Understanding the influence of the preschool home learning environment on early mathematics and literacy attainment

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Executive summary

Aims

1. This project examined the impact of the home learning environment (HLE), language and cognitive abilities on later academic development.
2. The core aims are summarised in our three research questions:

   a. To what extent do preschool early number skills, language and cognitive skills predict mathematics and literacy outcomes in Key Stage 1?

   b. To what extent does the preschool HLE predict mathematics and literacy outcomes in Key Stage 1?

   c. To what extent does the primary HLE predict mathematics and literacy outcomes in Key Stage 1? Does the primary HLE modify any influence of the preschool HLE?

Methods

3. The children were recruited in their preschool year (the academic year in which they turned four years of age). We recruited 41 Early Years settings, of which 40 had parents who consented for their children to participate. These 40 participating settings were distributed across three counties in the North West of England.
4. Parents were asked to complete two HLE questionnaires that gathered information on a range of factors including the frequency of different types of home learning experiences at two different time points. At the start of the study, parents were asked to complete a preschool HLE questionnaire. When their children were in Year 1 the parents were asked to complete a primary HLE questionnaire.
5. The preschool HLE questionnaire indexed three types of home learning experiences; meaning-related home literacy experiences (that focus on the meaning of written or oral language at the level of words, sentences or narratives), code-related home

literacy experiences (that focus on the phonological and orthographic structure of language) and home numeracy experiences. Shared book reading was assessed using a book title checklist where parents had to indicate which children's book titles they recognised.

6. Preschool code-related home literacy experiences fractionated into two subscales: letter-sound interactions and letter activities. The items within the letter-sound interactions subscale had greater emphasis on the links between letters and sounds and adult-child interaction e. g. Is prompted to identify letters in books or the environment (e.g. "Can you see a 's' on the sign?", "What letter does the word cat begin with?"). The items within the letter activities subscale had more limited emphasis on letter-sound links and adult-child interaction (e. g. Sings or recites the alphabet).
7. The primary HLE questionnaire indexed four types of home learning experiences; meaning-related home literacy experiences, code-related home literacy experiences, home numeracy experiences and home writing experiences. Shared book reading was assessed using a book title checklist where parents were asked to indicate which children's book titles they recognised and an author checklist where parents were asked to indicate which children's book authors they recognised.
8. The children were assessed on four separate occasions. In the spring term of their preschool year their early number skills were assessed. In the summer term of their preschool year, their language and cognitive skills were assessed. In the summer term of Year 1, their language, reading and mathematics skills were assessed. In the autumn term of Year 2, their spelling and writing skills were assessed.

9. The cognitive assessments in preschool covered nonverbal reasoning and executive functioning. The language assessments in preschool and primary covered vocabulary and phonological awareness (the ability to identify speech sounds within words).
10. A total of 274 parent-child dyads participated in the preschool phase of the study. The sample was broadly representative in terms of both national levels of deprivation and the types of preschool setting attended. A total of 120 parent-child dyads from the preschool sample consented to take part in the primary phase of the study. This sub-sample continued to be broadly representative in terms of both national levels of deprivation and the types of preschool setting attended.

Findings

11. Preschool early number skills predicted children's performance on a standardised mathematics attainment test in Year 1. Promotion of counting, number transcoding and simple calculations supported by manipulatives during the preschool period will provide a firm foundation for later mathematics development.
12. Preschool language skills predicted children's mathematics and reading attainment in Year 1 and their word spelling skills in Year 2. Promotion of phonological awareness and vocabulary during the preschool period will provide a firm foundation for later academic development.
13. Preschool nonverbal skