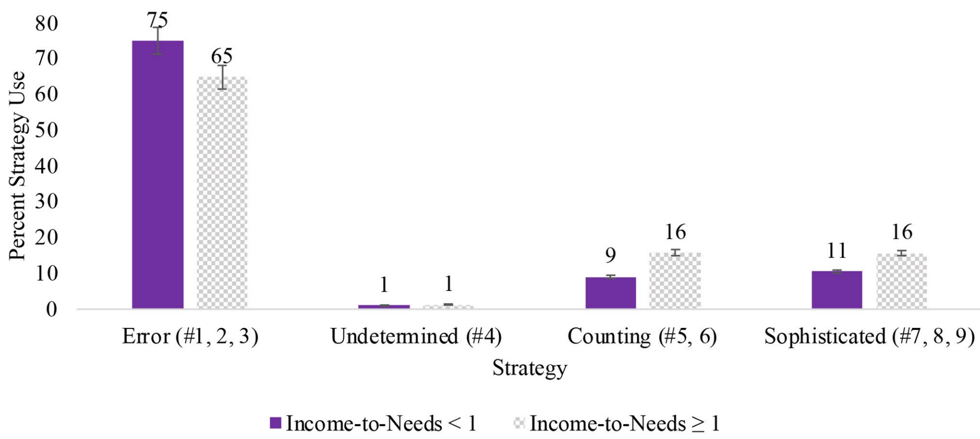

FIGURE 1
Strategy use by lower- and higher-income groups.

Results from regression analyses predicting average strategy use from home activities composites (Table 7) indicate that basic activities significantly negatively predicted strategy use and advanced math and literacy activities significantly positively predicted strategy use overall and for simple addition problems. For the complex addition problems, basic activities negatively predicted strategy use and literacy activities positively predicted strategy use, but advanced math activities did not.

As part of Aim 2, we also examined more in-depth differences between lower- and higher-income groups in reported engagement in home activities. As in Aim 1, we used income as a measure of SES, and used an income-to-needs ratio of 1 as a threshold, comparing less than 1 with greater than or equal to 1.

T-tests were used to compare home activities for lower- and higher-income groups. For home activities, results indicated that there were significant differences in literacy activities ($M_{low} = 3.09$, $M_{high} = 3.62$; $t(320) = -4.52$, $p < 0.001$, $d = -0.510$), such that children from higher-income backgrounds engaged in literacy activities at home more frequently than children from lower-income backgrounds. There were no significant differences in basic activities ($M_{low} = 3.53$, $M_{high} = 3.50$; $t(319) = 0.262$, $p = 0.794$, $d = 0.030$) or advanced math activities ($M_{low} = 2.86$, $M_{high} = 2.86$; $t(319) = 0.014$, $p = 0.989$, $d = 0.002$).

3.3.3. Aim 3: Structural characteristics × home learning environment

The third aim was to examine if children's engagement in home activities moderated the relations between SES and children's addition strategy use. Separate analyses were conducted for each activity type: basic, advanced math, and literacy activities. Table 8 shows results from regression models predicting average strategy use. Results indicated that advanced math and literacy activities significantly predicted strategy use overall as well as for the simple and complex problems. However, none of the SES x activities interactions were significant for any activity type indicating that home activities did not serve as a moderator between SES and children's addition strategy use.

4. Discussion

The goal of the current study was to examine the role of home environmental factors in children's accuracy and strategy sophistication while solving numerical addition problems. We considered both structural characteristics of the home (e.g., SES) and the home learning environment (e.g., engagement in math and literacy activities at home). Findings indicated that SES related to children's strategy sophistication (Aim 1), and that frequency of engaging in advanced math and literacy activities at home predicted strategy sophistication (Aim 2); however, in contrast to our

TABLE 7 Summary of regressions predicting average strategy use from home activities.

	Average strategy use (overall)			Average strategy use (simple problems)			Average strategy use (complex problems)		
Variable	*β (SE)*	*t*	*p*	*β (SE)*	*t*	*p*	*β (SE)*	*t*	*p*
Basic activities	−0.514 (0.117)	−4.387	<0.001***	−0.625 (0.142)	−4.403	<0.001***	−0.348 (0.111)	−3.124	0.002**
Advanced math activities	0.238 (0.116)	2.049	0.041*	0.319 (0.141)	2.276	0.023*	0.114 (0.110)	1.038	0.299
Literacy activities	0.490 (0.116)	4.224	<0.001***	0.527 (0.141)	3.753	<0.001***	0.434 (0.110)	3.938	<0.001***
	$R^2 = 0.104$			$R^2 = 0.095$			$R^2 = 0.074$		
	$F(3, 356) = 13.79$, $p = <0.001$***			$F(3, 356) = 12.41$, $p = <0.001$***			$F(3, 356) = 9.528$, $p = <0.001$***		

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

TABLE 8 Summary of regression models predicting average strategy use.

	Average strategy use (overall)			Average strategy use (simple problems)			Average strategy use (complex problems)		
	β	*t*	*p*	*β*	*t*	*p*	*β*	*t*	*p*
Basic activities									
SES	0.150	1.563	0.119	0.173	1.469	0.143	0.116	1.280	0.202
Activities	0.081	1.013	0.312	0.065	0.657	0.512	0.106	1.410	0.160
SES × Activities	0.016	0.572	0.567	0.009	0.274	0.785	0.026	0.988	0.324
	$R^2 = 0.129$			$R^2 = 0.090$			$R^2 = 0.145$		
	$F(3,288) = 14.32$, $p < 0.001$**			$F(3,288) = 9.547$, $p < 0.001$**			$F(3,288) = 16.28$, $p < 0.001$**		
Advanced math activities									
SES	0.155	1.954	0.052	0.195	1.997	0.0468*	0.095	1.272	0.205
Activities	0.256	3.490	<0.001**	0.283	3.146	0.002**	0.214	3.093	0.002**
SES × Activities	0.019	0.674	0.501	0.004	0.131	0.896	0.040	1.529	0.127
	$R^2 = 0.162$			$R^2 = 0.119$			$R^2 = 0.169$		
	$F(3,288) = 18.50$, $p < 0.001$**			$F(3,288) = 12.98$, $p < 0.001$**			$F(3,288) = 19.45$, $p < 0.001$**		
Literacy activities									
SES	0.177	1.318	0.189	0.233	1.412	0.159	0.093	0.734	0.464
Activities	0.204	2.356	0.019*	0.219	2.067	0.0396*	0.180	2.207	0.028*
SES × Activities	−0.001	−0.014	0.989	−0.016	−0.367	0.714	0.022	0.679	0.498
	$R^2 = 0.144$			$R^2 = 0.106$			$R^2 = 0.149$		
	$F(3,289) = 16.16$ $p < 0.001$**			$F(3,289) = 11.36$, $p < 0.001$**			$F(3,289) = 16.94$, $p < 0.001$**		

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

expectations, engaging in activities at home did not moderate the relations between SES and strategy sophistication (Aim 3).

4.1. SES and strategy use

Previous research has found that problem-solving accuracy and strategy use vary for children from different socioeconomic backgrounds. Specifically, studies have shown that children from lower-income backgrounds have lower accuracy and use less sophisticated strategies when solving problems than children from higher-income backgrounds (Laski et al., 2016). We replicated these results in the current study, finding that children from higher SES backgrounds (based on income and parent education) were more likely to solve addition problems accurately using more sophisticated strategies. This pattern was consistent for both simple addition problems and complex addition problems. Overall, we found that SES explained 13% of the variance in strategy sophistication. For comparisons based on only income, we found that children from higher-income backgrounds were more likely to use counting and sophisticated strategies and less likely to have errors than children from lower-income backgrounds. Specifically, children from lower-income backgrounds had errors on 75% of problems, compared to 65% of problems for children from higher-income backgrounds. Many factors, including differences in access to resources and learning opportunities, may contribute to these differences. In order to get a better understanding of the factors impacting these differences, we further examined the role of the home learning environment as one of the variables driving the association between strategy use and SES. Understanding the role of these home factors is important for developing interventions and making recommendations for ways to support children in their development of math and problem-solving skills.

4.2. Home learning environment and strategy use

We examined the home learning environment in relation to children's addition accuracy and strategy sophistication, as previous research has shown that engagement in math and literacy activities at home positively relates to children's math skills. Overall, our results showed variability in families' engagement in each type of activity at home. In examining differences between lower- and higher-income groups, we found that children from higher-income backgrounds engaged in more literacy activities than children from lower-income backgrounds, but that there were no differences between groups in basic activities or advanced math activities. Previous studies of the home math environment show inconsistent patterns, with some studies finding that children from higher-income backgrounds engage in more math activities at home than children from lower-income backgrounds (DeFlorio and Beliakoff, 2015) and that SES relates to engagement in math activities at home (Susperreguy et al., 2020), some finding that there are no significant relations between home math activities and SES (Hart et al., 2016; De Keyser et al., 2020), and other studies finding that home math activities relate to parent education-based measures of SES but not income-based measures of SES (Muñez et al., 2021). In the current study, it is possible that while there were no differences between groups in the frequency of engaging in basic activities and advanced math activities, there could be potential differences in other aspects of engagement in the activities, such as the type and quality of parent–child interactions during the activities.

In examining relations between home learning activities and addition strategy sophistication, we found different patterns of results for each activity type. Engaging in literacy activities was correlated with strategy use and significantly predicted average strategy use for simple and complex problems. This finding is consistent with prior work that shows positive relations between literacy activities and math performance (Anders et al., 2012; Manolitsis et al., 2013), and extends previous findings by examining these activities specifically in relation to arithmetic and problem-solving strategy sophistication. Previous research has suggested that engaging in literacy activities supports math development through vocabulary and language skills and through relations of the home literacy and home math environments (Anders et al., 2012; Manolitsis et al., 2013; Napoli and Purpura, 2018). In the current study, we also found that the frequency of engaging in literacy activities and advanced math activities at home was related. In addition, as previous research has indicated that language and phonological skills relate to arithmetic performance (Vukovic and Lesaux, 2013; Liu et al., 2020), it is also possible that engaging in literacy activities at home that support development of phonological skills can support children's development of arithmetic strategy use through these skills as well.

Engaging in basic activities did not correlate with strategy use and negatively predicted average strategy use for simple and complex addition problems. In contrast, engaging in advanced math activities was correlated with strategy use and positively predicted average strategy use. This is consistent with other research showing that advanced but not basic math activities are predictive of kindergarten children's performance on a standardized math test (Muñez et al., 2021). One reason for this difference may be the types of skills that are practiced during each type of activity. In the current study, advanced math activities included activities that were more directly related to arithmetic and problem-solving (e.g., learning simple sums, memorizing math facts, and comparing numbers) than basic activities, which were more focused on counting and cardinality skills (e.g., counting out loud, talking about how many objects are in a set). Previous research has shown that there can be specificity in the relations between home activities and math skills. For example, Leyva et al. (2021) found that the frequency of engaging in adding/subtracting activities at home predicted 4-year-old children's performance on addition and subtraction story problems. The current study adds to these findings by examining not only accuracy in problem solving, but strategy use during problem solving as well. In summary, our findings considering the different categories of home activities in relation to strategy use suggest that engaging in advanced math activities and literacy activities may support children's arithmetic and problem-solving skill development more than engaging in basic activities. These findings have implications for family engagement. Specifically, although basic activities (e.g., counting activities) are also important for children's early number skills, it is possible that engaging in activities around more advanced math skills (e.g., comparing numbers and quantities, applying basic number skills) may be particularly important for supporting more advanced math skills, such as arithmetic and use of sophisticated problem-solving strategies.

4.3. SES, home learning environment, and strategy use

We examined home activities as a potential moderator of the relations between SES and strategy use. As expected, our results indicated that engaging in advanced math activities and literacy activities at home predicted strategy use above and beyond SES. These results provide further evidence that home activities are important to consider in relation to children's addition accuracy and strategy sophistication, and that certain types of activities may relate to children's arithmetic skills more than others.

Contrary to our predictions, however, relations between SES and strategy use did not vary based on the frequency of engaging in activities at home. Previous studies have found varying relations between SES, the home learning environment, and children's math skills. For example, Dearing et al. (2012) found that general home learning investments (e.g., encouraging children to develop hobbies, the child having a desk or special place for reading or studying) mediated the relations between SES and math activities, and that math activities mediated the relations between general home learning investments and arithmetic performance. Another study examining relations of the home learning environment and math achievement found that SES moderated the relations between math achievement and general learning activities (e.g., play games or do puzzles, talk about nature or do science projects, play sports and build things together) and math achievement and between reading learning activities (e.g., frequency of looking at picture books) and math achievement, with results indicating that the relations between activities and achievement were stronger for children from higher SES backgrounds (Galindo and Sonnenschein, 2015). In addition, results from a meta-analysis found that overall, SES did not moderate relations of the home math environment and children's math achievement, however, there were differences in the effects based on the SES of the samples, with results indicating that the relation between direct activities and math was stronger for children from lower SES backgrounds than children from higher SES backgrounds (Daucourt et al., 2021).

Results from the current study add to these previous findings by indicating that engaging in advanced math activities and literacy activities at home predicted strategy use above and beyond SES. In the current study, we did not test if home activities mediated the relations of SES and strategy use, because SES did not predict engagement in basic or advanced math activities at home. Further, as described above, there were no differences between lower- and higher-income groups in basic activities or advanced math activities in the current sample. It is possible that other differences could contribute to the pattern of results. For example, the current measure of home learning activities focused on frequency of engaging in activities at home. It is possible that differences in how parents and children engage in activities together (e.g., the types of talk parents and children engage in, parent–child social engagement and interactions during the activities; and attitudes toward and enjoyment of the activities; Vandermaas-Peeler et al., 2009; Vandermaas-Peeler and Pittard, 2014) may impact relations of SES and strategy use differently than the frequency of engaging in activities together.

4.4. Limitations and future directions

The current study has several limitations and directions for future research. First, it is important to note the various ways SES is measured in the literature. Previous studies have used measures of SES including only income (Hart et al., 2016; Laski et al., 2016), income-to-needs calculated with income and family size (Dearing et al., 2012); school-based income-related variables (DeFlorio and Beliakoff, 2015; De Keyser et al., 2020), only parent education (Susperreguy et al., 2020) and a combination of income, parent education, and parent occupation (Galindo and Sonnenschein, 2015). Consistent with prior studies (e.g., Hauser, 1994; Levine et al., 2010; Daubert et al., 2019), the current study used a composite of income (income-to-needs calculated with annual household income and reported family size) and parent education (highest levels of education attained by the child's mother and other parent). It is possible that examining different aspects of socioeconomic status could influence results, as it is possible that different components of SES may relate to home learning activities and children's arithmetic skills differently.

It is also important to consider measurement of the home learning environment. The current study used parent-reported frequency of engagement in math and literacy activities at home. While this is a common method for measuring the home environment (Mutaf-Yıldız et al., 2020; Hornburg et al., 2021), other methods, such as observing parent–child engagement in activities at home, could provide additional information about the relations between home activities and addition strategy sophistication. In addition, the current measure primarily focused on formal/direct activities (Skwarchuk et al., 2014), rather than informal/indirect activities (such as playing math board or card games, singing counting songs, making up rhymes in songs; Skwarchuk et al., 2014.). As informal activities are also important for early math development and relate to children's math performance (Niklas and Schneider, 2014; Mutaf Yıldız et al., 2018; Zhang et al., 2020), future studies could examine these types of activities in relation to children's addition strategy use as well.

Further, the current study did not include measures to examine relations with other aspects of the home learning environment, such as parent attitudes and beliefs about math and literacy. As previous research indicates that parent attitudes and beliefs about math (e.g., importance of math, math anxiety, expectations for children's math learning) relate to children's math performance (Elliott and Bachman, 2018), it is possible that these factors could influence children's arithmetic and strategy sophistication as well.

Finally, in the current study, the number of problems that children answered correctly versus incorrectly was not evenly distributed. Children answered the majority of the arithmetic problems incorrectly. Future studies could examine relations between SES, home activities, and strategy sophistication in a sample with a more even distribution of correct and incorrect responses to see if results are consistent when children have higher accuracy in problem solving. In addition, future work could further examine the types of errors children made, to understand children's problem solving more in-depth. For example, studies could examine the absolute error as well as if errors fall into patterns which could indicate usage of other strategy types (e.g., an addend plus one, naming an addend; Laski et al., 2016). Examining these would allow for more understanding of relations between strategy use and error type as well as relations between SES, home activities, and addition strategy use.

4.5. Conclusion

The current study examined relations between SES, home math and literacy activities, and addition strategies. The study addressed a gap in the literature by examining these aspects of children's home environments in relation to both accuracy and strategy sophistication during an arithmetic problem-solving task. Findings indicated that SES related to strategy sophistication, and that engaging in basic activities negatively predicted strategy sophistication and engaging in advanced math and literacy activities positively predicted strategy sophistication. These results suggest that family engagement in activities at home may promote early arithmetic skills, and that the role of home environmental characteristics should be considered in children's arithmetic strategy use and performance over development. As children's early strategy use relates to later math and problem-solving abilities, understanding factors that influence strategy use is important for children's math development and achievement.

Data availability statement

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

Ethics statement

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

Author contributions

MD: conceptualization, formal analysis, writing – original draft. SJ: conceptualization, writing – review and editing, funding acquisition; GR: conceptualization, writing – original draft, supervision, funding acquisition. All authors contributed to and approved the manuscript.

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Conflict of interest

SJ has an indirect financial interest in the MIND Research Institute, Irvine, CA, whose interests are related to this work.

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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The role of preschoolers' home literacy environment and emergent literacy skills on later reading and writing skills in primary school: A mediational model

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The importance of the quality of home literacy environment and practices (HLE&P) in the earliest years on children's reading and writing development is recognized in the literature. However, whether and to what extent this relationship between preschoolers' HLE&P on their later reading and writing skills in primary school is mediated by emergent literacy competence remains to be clarified. It may be that preschool constitutes a significant opportunity for children to develop notational awareness and phonological awareness which are emergent literacy skills that are fundamental for later reading and writing skills. Children who experience literacy-poor HLE&P with fewer opportunities to practice more complex language skills and diverse vocabulary might develop adequate reading and writing skills when their emergent literacy skills in preschool are high (notational and phonological awareness). This longitudinal study aimed to investigate the mediational role of preschoolers' emergent literacy skills in preschool (notational and phonological awareness) in the relationship between HLE&P and reading and writing skills shown by the same children in primary school using a large-scale dataset. A total of 115 children (mean-age at last year of preschool=4.88±0.36) took part in the research. In preschool, children performed emergent literacy tasks and their parents completed a home literacy questionnaire. Later, in primary school, children completed standardized assessments of spelling (orthographic accuracy and fluency in a dictation task) and reading decoding (accuracy and speed in a text reading task) skills. The results of mediational analyses showed that notational awareness totally mediates the relationship between HLE&P and reading speed ($\beta=-0.17$, $p<0.05$) and writing accuracy ($\beta=0.10$, $p<0.05$), but not for reading accuracy in primary school. The mediational model with phonological awareness as mediator was not significant. The results are discussed in the light of the effect of preschool in contributing to filling children's home literacy gaps and disadvantages. In preschool, emergent literacy programs are essential to counterbalance the needs of preschoolers to develop adequate reading and writing skills when the family cannot provide enriched HLE&P from the early years of life.

KEYWORDS

home literacy environment and practices, notational skills, phonological skills, reading, writing, longitudinal research

1. Introduction

The importance of the quality of home literacy environment and practices (HLE&P) in the earliest years on the development of emergent literacy skills (Incognito and Pinto, 2021) and on children's reading and writing development (Kim, 2009) is recognized in the literature. Children in preschool develop important emergent literacy skills such as notational awareness and phonological awareness which are fundamental for later reading and writing skills (Pinto et al., 2009, 2016; Bigozzi et al., 2016a,b). Mol and Bus (2011) conducted a meta-analysis and found that shared book reading with preschoolers supported young children's language, reading, and spelling growth over time. However, whether and to what extent the relationship between preschoolers' HLE&P on their later reading and writing skills in primary school is mediated by emergent literacy skills remains to be clarified. As highlighted by meta-analysis in this field of research (Zhang et al., 2021) most studies used cross-sectional designs limiting our knowledge of long-term associations between HLE&P in the emergent literacy period and later formalized literacy outcomes. Moreover, the interconnections between children's home literacy factors and different environmental settings, such as preschool, require further investigations to understand the impact of home literacy on later reading and writing development. Therefore, we developed a longitudinal study aimed at examining the mediational role of preschoolers' emergent literacy skills in preschool in the relationship between HLE&P and reading and writing skills shown by the same children in primary school using a large-scale dataset.

1.1. Home literacy and emergent literacy skills in preschool

In this study, we refer to a model of reading and writing development in primary school closely linked to the previous important literacy experiences that young children have at home (Kim, 2009) and at preschool (Pinto et al., 2012). As documented in previous studies (Sénéchal and LeFevre, 2002), in fact, the predictors detected that the acquisition of reading and writing skills is best conceived as a *continuum* that begins in the preschool period and continues along the formalized literacy period. According to Bronfenbrenner's ecological theory (1979), it is possible to trace young children's reading and writing development by referring to the microsystem of the family where important informal home experiences related to literacy occur. Different theoretical frameworks have emerged in understanding the construct of *home literacy*. Comprehensively, models proposed in the literature (e.g., Sénéchal and LeFevre, 2002; Manolitsis et al., 2011) show that both code-related practices and meaning-related practices are important to fully conceive home literacy of children who are preschoolers. Code-related practices see a direct involvement of 4-to-6 years old children with print, such as invented spelling activities, meanwhile meaning-related activities focus on sharing and constructing meanings, such as 4-to-6 years old children's telling stories. Thus, home literacy is an articulated construct that includes practices that are autonomously activated by the child (Sénéchal and LeFevre, 2002), as well as practices guided by the parent, some of which incidentally promote literacy (e.g., joint reading of stories), while others are intentionally intended to promote literacy (e.g., the parent teaching the child the alphabet) (Sénéchal et al., 1996, 1998). Different families may vary in their HLE&P, for example in terms of literacy materials and stimuli used by the family or in terms of literacy practices, for example the participation of children in a joint book reading session with their parents (Niklas and Schneider, 2015) or telling and inventing stories, all activities connected to a child's cognitive, creative and lexical development (Noble et al., 2019). Most of the studies framed on the model of Home Literacy focus on a quite limited developmental span, usually ages 4–6. Moreover, there is the need to study home literacy in connection with preschool when young children have the opportunity to develop important emergent literacy skills for later reading and writing development, such as notational awareness and phonological awareness. Phonological awareness denotes 4-to-5 years old children's ability to identify units of sounds in words and manipulate patterns of sound, such as in the preschool activity of developing rhyme and identifying similar sounds in words. Phonological awareness is a key competence across alphabetic orthographies, but it plays a stronger role in predicting literacy outcomes in opaque orthographies where there is an irregular correspondence between sound-sign (Georgiou et al., 2012; Moll et al., 2014) in comparison to regular orthographies. Strictly linked to phonological awareness, notational awareness denotes 4-to-5 years old children's ability to translate sounds into appropriate written signs by using a phoneme-grapheme correspondence, such as the preschool activity of invented spelling. Prior studies have recognized the predictive role of phonological awareness and notational awareness for later reading and writing acquisitions, even if their predictive weight changes in relation to the specific characteristics of orthographies. In the transparent Italian language, the emergent literacy model validated by Pinto et al. (2009) was composed by preschoolers' notational awareness, phonological awareness, and textual awareness. Subsequent longitudinal research results based on this model (Bigozzi et al., 2016a) showed the predictive value of the three key emergent literacy skills on later reading and writing acquisitions. These results confirmed the predictive role of 4-to-5 years old children's phonological awareness on later literacy outcomes, even if 4-to-5 years old children's notational awareness played a stronger predictive role on later reading and writing acquisitions in Grade 1 and 2 (Pinto et al., 2017) in comparison to phonological awareness, while textual competence uniquely predicted later text writing skills (Pinto et al., 2016).

It is important to investigate the interaction between preschoolers' home literacy and emergent literacy skills in predicting primary school children's reading and writing skills in the Italian language which has regular and transparent orthography with an almost biunivocal correspondence between grapheme and phoneme. Each of the five vowels has only one orthographic translation in Italian, regardless of the context in which they are reported. Consonants have only one orthographic translation with a few exceptions (e.g., stop consonants and affricates: /k/and/g/; /tʃ/and/dʒ/). Beyond a few cases in which the orthographic rendition of the word is phonologically unpredictable (e.g., the voiceless velar/k/followed by the vowel/u/is rendered in/kwadro/ [picture] as "quadro"). Preschoolers with high levels of notational awareness show the ability to master the reciprocal sound-sign correspondence at the basis of reading and writing words, the availability in memory of the orthographic representation of the letters of a word and ability to transfer all this knowledge to a sheet of paper (Sénéchal et al., 2001; Pinto et al., 2009) with positive repercussions on their later reading and writing acquisitions in primary school years (Ouellette and Sénéchal, 2017; Albuquerque and Alves Martins, 2022). Thus, it may be expected that preschoolers' notational skills play a significant role in predicting reading and writing in interaction with home literacy. The predictive role of home literacy and emergent literacy skills in preschool must be tested in their simultaneous interaction, rather than in isolation, and across languages that differ in orthographic depth to confirm whether it is a language specific pattern or it is transversal across languages (Georgiou et al., 2012).

1.2. Reading and writing: The role of home literacy and emergent literacy skills

The close relationships between preschoolers' HLE&P on emergent literacy skills and later reading and writing have been identified in previous studies.

Previous studies have shown a direct relationship between home literacy and emergent literacy skills in preschool. For example, based on conceptual models in the literature (Fritjers et al., 2000; Rodriguez and Tamis-LeMonda, 2011), Kim et al. (2015) used a composite measure of home literacy in toddlerhood (e.g., 4.5 years old) and found that it predicted both vocabulary and decoding skills measured at preschool age. One longitudinal study (Sénéchal and LeFevre, 2014) from preschool to the beginning of Grade 1 showed links between home literacy environment and reading in English.

Another longitudinal study conducted in the transparent Italian language system (Incognito and Pinto, 2021) showed links between home literacy assessed as a composite score in the last year of preschool and emergent literacy skills assessed at the beginning and end of the preschool year. Indeed, preschoolers with high levels in home literacy practices were more likely to show high oral narrative skills and notational awareness at the beginning of the last year of preschool, while this relationship was less evident for phonological awareness. A link between home literacy and preschoolers' emergent literacy skills has also been found in Korean children of four and 5 years (Kim, 2009) since frequent reading at home was positively associated with children's emergent literacy skills, as well as conventional literacy skills.

Research with preschoolers has also revealed connections between emergent literacy skills with later reading and writing acquisitions in the formalized literacy period in different language systems (e.g., Silinskas et al., 2020; Zhang et al., 2020). In consistent orthographies, like Italian, which have a biunivocal relationship between phoneme and grapheme, preschoolers who master the correspondence between sound-sign, named notational awareness, are more likely to succeed in later reading and writing tasks at school (Pinto et al., 2012). Also, preschoolers' ability to identify and manipulate phonological segments in spoken words, named phonological awareness, have consistently been found to be closely associated with children's reading development with different predictive weights depending on the characteristics of orthographies in transparent languages (Landerl et al., 2019). It is important to adopt a cross-linguistic perspective on the study of home literacy impact on early literacy development (Inoue et al., 2020). Taken together, a body of research has provided evidence of relationships between HLE&P with preschoolers' emergent literacy skills and primary school children's reading and writing skills.

These results suggest the importance of a future study in order to provide an accurate picture of the relationships between preschoolers' HLE&P, emergent literacy skills, with later reading and writing skills using mediational models. Indeed, it would be desirable to promote a better understanding of the transition from emergent to formalized literacy period by considering the preschool period as a key period for reading and writing acquisitions. The longitudinal study by Inoue et al. (2018) showed the relationships between home literacy environment and emergent literacy skills in kindergarten, and different reading outcomes in primary school years in Canadian children learning to read English. Although the literature informs us about the relationships between home literacy and emergent literacy skills or between home literacy and later reading and writing development, there is a lack of knowledge about the mediational role of preschoolers' emergent literacy skills in the relationship between HLE&P and later reading and writing skills in transparent orthographies like Italian.

2. This study

A longitudinal study was developed to investigate the pattern of relationships between HLE&P with emergent literacy skills (i.e., notational awareness and phonological awareness) measured in preschool, and later reading and writing skills measured in the same children in the first grade of primary school. We intended to explore this pattern of relationships using a longitudinal mediational model, rather than by the more commonly used direct model of analysis widely spread in the literature. The longitudinal research design allowed us to connect preschool, as a key period for reading and writing acquisitions, with the formalized school period that in the Italian educational context starts at 6 years and corresponds to the formalized teaching of reading and writing. Following models of emergent literacy, we assumed as mediators preschoolers' notational awareness and phonological awareness, chosen for their significant predictive contribution to reading and writing found in previous studies conducted in the Italian transparent language system (Pinto et al., 2009; Bigozzi et al., 2016b).

We expected HLE&P to positively contribute to the development of emergent literacy skills in preschoolers and later reading and writing skills in primary school. More specifically, we expected that this relationship would take the form of a mediational model where preschoolers' emergent literacy skills exert a significant mediational role between HLE&P measured in preschool and later reading and writing skills measured in primary school.

3. Methods

3.1. Participants

A total of 115 children (mean-age at the last year of preschool = 4.88 ± 0.36; male = 57% and female = 43%) attending public all-day preschools in Italy were followed longitudinally till the first year of primary school. *In a first step*, the children were tested when attending their last year of preschool. The Italian preschool is a 3-year program that involves children from 3 to 6 years with a curriculum that follows national guidelines established by the Ministry of Education. Italian preschool programs do not provide formal instruction in reading and writing, rather they include pre-reading and pre-writing activities with a multimodal modality (e.g., drawing, invented spelling, songs) with the aim of facilitating children's knowledge of letters, letter-sound and letter-sign correspondences. Approximately 96% of Italian preschools are public and are attended by approximately 98% of children with a school week of about 40 h. The transition from preschool to primary school usually occurs in the same school district making it quite easy to follow children longitudinally over time. *In a second step*, the same children were tested 1 year later when attending their first grade in primary school when formal teaching of reading and writing occurs. The Italian primary school is a 5-year program that involves children from 6 to 10 years with a curriculum that follows national guidelines established by the Ministry of Education. In the Italian schooling system, the formal instruction of reading and writing starts at the beginning of the first year of primary school with the expectation that children can reach an adequate level of coding and decoding accuracy at the end of the year (Pinto et al., 2015).

Participants were recruited from public schools located in two small towns in central Italy. They came from families with medium socioeconomic backgrounds, in line with the 2022 budget estimates (ISTAT,[1] 2022).

Children with any known special educational needs or impairments/disorders were excluded from analyses to avoid any additional difficulties that could potentially affect their performance.

School authorities, parents, and children gave consent to participate in the study.

3.2. Measures

3.2.1. First step of assessment in preschool—Home literacy environment and practices

To investigate preschool children's home literacy and practices, we used a questionnaire (see Incognito and Pinto, 2021) that required parents to determine the extent of the reading material that children between three and 5 years old had access to at home; parents' habits with regard to reading with and to the child; parent's opinions on how they approached the child's development of oral language, writing and reading; parents' observations on the child's behavior with regard to written language; and how parents answered any questions on the subject. The questionnaire collected data on activities consistent with existing models, including activities in which both father and mother are involved. Examples of items were "When does your child receive books and/or periodicals?" or "Do you read books and/or periodicals to your child?" or "When faced with your child's curiosity about written things, how do you deal with it? (e.g., do you tell him/her what is written in it; take cues to teach him/her the first rules of writing; etc.)." Responses were required on a 3-point scale noting the frequency of the behavior enacted. The range of responses was from 0 to 3 points. The questionnaire consisted of 15 items. Both parents separately completed the questionnaire. A composite score was generated by averaging the mother's and father's scores. Based on home literacy indices, the children were distributed as follows: 46% with low levels of home literacy and 54% with high levels of home literacy. In the data used in this study, Cronbach's alpha coefficient for the composite measure of the HLE&P was 0.70.

3.2.2. First step of assessment in preschool—Notational awareness

Notational awareness was evaluated with an invented spelling task (Bigozzi et al., 2016a). Children were asked to draw, write, and read aloud what they had written by following it with their finger. The task was administered individually, and each child was equipped with a pencil and a white A4 sheet of paper to perform the test, which consisted of seven items. The first item is familiarization in which the child is asked to write his/her name as he/she knows how and read it by following it with his/her finger.

The other six items encode three components of notational awareness, which shows whether the child is aware of the diversity between iconic representation and written sign, numerical variation, and variation in phonemic units.

Specifically, two items measured the conceptual knowledge of orthographic notation that shows whether children are aware that there is a specific and exclusive sign system, other than the iconic sign, for writing the sound stream. An example item was, "Can you draw an apple? Can you try to write *mela* (apple)? Can you try to read what you wrote by following it with your finger?"

Another two items measured conceptual knowledge of the orthographic variation of sound quantity showing whether the child is aware that the number of spoken word sounds and the number of written sounds. An example item was, "Can you try to write the shortest word and the longest word you know? Can you try to read what you wrote by following it with your finger?"

Finally, two items measured conceptual knowledge of the orthographic variation of phonemic units. This coding scheme shows whether children are aware that similar sounds require the affixation of similar signs and different sounds of different signs. An example item was, "Can you try to write *gatto* (cat) and *gatti* (cats)? Can you try to read what you wrote by following it with your finger?"

Each item was coded, and a mean score was calculated. Participants' scores ranged from a minimum of 0 to a maximum of 3. The agreement index of independent judges was between 90 and 99%. In the data used in this study, Cronbach's alpha coefficient for the composite measure of the notational awareness context was 0.85.

3.2.3. First step of assessment in preschool—Phonological awareness

To assess phonological awareness, a task involving the identification and production of sound patterns was administered (Dowker and Pinto, 1993; Pinto et al., 2009). Children were exposed to two verbal stimuli, one containing rhymes, and the other containing a series of alliterating words. Children were asked to listen to a short poem and invent a similar poem, with the stimuli acting as examples.

According to the Dowker and Pinto task, examples of Italian stimulus poems included: (1) Rhyming: II gatto Martino/ Uscendo il mattino/ Scendendo le scale/ Si fece del male. ("The cat Martino/Getting up in the morning/and going downstairs/Hurt himself."); (2) Alliterating: Per una strada/Stretta e storta/Una strana cavalla/Trotta stanca. ("Along a street/Narrow and crooked/a strange horse/trotted wearily.")

Three scores were derived for rhythm (children's ability to reproduce the prosody), rhyme (children's ability to detect the rhymes

1 https://www.istat.it/it/files//2022/12/Istat-Audizione-Bilancio-2023.pdf

within the stimulus), and alliteration (children's ability to detect alliterations within the stimulus); specifically, the rhythm of a poem is given by the way the lines are structured. By rhyme we mean when two or more words share sounds at the end of the word itself, usually based on a corresponding vowel and the sound that follows it. Whereas, alliteration is a repetition of letter sounds within words. A score of 0 indicated no rhythm/rhyme/alliteration produced, 1 indicated one rhythm/rhyme/alliteration produced, and 2 indicated two or more rhythms/rhymes/alliterations produced. The agreement index of independent judges was between 90 and 99%. In the data used in this study, Cronbach's alpha coefficient for the composite measure of the phonological awareness context was 0.84.

3.2.4. Second step of assessment in primary school—Writing skills

3.2.4.1. Writing accuracy

A paper-and-pencil text dictation standardized for the Italian population (Tressoldi and Cornoldi, 2000) was used to measure writing accuracy in primary school children. The dictation was performed individually by children in a collective classroom session during school time. Based on the procedure in the manual, the children had to listen to a recorded text and to write down the text. We referred to the classification by Pinto et al. (2012) to identify the orthographic errors in text dictation. The classification allows one to identify the entire variability of orthographic errors that children may commit in Italian orthography, including the cases in which the pronunciation of the target word is preserved despite the spelling violation (e.g., "hanno" [have] instead of "anno" [year]), and the cases in which the pronunciation of the target word is changed due to a spelling violation ("tristezza" instead of "tristeza" [sadness]). The ratio between the total number of orthographic errors and the total number of written words produced the "writing accuracy" score (see, Pinto et al., 2012). According to the norms of this writing test, Cronbach's alpha coefficient for the scale is 0.83.

3.2.5. Second step of assessment in primary school—Reading skills

3.2.5.1. Reading accuracy and reading speed

The MT reading test (Cornoldi et al., 1998) was used to measure reading accuracy and reading speed in primary-school children. It is a standardized test with strong psychometric properties administered by the experimenter to the children individually. Based on the procedure in the manual, the child is asked to read a text aloud as best as he/she could, while the experimenter registered the reading time and errors. The number of errors while reading aloud, such as mispronounced, or omitted, or added syllables produced the "reading accuracy" score. The ratio between the reading time in seconds and the total number of read syllables produced the "reading speed" score (e.g., the higher the score, the slower the children read). According to the norms of this reading test, Cronbach's alpha coefficient for the scale is 0.70.

3.3. Data analysis

The main descriptive statistics for each variable (mean, standard deviation, minimum and maximum) and the Shapiro Wilk test for normality were calculated.

Preliminarily, Pearson's bivariate correlations were performed to test the relationships between the home literacy variable and the emergent literacy outcome variables measured in the last year of preschool, i.e., phonological awareness and notational awareness, and the school performance outcome variables measured in first grade, i.e., reading accuracy, reading speed, and writing accuracy.

In view of the observed correlations, causal relationships were tested with multiple linear regressions. The checking of causal relationships of variables is a necessary condition to carry out mediational models. Indeed, first, the (simple) mediational model requires that the process by which a variable X (independent variable - IV) has an effect on Y (dependent variable - DV) can be described as follows: X has an effect on M, M has an effect on Y, and therefore X has an effect on Y because of the intervention of M. The mediational model holds if the mediating variable possesses certain characteristics such as M must be able to be caused by X (Hayes, 2013). Second, in the case of a parallel (multiple) mediation model, a distinguishing feature is the assumption that no mediator causally influences another. These mediators are allowed to correlate with one another, but not to influence each other in causality. With parallel mediation, we can test each proposed mediator taking into account the shared variance among them. However, overly correlated mediators can create multicollinearity, which affects the estimation of their partial relationships with the outcome variable (Hayes, 2013).

Considering that the mediating variables (phonological and notational awareness) have a reciprocal causal effect and that phonological awareness is not caused by home literacy (see regressions in Results), we decided to perform simple mediation analyses.

Therefore, three simple mediating models were run, in which the independent variable (IV) was home literacy, the dependent variables (DV) were outcomes in school performance, and the mediating variables (MV) were emergent literacy skills: (1) DV: reading accuracy, IV: home literacy and MV: notational awareness; (2) DV: reading speed, IV: home literacy and MV: notational awareness; and (3) DV: writing errors, IV: home literacy and MV: notational awareness.

For the indirect effects, the percentile bootstrap was used to derive robust estimates of standard errors and confidence intervals for regression coefficient estimates.

4. Results

Table 1 shows the main descriptive statistics for each variable (mean, standard deviation, minimum and maximum) and the Shapiro Wilk test for normality. The results are in line with previous studies having a similar population, in terms of age and level of schooling and socioeconomic background (e.g., Pinto et al., 2015; Incognito and Pinto, 2021).

Table 2 shows the results of bivariate correlations with Pearson's coefficient. The results show that home literacy is significantly correlated with both emergent literacy skills, i.e., phonological awareness ($r = 0.58$, $p < 0.01$), notational awareness ($r = 0.55$, $p < 0.01$), and formalized literacy skills, i.e., reading speed ($r = -0.32$, $p < 0.05$), writing accuracy ($r = 0.23$, $p < 0.05$), except for reading accuracy ($r = 0.02$, $p =$ n.s.). All significant correlations are positive, except for reading speed in which correlation is negative. Therefore, the higher the level of home literacy, the higher the performance in emergent and formalized literacy tasks.

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TABLE 1 Descriptive statistics and Shapiro–Wilk coefficients.

	Mean (SD)	Minimum	Maximum	Shapiro–Wilk test
Home literacy	1.87 (0.78)	0	3	0.93***
Phonological awareness	1.62 (0.49)	0	2	0.75***
Notational awareness	2.38 (0.71)	0	3	0.82***
Reading accuracy	1.66 (2.24)	0	12	0.73***
Reading speed	1.31 (0.46)	0.39	2.57	0.96*
Writing accuracy	3.58 (4.30)	0	27	0.62***

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

TABLE 2 Pearson's correlational bivariate analysis.

	Home literacy	Phonological awareness	Notational awareness	Reading accuracy	Reading speed	Writing accuracy
Home literacy	-	0.58**	0.55**	−0.02	−0.32*	0.23*
Phonological awareness		-	0.53**	−0.05	−0.30*	0.03
Notational awareness			-	−0.11	−0.30*	0.29*
Reading accuracy				-	0.30*	−0.13
Reading speed					-	0.32*
Writing accuracy						-

**Correlation is significant at the 0.01 level (two-tailed). *Correlation is significant at the 0.05 level (two-tailed).

Multiple linear regressions were run to test the model's assumptions of mediation (simple or parallel) analysis. The results of the regressions show that phonological and notational awareness affect each other and that home literacy has no effect on phonological awareness (Table 3).

The simple mediating models were run separately for each formalized literacy variable.

Notational awareness turns out to be total mediator in the relationship between home literacy and reading speed (Figure 1) and writing accuracy (Figure 2). In both cases, the indirect effect is significant at $p < 0.05$, but total effect is not. Mediation occurs if the effect of the independent variable on the dependent variable is reduced (partial mediation) or canceled (total mediation) when the mediator is included (Hayes, 2009).

In line with Preacher and Hayes (2008), bootstrapping results showed that the indirect effect of home literacy on reading speed *via* notational awareness was significant (Lower C.I: −0.21; Upper C.I: −0.01), since zero was not included in the 95% confidence interval.

In the same way, bootstrapping results showed that the indirect effect of home literacy on writing accuracy *via* notational awareness was significant (Lower C.I: 0.10; Upper C.I: 1.10), since zero was not included in the 95% confidence interval.

5. Discussion

This longitudinal study provides results on the developmental relationships between home literacy and emergent literacy skills assessed in preschoolers, and their later reading and writing skills, assessed 1 year later when the same children attended primary school. Following Bronfenbrenner (1979) ecological theory and the field of research on emergent literacy (Sénéchal and LeFevre, 2002), theoretically, the study extended previous research on the connections between home literacy, emergent literacy skills, reading and writing outcomes by bridging significant life contexts such as home, preschool, and formalized schooling in a unitary way. Empirically, the study's findings added to the limited literature of precursors of reading and writing development by testing the mediating role of emergent literacy skills in the relationship between early home literacy and later reading and writing skills in a transparent orthography like Italian. The essential role of the emergent literacy period for the development of early reading and writing in primary school in children learning Italian which has a transparent orthography emerged in the literature (Pinto et al., 2017) was confirmed by our results. A large part of previous studies (e.g., Kim, 2009) mainly focused on investigating direct relationships between home literacy and later reading and writing skills. Few studies considered indirect and mediational pathways (e.g., Inoue et al., 2018). Our results provide significant developmental and mediational relationships between home literacy, emergent literacy skills, and later reading and writing skills in a transparent orthography.

Prior to considering the results of the mediational models, the results of correlation analyses provide interesting insights about the connections *within* the period of emergent literacy and *between* emergent and formalized literacy periods.

Regarding the connections *within* the period of emergent literacy, the results of correlation analyses showed preschoolers who have higher scores in their HLE&P have higher notational awareness denoting higher availability in their memory of the orthographic representation of the letters of a word and they are able to write letter-like sign on a sheet of paper. Also, preschoolers who have higher scores in their HLE&P have higher phonological

TABLE 3 Multiple linear regression analyses.

		β^1	t	p-Value	R-squared
DV: Phonological awareness	Home literacy	0.15	1.52	0.13	0.30***
	Notational awareness	0.46	4.78	<0.001	
DV: Notational awareness	Home literacy	0.38	4.57	<0.001	0.41***
	Phonological awareness	0.39	4.78	<0.001	

[1]Standardized coefficients; *** $p < 0.001$.

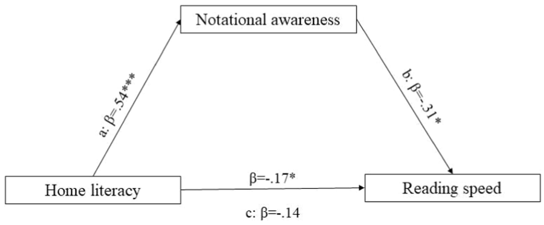

FIGURE 1
Mediation model: Home literacy (IV), notational awareness (MV) and reading speed (DV). ***Means that the effect is significant at $p<0.001$; ** the effect is significant at $p<0.01$; * the effect is significant at $p<0.05$. All presented effects are unstandardized; a is the effect of home literacy on notational awareness; b is the effect of notational awareness on reading speed; β is the indirect effect of home literacy on reading speed; c is the total effect of home literacy on reading speed.

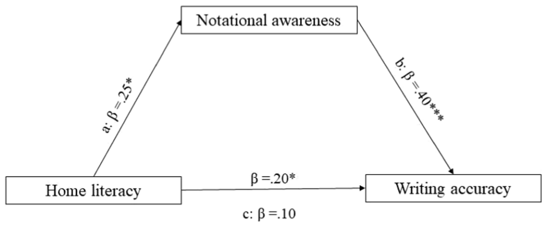

FIGURE 2
Mediation model: Home literacy (IV), notational awareness (MV) and writing accuracy (DV). ***Means that the effect is significant at $p<0.001$; **the effect is significant at $p<0.01$; *the effect is significant at $p<0.05$. All presented effects are unstandardized; a is the effect of home literacy on notational awareness; b is the effect of notational awareness on writing accuracy; β is the indirect effect of home literacy on writing accuracy; c is the total effect of home literacy on writing accuracy.

awareness denoting higher ability to detect sound units in language flow and to intentionally handle them. The richness of home environment, in terms of language and literacy stimuli and materials provided by the family, and the quantity and quality of child-parents' language and literacy practices (Niklas and Schneider, 2015) is associated with higher notational awareness and phonological awareness, which are emergent literacy skills essential for developing adequate reading and writing skills at school (Pinto et al., 2012). This result is in line with studies conducted in a transparent language system such as Italian (Incognito and Pinto, 2021) and other language systems (Kim, 2009) that showed links between home literacy and emergent literacy skills.

Regarding the connections *between* emergent and formalized literacy periods, the results of correlation analyses showed preschoolers who have higher scores in their HLE&P have higher reading and writing skills, measured 1 year later in primary school. Although studies have demonstrated significant linkages between home literacy environment and reading in different orthographies, such as English (e.g., Sénéchal and LeFevre, 2014), our results contribute to expanding our understanding of these linkages in a transparent orthography like Italian.

The most innovative contributions are the results of the mediational analyses that showed the key role of preschoolers' notational awareness in mediating the relationship between home literacy and formalized literacy skills. This salience of notational awareness is not surprising and supports previous research conducted in transparent orthographies (Pinto et al., 2012; Bigozzi et al., 2016b) which showed that notational awareness is fundamental for writing and reading tasks, and its deficiency is a predictor of dyslexia. Notational awareness in preschool children is a crucial ability because it allows a coding of sound to written signs and to connect them to each other. To develop notational awareness, it is necessary to develop a sensitivity of sound-sign integration which may be supported by home and preschool (Incognito et al., 2021). Children's HLE&P can vary (Sénéchal and LeFevre, 2002; Manolitsis et al., 2011). From an early age, at home children might participate in home literacy practices and activities important for literacy development such as joint parent–child reading, telling and inventing stories, that implicitly provide a knowledge about sound-sign integration or the opportunity of reflecting on language. Beyond home, in preschool children develop and improve their notational awareness. It emerged as a concatenated effect between home literacy, preschool, and primary school. Indeed, our findings suggest that, within the preschooler group, children who grow up in families with higher levels of home literacy environment and whose parents tend to engage in discourse about the books written system or literacy aspects tend to have higher notational skills in preschool which support their reading and writing skills in primary school. This type of mediation of preschoolers' notational skills might facilitate their later literacy development, especially in Italian in which there is a biunivocal correspondence between sound-sign.

A particularly innovative finding was that only notational awareness acts as a significant mediator in the relationship between preschoolers' home literacy and their later reading and writing skills in primary school, and not phonological awareness. In accordance with Bigozzi's earlier findings (2016), this phenomenon can be explained in that phonological awareness involves only the verbal channel (rhymes, oral alliteration) whereas notational awareness specifically refers to the relationship between sound and sign. Although phonological awareness is an important emergent literacy skill, its contribution to literacy development is particularly evident in opaque orthographies that require a strong sensitivity to different sounds forming words. Our results indicate that preschoolers' phonological awareness is associated with later reading and writing skills, but that it did not act as mediator in the relationship between home literacy and subsequent literacy acquisitions. Another important line of reasoning might refer to the fact that in the Italian alphabetic language the correspondence is phoneme-grapheme, whereas the meta-phonological activity done at home is more at the level of syllables and phoneme and grapheme groups/patterns, i.e., the home literacy practices referring to phonological competence work at a less analytical level than that required for reading and writing, e.g., the parent plays the rhyming game rather than asking the child what happens if he removes a phoneme from a word. Schooling acts systematically through targeted work on phonology rather than what happens at home.

These findings advance our understanding of the important role of early HLE&P and notational skills for children's reading and writing skills in a transparent orthography like Italian. Two major practical implications can be drawn from our findings. First, the importance of the level of home literacy for the development of emergent literacy skills in preschool and for the development of reading and writing in primary school should be recognized. Appropriate actions, such as promoting awareness in parents about the importance of home literacy should be nurtured in Italy, as well as in other countries, to ensure that children have the opportunity at home to engage with language and literacy activities with parents. Second, future studies should put their emphasis on how best to design preschool intervention programs so as to maximize preschoolers' emergent literacy skills (Incognito et al., 2021), especially notational awareness which had a significant mediational role in our findings, in connection with families. The instruments used to assess HLE&P allow us to obtain useful information in view of the preparation of appropriate interventions to promote literacy development.

5.1. Limitations and future research

From a methodological point of view, the collection of information about HLE&P was based on a self-report questionnaire. We are aware that data based on multiple observations or interviews could provide stronger evidence of home literacy levels. In this respect, also to add the use of written parental reports on how and the extent to which they engage their children in literacy activities could give us a better idea about home literacy practices. Future studies should also consider the influence of both contextual and cognitive predictors of literacy development in preschool children simultaneously (see, e.g., Bonifacci et al., 2022). Furthermore, a longitudinal study with follow up which could identify children with reading or writing difficulties at the end of the second grade of primary school should give us a fuller picture about the relationships between home literacy, emergent literacy skills, and later achievements in reading and writing at school.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the University of Florence Ethics Committee. 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.

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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Home literacy environment and early reading skills in Japanese Hiragana and Kanji during the transition from kindergarten to primary school

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We examined the reciprocal associations between home literacy environment (HLE) and children's early reading skills in syllabic Hiragana and morphographic Kanji in a sample of Japanese parent–child dyads. Eighty-three children were followed from kindergarten to Grade 3 and tested on Hiragana reading accuracy in kindergarten, Hiragana word reading fluency in kindergarten and Grade 1, and Kanji reading accuracy in Grade 1 to Grade 3. Their parents answered a questionnaire about HLE [parent teaching (PT) in Hiragana and Kanji, shared book reading (SBR), and access to literacy resources (ALR)], parents' needs for early literacy support by teachers, parents' expectations for children's reading skills, parents' worry about children's homework, and mother's education level. Results showed first that ALR, but not PT and SBR, was associated with reading skills in Hiragana and Kanji. Second, whereas Hiragana reading in kindergarten was not associated with PT in Hiragana in kindergarten, it negatively predicted PT in Hiragana in Grade 1. However, Kanji reading accuracy was not associated with PT in Kanji across Grades 1 to 3. Third, parents' worry was negatively associated with children's reading performance across Grades 1 to 3 but positively associated with PT in Hiragana and Kanji. Finally, while parents' expectations were positively associated with children's reading performance across Grades 1 to 3, they were negatively associated with PT in Hiragana and Kanji in Grades 1 and 2. These results suggest that Japanese parents may be sensitive to both their children's reading performance and social expectations for school achievement and adjust their involvement accordingly during the transition period from kindergarten to early primary grades. ALR may be associated with early reading development in both Hiragana and Kanji.

KEYWORDS

home literacy environment, early literacy skills, Japanese Hiragana and Kanji, parent expectation, parent affect

1. Introduction

Early reading skills develop rapidly at the beginning of primary school and thereafter by receiving formal literacy instruction. Although schools facilitate the development of children's literacy skills, parental involvement and the home literacy environment are also responsible for reading development (Sénéchal and LeFevre, 2002; Niklas and Schneider, 2017; Inoue et al., 2020b; Silinskas et al., 2020; Georgiou et al., 2021). An increasing number of studies have demonstrated that home literacy environment (HLE) predicts children's language and literacy development across a variety of languages and cultural contexts (Manolitsis et al., 2011; Niklas and Schneider, 2013; Sénéchal and LeFevre, 2014; Inoue et al., 2018a; Zhang et al., 2020). However, the majority of HLE studies have been conducted in North America and Europe with children learning to read in an alphabetic orthography, and studies in non-alphabetic orthographies are still relatively rare, except for those in Chinese (e.g., Chow et al., 2008; Deng et al., 2015; Zhang et al., 2020). In fact, to our knowledge, few studies in Japanese have examined the longitudinal links between HLE and children's reading skills during the transition period from kindergarten to early primary grades. To better understand the effects of different aspects of HLE on children's literacy skills, further studies in more diverse cultural contexts are needed (McBride et al., 2022). In addition, although several studies have provided evidence for the "evocative" effects of children's literacy skills on parental teaching (i.e., early child's literacy skills predict later parental involvement; Niklas and Schneider, 2013; Sénéchal and LeFevre, 2014; Deng et al., 2015; Inoue et al., 2018a; Silinskas et al., 2020, 2021; Georgiou et al., 2021), few have examined the longitudinal influences of reading skills in two different scripts on parent teaching simultaneously. Thus, in this study, we examined the longitudinal associations between HLE and early literacy skills in syllabic Hiragana and morphographic Kanji among Japanese children from kindergarten to Grade 3.

1.1. The associations between HLE and children's early literacy skills

The HLE includes a variety of parent–child activities related to literacy (Burgess, 2002; Manolitsis et al., 2011). According to the Home Literacy Model (Sénéchal and LeFevre, 2002; Sénéchal, 2006), parent–child interactions during home literacy activities are broadly classified into two categories: code-related (formal) and meaning-related (informal) activities. Code-related activities are usually assessed with the frequency of parental teaching (PT) of letters/words, while meaning-related activities are often operationalized as the frequency of shared book reading (SBR). Previous studies have shown that (a) code-related activities are associated with word reading through their effect on letter knowledge, and (b) meaning-related activities are associated with oral languages skills, including vocabulary (Sénéchal, 2006; Silinskas et al., 2010b; Sénéchal and LeFevre, 2014; Inoue et al., 2018b, 2020b). Additionally, several studies have suggested that access to literacy resources (ALR), often operationalized with the number of children's books at home and the frequency of library/bookstore visits, may play a unique role in children's language and literacy development (e.g., Liu et al., 2018; Zhang et al., 2020) over and above the effects of code-related and meaning-related activities.

Previous studies have consistently indicated the influence of the three aspects of HLE on children's language and literacy development across languages and cultural contexts (Silinskas et al., 2010b; Manolitsis et al., 2011; Sénéchal and LeFevre, 2014; Inoue et al., 2018a, 2020b). For example, Sénéchal and LeFevre (2014) found that SBR in kindergarten predicted growth in receptive vocabulary from kindergarten to Grade 1, whereas PT of reading in kindergarten predicted early literacy in kindergarten and Grade 1 and growth in word reading during Grade 1. In a cross-linguistic study with children from Grade 1 to Grade 2, Inoue et al. (2020b) examined the relationship between HLE and literacy skills across four alphabetic orthographies (English, Dutch, German, and Greek) and found that PT was associated with letter knowledge or phonological awareness in Dutch and Greek, while ALR was associated with different emergent literacy skills in all the languages (for similar findings, see Inoue et al., 2018b; Manolitsis et al., 2011; Silinskas et al., 2013, 2020). It should be noted, however, that while many studies found a positive association between parent teaching with children's reading performance in primary school (Sénéchal and LeFevre, 2014), some others found negative associations between parent teaching and children's reading (Manolitsis et al., 2013; Silinskas et al., 2021). This discrepancy in the findings of previous studies may partly be due to differences in the age of participants between the studies. In fact, some longitudinal studies (Bradley et al., 2001; Georgiou et al., 2021) have reported that the relationships between parent teaching of reading at home and children's early reading skills may change depending on children's developmental phases.

Several studies have also suggested that the relationship between HLE and children's literacy skills may be reciprocal and that children's early literacy skills can impact parental involvement in home literacy activities (Sénéchal and LeFevre, 2014; Silinskas et al., 2021). More specifically, previous studies have indicated that PT often shows positive associations with children's literacy skills in kindergarten, while the relationship may become negative after formal instruction commences at primary school (Silinskas et al., 2010b; Deng et al., 2015; Georgiou et al., 2021; Silinskas et al., 2021). Interestingly, this developmental shift in the relationship between parent teaching and children's literacy skills has been reported to be slightly delayed among English-speaking families (Georgiou et al., 2021) compared to those in relatively transparent orthographies (Silinskas et al., 2012; Inoue et al., 2018a), possibly reflecting the nature of the orthography and parents' perceptions for their children's reading achievement. Therefore, the association of children's performances with PT may be partly different depending on the script children are learning to read, the educational system, and their developmental phases.

Beyond HLE, some researchers have argued that parental expectations and emotions toward children's achievement could be a driving factor in the effect of children's early literacy performance on later HLE (Pomerantz and Eaton, 2001; Silinskas et al., 2010a, 2013). For example, parental negative affect, such as irritation and frustration, feeling stressed, or worry about their children's performance, may result in more controlling parental practices (Pomerantz and Eaton, 2001). Similarly, parents' expectations for their child's future performance may reflect the child's current performance levels and trigger certain literacy-related activities at home (Lynch et al., 2006; Froiland et al., 2012; Liu et al., 2018; Zhang et al., 2020). Indeed, Silinskas et al. (2015) found that children's performance in Grade 1 had a negative effect on mothers' negative affect, help, and monitoring. In addition, they found that the lower the children's academic performance from Grade 1 to Grade 4, the more homework assistance mothers provided. Liu et al. (2018) also showed that parents' expectation was associated with both parent teaching and children's word reading skills in kindergarten. Moreover, Froiland et al. (2012) reported that parents' expectation in kindergarten was associated with home literacy support, and that it exerted a positive effect on adolescent academic achievement *via* expectations held in Grade 8.

1.2. Japanese Hiragana and Kanji writing system

The Japanese writing system uses two contrastive types of scripts in combination: Kana (Hiragana and Katakana) and Kanji (Koda, 2017). Of the two types of Kana scripts, Japanese children usually learn Hiragana first. Hiragana is a transparent orthography in which each character represents a syllable or mora (a syllable-like phonological unit), and the correspondences between characters and sounds are highly consistent. For example, the Hiragana character お represents the same mora /o/ across different words, such as おや /o-ya/ 'parent,' かお /ka-o/ 'face,' and おもしろい /o-mo-shi-ro-i/ 'interesting.' In contrast, Kanji is a morphographic script originating from Chinese in which one character can represent multiple morphemic units that are frequently multisyllabic (e.g., 生 can mean 'birth', 'life', and 'raw', and it can be read as /sei/, /syo/, /sei/, /u/, and /nama/ depending on the word context). Most Kanji characters correspond to two types of phonological representations: the original Chinese pronunciation (*On*-reading), which is mainly used for compound words, and the Japanese translation of the original Chinese character (*Kun*-reading), which is more common for single-character words. On-readings are generally single syllables, and thus, Kanji characters can be considered morphosyllabic when they are read in On-readings. Japanese children receive formal instruction in Hiragana at the beginning of primary school and start learning Kanji characters in the middle of the first grade with frequent characters (e.g., 花 /hana/ 'flower', 男 /otoko/ 'man'). As children advance through grades, they learn characters with increasingly abstract meanings and complex forms (e.g., 難 /nan/ 'difficulty'). Children's early texts are frequently written only in Hiragana (e.g., かわであそぶ / ka-wa-de-a-so-bu/ 'play in a river'), but the rate of Kanji use in texts gradually increases as children learn more Kanji characters (e.g., 川で遊ぶ /kawa-de-aso-bu/).

1.3. Home literacy environment and early literacy skills in Japanese

To our knowledge, only a few studies in Japanese have examined the longitudinal links between HLE and children's reading skills during the transition period from kindergarten to early primary grades (Hamano and Uchida, 2012; Inomata et al., 2016; Inoue et al., 2018a), and their findings were mixed. Inomata et al. (2016) showed that parent teaching was associated with spelling in Hiragana in 5-to 6-year-old Japanese kindergarteners. In addition, they reported that neither shared book reading, nor parent teaching was associated with reading in Hiragana, after controlling for children's cognitive-linguistic skills (phonological processing, rapid naming, visual processing, and receptive vocabulary). Hamano and Uchida (2012) reported that the number of books at home, in addition to parents' education level and family income, was associated with Hiragana literacy skills in 3-to 5-year-old Japanese children. In contrast, Inoue et al. (2018a) found that children's Hiragana reading skills in Grade 1 were negatively associated with parent teaching in Grade 2, suggesting that Japanese parents adjusted their involvement to their child's literacy skills. Indeed, given that over 90% of third-year kindergarten children in Japan can master reading basic Hiragana characters before formal literacy instruction in school (Shimamura and Mikami, 1994; Ota et al., 2018), it is natural for parents to be sensitive to their children's performance during the transition period from kindergarten to primary school.

However, there are some important limitations in the existing HLE studies in Japanese. First, despite the unique characteristics of the Japanese writing system that requires children to learn two scripts (syllabic Hiragana and morphographic Kanji), the effects of HLE on children's Hiragana and Kanji reading skills have not been analyzed separately. Thus, it remains unclear whether HLE can differentially influence early Hiragana and Kanji reading skills. Given the contrastive characteristics of the two scripts, it is important to examine the reciprocal relationship between HLE and children's literacy skills in both scripts separately and simultaneously. Second, no longitudinal studies have covered the transition from kindergarten to the early primary grades. Finally, no previous studies in Japanese have included parental affects and expectations regarding children's literacy performance, and thus, the potential roles of these parental factors in the associations between HLE and children's literacy skills remain unclear.

1.4. The present study

In this study, we examined the relationship between HLE and children's early reading skills in syllabic Hiragana and morphographic Kanji in a sample of Japanese parent–child dyads followed from kindergarten to Grade 3. The purpose of this study was two-fold: (1) to examine the longitudinal effects of HLE on Hiragana and Kanji reading in Japanese children from kindergarten to Grade 3; (2) to examine the longitudinal effects of parental expectations, parental affects, and child reading performance on PT of Hiragana and Kanji. This study is an important addition to the findings of previous studies because it provides evidence from the longitudinal associations between HLE, parent expectations and affects, and children's reading skills in two different scripts covering the transition from kindergarten to the early primary grades.

The present study examined the following three research questions:

(a) Do the HLE components (i.e., PT, SBR, and ALR) have different effects on reading skills in Hiragana and Kanji? We hypothesized that ALR would be positively associated with reading skills in Hiragana and Kanji during the period, while the effects of PT and SBR on reading skills would be relatively limited (Hamano and Uchida, 2012; Inomata et al., 2016; Inoue et al., 2018a, 2020b).

(b) Are Japanese parents' affects and expectations associated with HLE, especially PT of Hiragana and Kanji? We hypothesized that parents' affect (operationalized as parents' worry about their child's homework in this study) would be positively associated with PT, but negatively with the child's reading skills (Silinskas et al., 2010a, 2013, 2015). In addition, we expected that parents' expectations for their child's reading performance would be associated with parent teaching and the child's reading skills (Lynch et al., 2006; Froiland et al., 2012; Liu et al., 2018; Zhang et al., 2020).

(c) Do children's reading skills in Hiragana and Kanji differentially predict the frequency of parents' teaching in each script? We hypothesized that Hiragana reading skills would negatively predict PT of Hiragana in kindergarten to Grade 1, and Kanji reading skills would also negatively predict PT of Kanji in Grade 2 to Grade 3 (Silinskas et al., 2010a, 2021; Deng et al., 2015; Inoue et al., 2018a; Georgiou et al., 2021).

2. Materials and methods

2.1. Research design

To examine the relationship between HLE and reading skills in Hiragana and Kanji at different time periods, we conducted longitudinal analyzes for Hiragana reading from kindergarten to Grade 1, and for Kanji reading from Grade 1 to Grade 3. The children were tested four times over the 3 years on word reading skills (Hiragana reading accuracy, Hiragana word reading fluency, and Kanji reading accuracy) with 10-to 12-month intervals: at the end of kindergarten (Time 1) and the middle of Grade 1 (Time 2), Grade 2 (Time 3), and Grade 3 (Time 4).

In Japan, formal literacy instruction generally begins in Grade 1. Children first learn Hiragana and then begin to learn Kanji in the middle of Grade 1. According to the national curriculum (Ministry of Education, Culture, Sports, Science and Technology, 2017), children formally learn 80 Kanji characters in Grade 1, 160 in Grade 2, and 200 in Grade 3 at school. Given this sequential learning of Hiragana and Kanji set by the national curriculum, we assessed Hiragana reading accuracy only in kindergarten, Hiragana reading fluency in kindergarten and Grade 1, and Kanji reading accuracy in Grades 1 to 3. HLE and parental expectations and affect were assessed by parent questionnaires at all four time points.

2.2. Participants

We approached several kindergartens and elementary schools to recruit participating children in Okayama city, Japan. The participants were Japanese kindergarten children ($N = 83$, $M_{age} = 75.6$ months, SD = 3.4) who were given parental permission to participate in this study, and they were followed until the middle of Grade 3. Using G*Power (Version 3.1.9.7; Faul et al., 2009) with an effect size of 0.2, the α error probability of 0.05, the 1-β error probability of 0.8, and the number of predictors of five (see below for details of the analysis), the required sample size for multiple regression analysis was estimated to be 70. The sample size of this study generally met these conditions. All participants were native Japanese speakers. In addition, the parents of the children participated in the study by completing a questionnaire. The median of mothers' education attainment in our sample was "graduated from junior college or technical college level." This was slightly higher than the general population, according to the latest census data (Ministry of Internal Affairs and Communications, 2020). Parental and school consent was obtained prior to testing. Ethical approval was obtained from Okayama University.

2.3. Measures

2.3.1. Children's reading skills

2.3.1.1. Hiragana reading accuracy

The Hiragana nonword decoding task (Tanji and Inoue, 2022) was used. The task consisted of 15 four-character Hiragana nonwords. The nonwords included 46 basic Hiragana characters with four voiced, one semi-voiced, and five special sounds, and they were arranged in terms of increasing level of difficulty. The items were divided into three columns with five nonwords on a page. Children were required to read the nonwords as accurately as possible. The total number of correct answers was considered, and the maximum score was 15. Cronbach's alpha reliability in our sample was 0.87.

2.3.1.2. Hiragana reading fluency

The Hiragana word reading fluency task (Inoue et al., 2020a; Tanji and Inoue, 2022) was used. The task comprised 104 four-character Hiragana words taken from Grade 1 textbooks. The words were divided into four columns with 20 or 21 words on a page. A practice trial that required reading an eight-word list was conducted before testing to ensure familiarity. Children were asked to read the list of words as quickly as possible. The score was the number of words correctly read within 45 s with a maximum score of 104. The correlation between kindergarten and Grade 1 was 0.93, indicating the stability of the measure.

2.3.1.3. Kanji reading accuracy

The Kanji reading task was adopted from Inoue et al. (2017) and used to assess Kanji reading accuracy. In Grades 1 and 2, the task consisted of 50 Kanji characters (10 characters from Grades 1 to 4 and 5 characters from Grades 5 and 6 were selected from the national standard curriculum; Ministry of Education, Culture, Sports, Science and Technology, 2017). In Grade 3, we used a list of 120 Kanji characters (20 characters from each grade from 1 to 6 were selected). The number of items was increased for Grade 3 children to avoid a possible ceiling effect. The items were arranged according to an increasing level of difficulty, and five characters were printed on each page. Children were required to read the Kanji characters as accurately as possible. A child's score was the total number of correct answers. Cronbach's alpha reliability in our sample was 0.97, 0.96, and 0.98 for Grades 1 to 3, respectively.

2.3.2. Parents' questionnaire

The parents were asked to answer questions about (a) mothers' education level, (b) HLE (parent teaching of Hiragana and Kanji, shared book reading, and access to literacy resources), (c) parents' needs for early literacy support by teachers, (d) parents' expectations for children's literacy skills, and (e) parents' worry about children's homework. Most of the questions were adopted from previous studies, including those in Japanese (e.g., Deng et al., 2015; Inoue et al., 2018a).

2.3.2.1. Mothers' education

We asked parents to report mothers' highest achieved education level among six options ranging from *junior high school graduate* (0) to *completed master's course at graduate school* (5).

2.3.2.2. Parent teaching in Hiragana

PT in Hiragana was assessed using three 5-point Likert scale questions. The first question asked "how often did parents teach their child to read Hiragana characters," and parents responded on a scale ranging from *never* (0) to *daily* (4). The second and third questions asked "how often did parents teach their child to read Hiragana words" and "how often did parents teach their child to write Hiragana characters." PT in Hiragana was assessed in kindergarten and Grade

1. Cronbach's alpha reliability in our sample was 0.85 in kindergarten and 0.90 in Grade 1.

2.3.2.3. Shared book reading

SBR was assessed using two 5-point Likert scale questions. The first question asked "how often did parents read to their child on weekdays (Monday to Friday)," and parents responded on a scale ranging from *never* (0) to *daily* (4). The second question asked "how often did parents read to their child on weekends (Saturday and Sunday)," and parents responded on the same scale. SBR was assessed four times in kindergarten, Grades 1, 2, and 3. In our sample, Cronbach's alpha reliability was 0.69, 0.91, 0.91, and 0.88 for kindergarten and Grades 1 to 3, respectively.

2.3.2.4. Parent teaching in Kanji

PT in Kanji was assessed using two 5-point Likert scale questions. The first question asked "how often did parents teach their child to read Kanji characters," and parents responded on a scale ranging from *never* (0) to *daily* (4). The second question asked "how often did parents teach their child to write Kanji characters." PT in Kanji was assessed three times in Grades 1, 2, and 3. Cronbach's alpha reliability in our sample was 0.90, 0.91, and 0.85 for Grades 1 to 3, respectively.

2.3.2.5. Access to literacy resources

We used a 5-point Likert scale question that asked "how often did parents go to the library or bookstore with their child," and parents responded on a scale ranging from *none* (0) to *two to 3 days in a week* (4). ALR was assessed three times in kindergarten, Grade 2, and Grade 3. The correlations between time points ranged from 0.43 to 0.57.

2.3.2.6. Parents' needs for early literacy support by teachers

Two 5-point Likert scale questions were used to assess parents' needs for early literacy support by teachers. The first question asked "whether parents wanted their child's teacher to assess the child's literacy skills as soon as he/she goes to primary school," and parents responded on a scale ranging from *strongly disagree* (0) to *strongly agree* (4). The second question asked "whether parents wanted their child's teacher to provide early literacy support when the child goes to primary school," and parents responded on the same scale. Parents' needs were only assessed in kindergarten. Cronbach's alpha reliability in our sample was 0.91.

2.3.2.7. Parents' expectations for child's literacy skills

Parents were asked to report on their expectations about their child's current and future literacy skills using two 5-point Likert scale questions. The questions asked "how well did parents think their child was/would be doing in reading and writing at the time/in the future," and parents responded on a scale ranging from *not good at all* (0) to *very well* (4). Parents' expectations were assessed three times in Grades 1, 2, and 3. Cronbach's alpha reliability in our sample was 0.79, 0.90, and 0.93 for Grades 1 to 3, respectively.

2.3.2.8. Parents' worry about child's homework

Parents were asked to report on their worries about their child's homework using a 5-point Likert scale question. The question asked "how much trouble did parents have with their child's homework," and parents responded on a scale ranging from *strongly disagree* (0) to *strongly agree* (4). Parents' worry about homework was assessed three times in Grades 1, 2, and 3. The correlations between time points ranged from 0.56 to 0.72.

2.4. Procedure

The children were assessed at the end of kindergarten (January/February) and the middle of Grades 1, 2, and 3 (September/October): Time 1 to Time 4, respectively. Kanji reading accuracy was not assessed in kindergarten because children had not started learning Kanji characters and, thus, a floor effect was expected. In addition, Hiragana reading accuracy was not assessed in Grades 1 to 3 because a ceiling effect was expected (see Mikami et al., 2008; Ota et al., 2018). The children were tested individually in their kindergartens and schools during school hours by trained experimenters. Administration and scoring were standardized across all children by using a manual of test administration procedures and scoring sheets to enhance the reliability of our data. Several experimenters visited the kindergartens/schools and tested children simultaneously. The testing time lasted for 30 min at Time 1 and 20 min at Time 2 to Time 4. The data collection schedule at the kindergartens/schools was developed in consultation with the school principal and the participants' teachers in each kindergarten/school prior to the data collection at each time point. The parents completed the questionnaires at approximately the same time as their children. The distribution and collection of the questionnaires were assisted by the participants' teachers.

2.5. Statistical analysis

To examine the longitudinal associations between the HLE components, parents' affects, and early reading skills in Hiragana and Kanji, we performed multiple regression analyzes using SPSS 25.0 (IBM Corp, 2017). To avoid alpha inflation due to a large number of hypothesis testing using the same variables, we focused on longitudinal associations between the variables and did not test concurrent associations. Separate sets of regression models were estimated for the two scripts. First, two models were estimated for predicting children's Hiragana reading and PT in Hiragana, respectively. In Model 1, to examine the effect of HLE on Hiragana reading, the three HLE components (PT, SBR, and ALR) in kindergarten were entered for predicting Hiragana reading fluency in Grade 1. In Model 2, to examine the effect of parental affect and child's reading skill on PT in Hiragana, mother's education, parents' needs for early literacy support by teachers, and Hiragana reading fluency in kindergarten were entered for predicting PT in Hiragana in Grade 1. In addition, to examine the unique effect of the predictor variables, the models were estimated both with and without controlling for the effect of autoregressors (i.e., the same variables at the previous time point). Next, four separate regression models were estimated for predicting Kanji reading accuracy and PT in Kanji. In Model 1, to examine the effect of HLE on Kanji reading, parents' expectations, PT in Kanji, and SBR in Grade 1 were entered for predicting Kanji reading accuracy in Grade 2. In Model 2, to examine the effect of parental affects and expectations and child's reading skill on PT in Kanji, mother's education, parents' expectations, parents' worry, and Kanji reading accuracy in Grade 1 were entered for predicting PT in Kanji in Grade 2. In Model 3, parents' expectations and the three HLE components in Grade 2 were entered for predicting Kanji reading accuracy in Grade 3. Finally, in Model 4, mother's education, parents' expectations, parents' worry, and Kanji reading accuracy in Grade 2 were entered for predicting PT in Kanji in Grade 3. All four models were estimated both with and without controlling for the effects of autoregressors to examine the unique effect of the predictor variables.

3. Results

3.1. Preliminary data analysis

Table 1 displays the descriptive statistics for all measures. The distributional properties of the variables indicated that Kanji reading accuracy was positively skewed at Time 2. Therefore, square root transformation was applied to improve the distribution. In addition, Hiragana reading accuracy at Time 1 was negatively skewed, and reflect and square root transformation was performed. The reflected

TABLE 1 Descriptive statistics for child and parent measures.

	Time 1				Time 2				Time 3				Time 4			
	Kindergarten (*N*=83)				Grade 1 (*N*=79)				Grade 2 (*N*=69)				Grade 3 (*N*=59)			
Measure (max)	M	SD	Skew	Kurt	M	SD	Skew	Kurt	M	SD	Skew	Kurt	M	SD	Skew	Kurt
Child measures																
Age in months	75.59	3.36	−0.11	−0.99	83.67	3.48	−0.09	−1.07	96.10	3.54	−0.16	−1.06	108.14	3.39	−0.10	−1.07
Hiragana reading accuracy (15)	11.96	3.07	−1.73	3.69	–	–	–	–	–	–	–	–	–	–	–	–
Hiragana reading fluency (104)	27.71	14.31	−0.36	−0.21	40.46	15.14	0.16	−0.34	–	–	–	–	–	–	–	–
Kanji reading accuracy (Grade 1-Grade 2;50, Grade 3;120)	–	–	–	–	8.49	8.86	1.89	3.85	22.13	9.69	1.18	0.65	57.36	22.63	0.72	−0.24
Parent measures																
Mother's education (6)	3.80	1.27	−0.43	−1.25	–	–	–	–	–	–	–	–	–	–	–	–
Parent teaching (PT)																
Teach to read Hiragana characters (4)	2.40	0.94	−0.89	0.47	1.99	1.33	0.13	−1.26	–	–	–	–	–	–	–	–
Teach to read Hiragana words (4)	2.48	0.91	−0.33	−0.25	2.16	1.20	0.06	−1.04	–	–	–	–	–	–	–	–
Teach to write Hiragana characters (4)	2.32	0.95	−0.69	2.00	2.45	1.20	−0.34	−0.93	–	–	–	–	–	–	–	–
Shared book reading (SBR)																
Read to child: weekdays (4)	2.57	1.14	−0.33	−0.92	2.13	1.15	0.22	−1.02	1.23	1.23	0.51	−0.95	0.92	1.10	1.05	0.39
Read to child: weekend (4)	3.00	1.14	−0.96	−0.10	2.44	1.26	−0.33	−1.07	1.26	1.24	0.63	−0.62	1.29	1.33	0.36	−1.38
Parent teaching in Kanji (PTK)																
Teach to read Kanji characters (4)	–	–	–	–	2.18	1.21	−0.27	−0.91	2.59	0.93	−1.11	1.27	2.12	1.00	−0.78	−0.14
Teach to write Kanji characters (4)	–	–	–	–	1.60	1.37	0.36	−1.11	2.42	1.05	−0.85	0.18	1.90	1.11	−0.19	−0.72
Access to literacy resources (ALR)																
Go to bookstores/libraries (4)	1.71	0.67	0.16	−0.41	–	–	–	–	1.58	0.73	0.33	−0.38	1.54	0.65	0.03	−0.16
Parents' needs for early literacy support by teachers																
Needs for teachers to understand child's reading skill (4)	2.72	1.07	−0.43	−0.78	–	–	–	–	–	–	–	–	–	–	–	–
Needs for early intervention in reading skill by teachers (4)	2.63	1.10	−0.58	−0.36	–	–	–	–	–	–	–	–	–	–	–	–
Parents' expectations for child's literacy skills																
Expectation for child's reading skills: now (4)	–	–	–	–	2.17	0.89	0.14	−0.88	2.38	1.05	0.08	−1.18	2.25	0.90	0.34	−0.56
Expectation for child's reading skills: future (4)	–	–	–	–	2.71	0.83	−0.58	−0.02	2.68	0.93	−0.26	−0.73	2.53	0.97	0.04	−0.94
Parents' worry about child's homework																
Worry about child's homework engagement (4)	–	–	–	–	1.59	1.07	0.35	−0.61	1.41	1.08	0.85	0.50	1.51	1.06	0.75	0.26

scores were multiplied by −1 to correct for direction. In addition, outliers on several measures in each sample (defined as over 2.5 *SD* above/below the mean) were winsorized to the next non-outliers' score of ±1 to reduce their potential effects on the results (Tabachnick and Fidell, 2013).

3.2. Correlation analysis

Table 2 presents the correlations between the HLE components and parents' variables across time points. The results showed that parents' expectations, parents' needs for teachers' support, and parents' worry for children's performance were correlated with PT. Specifically, parents' needs for teachers' support were positively correlated with PT in Hiragana in kindergarten ($r = 0.33$), indicating that the more parents wanted early support, the more often they taught Hiragana literacy skills to their children. In Grade 1, parents' expectations were negatively correlated with PT in Hiragana ($r = -0.37$), and parents' worry was positively correlated with PT in Hiragana ($r = 0.42$). Similarly, parents' expectations were negatively correlated with PT in Kanji ($r = -0.34$), and parents' worry was positively correlated with PT in Kanji in Grade 2 ($r = 0.43$). Furthermore, parents' worry, but not their expectations, was positively correlated with PT in Kanji in Grade 3 ($r = 0.58$).

Table 3 presents the correlations between children's and parents' variables across time points. Neither PT in Hiragana nor SBR in kindergarten was correlated with Hiragana and Kanji reading skills at any time point. In contrast, PT in Hiragana in Grade 1 was negatively correlated with Hiragana reading fluency in kindergarten and Grade 1 ($rs = -0.52$ and -0.49, respectively). In contrast, ALR in kindergarten was positively correlated with Hiragana reading fluency in Grade 1 ($r = 0.35$), and ALR in Grades 2 and 3 was correlated with Kanji reading accuracy in Grades 2 and 3 ($rs = 0.33$ and 0.29, respectively). In addition, parents' expectations in Grade 1 were correlated with Kanji reading in Grade 1 ($r = 0.31$), and parents' expectations in Grade 2 were correlated with Kanji reading in Grades 2 and 3 ($rs = 0.31$ and 0.46, respectively). On the other hand, parents' worry in Grade 1 was negatively correlated with Hiragana reading fluency ($r = -0.47$) and Kanji reading ($r = -0.38$) at the same time point, and parents' worry in Grades 2 and 3 was also negatively correlated with Kanji reading in Grades 2 and 3 ($rs = -0.28$ and -0.31, respectively).

3.3. Multiple regression analysis

Table 4 shows the results of multiple regression analyzes for predicting Hiragana reading skills and PT in Hiragana in Grade 1. In Model 1, whereas neither PT in Hiragana nor SBR predicted Hiragana reading fluency in Grade 1, ALR predicted Hiragana reading fluency in Grade 1 ($\beta = 0.30$). However, ALR did not hold a unique effect on Hiragana reading fluency in Grade 1 when the effect of Hiragana reading fluency in kindergarten was controlled (see Model 1b). In contrast, Model 2 showed that Hiragana reading fluency in kindergarten negatively predicted PT in Hiragana in Grade 1 ($\beta s = -0.60$ to -0.64) after controlling for the effect of PT in Hiragana in kindergarten, indicating that PT in Hiragana in Grade 1 was more frequent when their child's early Hiragana reading was poor.

Table 5 shows the results of multiple regression analyzes for predicting Kanji reading accuracy and PT in Kanji in Grades 2 and 3. Model 1 showed that none of the parents' variables in Grade 1 predicted Kanji reading accuracy in Grade 2. Similarly, Model 2 showed that Kanji reading accuracy in Grade 1 did not predict PT in Kanji in Grade 2. In contrast, in Model 3, ALR in Grade 2, but not PT in Kanji and SBR, predicted Kanji reading in Grade 3 ($\beta = 0.42$). However, ALR in Grade 2 did not hold a unique effect on Kanji reading accuracy in Grade 3 when the effect of autoregressor was controlled (see Model 3b). Finally, Model 4 showed that parents' worry about their child's homework in Grade 2 was associated with PT in Kanji in Grade 3 ($\beta = 0.30$), indicating that the more concerned parents were about their child's homework, the more often they taught Kanji literacy skills to their children. However, the effect of parents' worry in Grade 2 on PT in Kanji in Grade 3 became nonsignificant when the effect of PT in Kanji in Grade 2 was taken into account (see Model 4b).

4. Discussion

This study examined the reciprocal associations between HLE and children's reading skills in Hiragana and Kanji in a sample of Japanese parent–child dyads from kindergarten to Grade 3. Specifically, we sought to answer the three research questions: (a) Do the HLE components (i.e., PT, SBR, and ALR) have different effects on reading skills in Hiragana and Kanji, (b) are parents' affects and expectations associated with HLE, and (c) do children's reading skills in Hiragana and Kanji differentially predict the frequency of parents' teaching in each script?

4.1. HLE and early Hiragana and Kanji reading skills

Regarding our first research question, the results showed that neither PT nor SBR predicted reading skills in Hiragana and Kanji. These results, together with similar findings from previous studies in different languages (e.g., Deng et al., 2015; Inoue et al., 2018a,b; Silinskas et al., 2021), suggest that the effect of PT and SBR may be time-sensitive and reduced as children exposed to formal literacy instruction. According to the Home Literacy Model (Sénéchal and LeFevre, 2002; Sénéchal, 2006), code-related (formal) activities (i.e., teaching of letters and words) have been found to predict word reading through its effects on letter knowledge, and meaning-related (informal) activities (i.e., shared book reading) have been to predict word reading through its effects on vocabulary and phonological awareness (e.g., Sénéchal, 2006; Silinskas et al., 2010b; Sénéchal and LeFevre, 2014; Torppa et al., 2022; Zhang et al., 2023). In Japan, it is possible that the effects of PT be limited, especially after schooling, because most children acquire letter knowledge before schooling. In addition, previous Japanese studies did not ask separate questions on the frequency of teaching Hiragana and Kanji reading (e.g., Inoue et al., 2018a; Inoue et al., 2023). Our results showed that there was no significant relationship between Hiragana and Kanji reading and each parent teaching after entering school even when the questions were separated for each script.

In contrast, ALR positively predicted reading skills in both scripts. Similar findings have been reported in several studies showing that ALR was associated with children's reading skills

TABLE 2 Correlation between parent variables.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	MotherEduc	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	PTH_K	−0.12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	SBR_K	0.15	0.29*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	ALR_K	0.19	0.12	0.36**	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	PNeeds_K	−0.23*	0.33**	0.01	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	PTH_G1	−0.15	0.12	0.07	−0.09	0.16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7	PTK_G1	−0.08	0.28*	0.09	−0.03	0.19	0.35**	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8	SBR_G1	0.20	0.26*	0.74***	0.35**	0.04	0.12	0.09	–	–	–	–	–	–	–	–	–	–	–	–	–
9	PExpect _G1	0.22	0.26*	0.13	0.07	−0.12	−0.37**	0.07	0.07	–	–	–	–	–	–	–	–	–	–	–	–
10	PWorry_G1	−0.07	−0.03	−0.01	−0.18	0.24*	0.42***	0.06	−0.02	−0.49***	–	–	–	–	–	–	–	–	–	–	–
11	PTK_G2	0.10	−0.03	0.04	−0.05	0.24	37**	0.29*	0.21	−0.25*	0.31*	–	–	–	–	–	–	–	–	–	–
12	SBR_G2	0.20	0.29*	0.58***	0.17	−0.02	0.00	0.12	0.78***	0.11	0.07	0.15	–	–	–	–	–	–	–	–	–
13	PExpect_G2	0.07	0.19	0.30*	0.15	−0.19	−0.48***	0.01	0.14	0.67***	−0.48***	−0.34**	0.13	–	–	–	–	–	–	–	–
14	ALR_G2	0.02	−0.03	0.18	0.56***	0.04	−0.08	0.19	0.15	−0.08	−0.14	0.02	0.05	0.06	–	–	–	–	–	–	–
15	PWorry_G2	0.04	0.01	−0.05	−0.09	0.34*	0.43***	0.10	0.05	−0.45***	0.56***	0.43***	0.12	−0.43***	−0.07	–	–	–	–	–	–
16	PTK_G3	0.19	0.36**	0.02	0.17	0.20	0.39**	0.26*	0.25	0.00	0.19	0.38**	0.12	−0.12	0.00	0.38**	–	–	–	–	–
17	SBR_G3	0.06	0.29*	0.56***	0.19	0.21	0.10	0.30*	0.56***	0.21	−0.01	0.25	0.60***	0.08	0.01	0.23	0.38**	–	–	–	–
18	PExpect_G3	0.16	0.17	0.27*	0.34**	−0.15	−0.38**	0.14	0.17	0.62***	−0.44***	−0.26	0.10	0.74***	0.15	−0.38**	0.02	0.17	–	–	–
19	ALR_G3	−0.05	0.21	0.05	0.42**	0.11	0.09	0.29*	0.11	−0.07	−0.19	0.04	0.03	−0.15	0.57***	0.09	0.11	0.14	0.05	–	–
20	PWorry_G3	−0.04	0.08	−0.13	−0.09	0.38**	0.49***	0.04	0.07	−0.45***	0.57***	0.46***	−0.02	−0.37**	−0.06	0.72***	0.58***	0.28*	−0.27*	0.05	–

MotherEduc = mother's education, PTH = parent teaching in Hiragana, SBR = shared book reading, PExpect = parents' expectations for child's reading skills, ALR = access to literacy resources, PTK = parent teaching in Kanji, PNeeds = parents' needs for early literacy support by teachers, PWorry = parents' worry about child's homework, K = Kindergarten, G1 = Grade 1, G2 = Grade 2, G3 = Grade 3.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

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TABLE 3 Correlation between child and parent variables.

Child variables	Parent variables								
	K				G1				
	PT in Hiragana	SBR	ALR	Needs	PT in Hiragana	PT in Kanji	SBR	Expectations	Worry
K									
Hiragana reading accuracy	−0.04	−0.15	0.18	−0.22	−0.35**	−0.24*	−0.11	0.23	−0.20
Hiragana reading fluency	0.04	0.16	0.35**	−0.29*	−0.52***	−0.07	−0.02	0.41***	−0.41***
G1									
Hiragana reading fluency	0.01	0.14	0.35**	−0.33**	−0.49***	0.00	−0.01	0.39**	−0.47***
Kanji reading accuracy	−0.00	0.06	0.31**	−0.08	−0.42***	0.14	−0.10	0.31**	−0.38**
G2									
Kanji reading accuracy	0.03	0.08	0.36**	−0.29*	−0.31**	0.15	−0.13	0.21	−0.34**
G3									
Kanji reading accuracy	−0.06	0.17	0.46***	−0.25	−0.40**	0.09	−0.10	0.24	−0.41***

Child variables	Parent variables										
	G2					G3					
	PT in Kanji	SBR	ALR	Expectations	Worry	PT in Kanji	SBR	ALR	Expectations	Worry	Mother's education
K											
Hiragana reading accuracy	−0.01	0.05	0.19	0.20	−0.12	0.13	−0.04	0.14	0.19	−0.02	0.16
Hiragana reading fluency	−0.20	0.13	0.29*	0.45***	−0.38**	−0.05	0.06	0.33**	0.55***	−0.35**	0.16
G1											
Hiragana reading fluency	−0.13	0.10	0.30*	0.43***	−0.33**	−0.08	0.03	0.28*	0.56***	−0.36**	0.15
Kanji reading accuracy	−0.15	0.09	0.23	0.36**	−0.29*	−0.05	−0.02	0.20	0.52***	−0.28*	0.14
G2											
Kanji reading accuracy	−0.17	0.03	0.33**	0.31**	−0.28*	−0.04	−0.09	0.36**	0.38**	−0.31*	0.12
G3											
Kanji reading accuracy	−0.12	−0.01	0.40**	0.29*	−0.30*	−0.09	−0.06	0.29*	0.46***	−0.31*	0.09

PT = parent teaching, SBR = shared book reading, ALR = access to literacy resources, Needs = parents' needs for early literacy support by teachers, Expectations = parents' expectations for child's reading skills, Worry = parents' worry about child's homework, K = Kindergarten, G1 = Grade 1, G2 = Grade 2, G3 = Grade 3.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

(Hamano and Uchida, 2012; Inoue et al., 2018b, 2020b; Georgiou et al., 2021). Several studies in Chinese have also provided evidence for the associations between ALR and Chinese character reading (Liu et al., 2018; Zhang et al., 2020, 2023). Given these empirical findings, one interpretation of our results is that having more reading materials available in the home can provide children with opportunities to practice reading Hiragana words and contribute to learning Kanji characters, possibly partly through enriching vocabulary knowledge (Zhang et al., 2020). Another interpretation may be that having access to printed materials at home can influence children's autonomy to read books and active interest in learning new words compared to engaging in parent-led activities such as shared book reading (see Van Bergen et al., 2017; Inoue et al., 2020b; Georgiou et al., 2021, for relevant discussions). It should be noted, however, that although ALR was consistently and weakly to moderately correlated with children's reading skills across grades (Table 3), it did not exert a unique effect on reading outcomes in either script when the effect of autoregressors was controlled. Therefore, caution should be exercised when interpreting our findings; while ALR and children's word reading skills may be associated, the effect of ALR further development of reading skills may be relatively limited.

TABLE 4 Multiple regression analyzes for HLE and Hiragana reading from kindergarten to grade 1.

Predictors	β	Total R^2	Total adjusted R^2
Model 1: Prediction of Hiragana reading fluency in G1			
1a: Without autoregressor			
Shared book reading (SBR)_K	0.02		
Access to literacy resource (ALR)_K	0.30*		
Parent teaching (PT) in Hiragana_K	0.01	0.09	0.05
1b: With autoregressor			
Shared book reading (SBR)_K	0.02		
Access to literacy resource (ALR)_K	−0.05		
Parent teaching (PT) in Hiragana_K	0.01		
Hiragana reading fluency in K	0.93***	0.83	0.82
Model 2: Prediction of parent teaching in Hiragana in G1			
2a: Without autoregressor			
Mother's education	0.03		
Parents' needs for early literacy support by teachers_K	−0.06		
Hiragana reading fluency_K	−0.60***	0.33	0.30
2b: With autoregressor			
Mother's education	0.05		
Parents' needs for early literacy support by teachers_K	−0.13		
Hiragana reading fluency_K	−0.64***		
Parent teaching (PT) in Hiragana_K	0.20†	0.37	0.33

K = Kindergarten, G1 = Grade 1.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, †$p = 0.07$.

4.2. Parental affects and expectations and parental teaching

Regarding the associations of parents' affects and expectations with HLE, parents' worry about their child's homework in Grade 2 was positively associated with PT in Kanji in Grade 3. In contrast, parents' expectations did not predict PT in Kanji in any grade (see Model 4 in Table 5). Similar findings have been reported in several previous studies (Pomerantz and Eaton, 2001; Silinskas et al., 2015). For example, Silinskas et al. (2015) showed that children's academic performance in Grade 1 predicted their mother's practices (e.g., helping and monitoring their child) in homework in Grade 3 through its effects on parental negative affect (e.g., feeling hopeless, frustrated) on homework. Pomerantz and Eaton (2001) also showed that parents'

TABLE 5 Multiple regression analyzes for HLE and Kanji reading from grade 1 to grade 3.

Predictors	β	Total R^2	Total adjusted R^2
HLE and Kanji reading in G1 and G2			
Model 1: Prediction of Kanji reading accuracy in G2			
1a: Without autoregressor			
Parents' expectations for child's literacy skills_G1	0.23		
Shared book reading (SBR)_G1	−0.13		
Parent teaching (PT) in Kanji_G1	0.13	0.08	0.03
1b: With autoregressor			
Parents' expectations for child's literacy skills_G1	−0.07		
Shared book reading (SBR)_G1	0.01		
Parent teaching (PT) in Kanji_G1	−0.07		
Kanji reading accuracy_G1	0.85***	0.66	0.64
Model 2: Prediction of parent teaching in Kanji in G2			
2a: Without autoregressor			
Mother's education	0.21		
Parents' expectations for child's literacy skills_G1	−0.26		
Parents' worry about child's homework_G1	0.03		
Kanji reading accuracy_G1	−0.13	0.15	0.09
2b: With autoregressor			
Mother's education	0.23		
Parents' expectations for child's literacy skills_G1	−0.27		
Parents' worry about child's homework_G1	−0.01		
Kanji reading accuracy_G1	−0.23		
Parent teaching (PT) in Kanji_G1	0.40**	0.30	0.24
HLE and Kanji reading in G2 and G3			
Model 3: Prediction of Kanji reading accuracy in G3			
3a: Without autoregressor			
Parents' expectations for child's literacy skills_G2	0.22		
Shared book reading (SBR)_G2	−0.09		
Access to literacy resources (ALR)_G2	0.42**		
Parent teaching (PT) in Kanji_G2	−0.04	0.23	0.17
3b: With autoregressor			
Parents' expectations for child's literacy skills_G2	−0.02		
Shared book reading (SBR)_G2	−0.05		
Access to literacy resources (ALR)_G2	0.09		

(Continued)

TABLE 5 (Continued)

Predictors	β	Total R^2	Total adjusted R^2
Parent teaching (PT) in Kanji_G2	−0.02		
Kanji reading accuracy_G2	0.89***	0.86	0.84
Model 4: Prediction of parent teaching in Kanji in G3			
4a: Without autoregressor			
Mother's education	0.20		
Parents' expectations for child's literacy skills_G2	−0.06		
Parents' worry about child's homework_G2	0.30*		
Kanji reading accuracy_G2	−0.03	0.15	0.08
4b: With autoregressor			
Mother's education	0.13		
Parents' expectations for child's literacy skills_G2	0.00		
Parents' worry about child's homework_G2	0.23		
Kanji reading accuracy_G2	−0.02		
Parent teaching (PT) in Kanji_G2	0.32*	0.24	0.16

G1 = Grade 1, G2 = Grade 2, G3 = Grade 3.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

concern for their children's academics has a positive effect on parental practices (e.g., monitoring and helping with homework) among parents with children in Grades 4 to 6. Taken together, these results suggest that negative parental affect, such as their worry about children's homework, may be more closely associated with parental involvement in children's learning at home than parents' expectations for their child's literacy skills. However, it should be noted that although parents' worry was weakly to moderately correlated with parent teaching in Kanji in Grades 2 and 3, it did not exert a unique effect on parent teaching in Kanji when the effect of autoregressor was controlled (see Model 4 in Table 5), suggesting that its effect on parent teaching might be relatively weak.

4.3. Early word reading skills and parental teaching

The results further showed that while Hiragana reading in kindergarten was not correlated with PT in Hiragana in kindergarten (Table 3), it negatively predicted PT in Hiragana in Grade 1 even after controlling for PT in Hiragana in kindergarten (Table 4). The negative relationship aligned with previous findings in different cultural contexts, including Japanese (Manolitsis et al., 2011; Deng et al., 2015; Inoue et al., 2018a; Silinskas et al., 2021). Specifically, Inoue et al. (2018a) showed that Hiragana reading in Grade 1 negatively predicted parent teaching of letters and words in Grade 2. Our results suggested that the negative relationship might be relatively stronger during the transition from kindergarten to Grade 1. Similar to previous studies in other cultures (e.g., Silinskas et al., 2010b, 2013, 2021), we found that children's reading skills have a negative effect on PT at times before and after the start of formal instruction in Japan, indicating that in the early years of schooling, the more parents have children with low reading levels, the more likely they are to be involved in direct teaching. Silinskas et al. (2021) suggested that parents might adjust their frequency of teaching to their children's needs for support following the transition to Grade 1. In this study, parents' needs for children's literacy support was associated positively with PT in Hiragana in kindergarten ($r = 0.33$, see Table 2) and negatively with Hiragana reading fluency in kindergarten ($r = -0.29$, see Table 3). These results support the notion that parents' affects and expectations for their children's performance can be reflected in parents' involvement at home, such as PT (Deng et al., 2015; Hemmerechts et al., 2016; Georgiou et al., 2021). Parents may be particularly responsive to their children's literacy skills at the beginning of formal schooling in Grade 1.

In contrast, children's Kanji reading in Grades 1 and 2 did not uniquely predict PT in Kanji in Grades 2 and 3. This might be because parents adjusted the frequency of Kanji teaching according to their child's autonomy in doing their homework rather than the performance level of the child's reading (Silinskas et al., 2015). It is also possible that the nature of parental involvement in children's learning may have changed from Grade 1 onwards in response to formal Kanji literacy instruction in primary school. Specifically, once formal instruction of Kanji commences, Japanese parents may be less likely to teach Kanji directly at home and spend more time on monitoring and helping with their children's homework (see Table 1).

4.4. Implications

Our findings have some important educational implications. First, ALR at home may be associated with early literacy development in both Hiragana and Kanji in Japanese. This implies that activities in which children can engage in self-regulated and playful activities may have a greater impact on their learning than parent-initiated activities (e.g., Grolnick and Ryan, 1987, 1989). In addition, a meta-analytic review (Sénéchal and Young, 2008) showed that parents listening to their children read could play a facilitative role in children's reading acquisition. We should encourage educators and parents not only to teach literacy to their children directly but also to consider providing more access to printed materials at home to enhance children's autonomy in accessing written material that can create a foundation for future literacy development. Moreover, the association between children's early reading skills and later parents' involvement suggests that educators should increase their communication with parents regarding their child's literacy performance and how they can help them achieve their learning goals.

4.5. Limitations

Several limitations of our study are worth noting. First, our sample size was relatively small. Thus, caution is required with interpreting the results. Consequently, the findings should be replicated in future studies with a larger and more representative sample. Second, we used single-item measures to assess ALR and parents' affect. This may have caused a potential underestimation of their effects on reading skills and HLE. Third, we did not assess parental reading levels or reading history. Some researchers have suggested that parents' reading proficiency may be associated with both HLE and children's reading development (see van Bergen et al., 2017; Hart et al., 2021; Torppa et al., 2022). Furthermore, HLE and parents' concerns may also be related to parents' reading history. Future research should consider these potential factors when examining the relationship between HLE and children's literacy skills. Finally, the study did not include measures of children's interest in literacy activities and reading independently, both of which have been demonstrated to be influential in early reading development (Martini and Sénéchal, 2012; Silinskas et al., 2020; Georgiou et al., 2021; Li and Li, 2022).

5. Conclusion

The present study examined the reciprocal associations between HLE and children's reading skills in Hiragana and Kanji in a sample of Japanese parent–child dyads from kindergarten to Grade 3. The results show that Japanese parents may be sensitive to both their children's reading performance and social expectations for school achievement and adjust their involvement accordingly during the transition period from kindergarten to early primary grades. The results further suggest that ALR may be associated with early reading development in both Hiragana and Kanji. These findings provide further evidence for the roles of HLE, parental awareness, and responsiveness to children's performance. Future studies should consider the education system and social expectations for children's achievement in examining the relationship between HLE and early reading acquisition.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee, Graduate School of Education, Okayama University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

TT and TI substantially contributed to the study conceptualization, data analysis, and interpretation. TT substantially contributed to the manuscript drafting. 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

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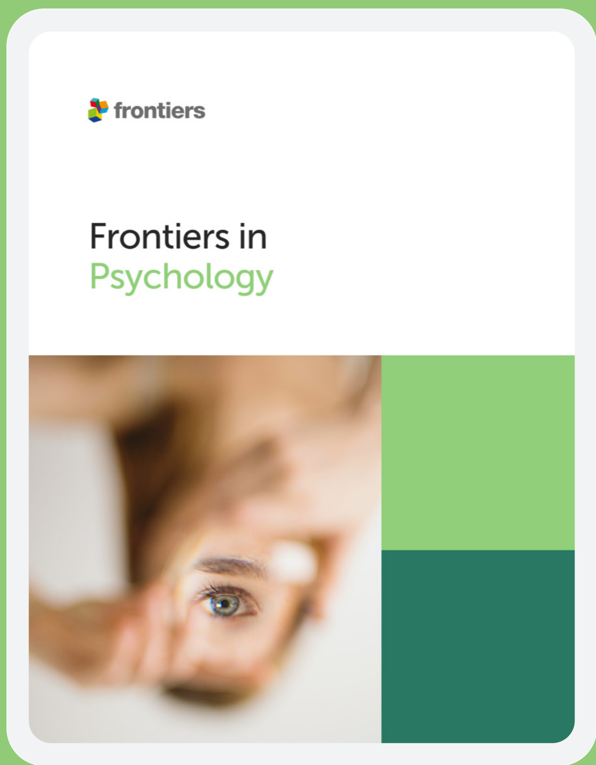

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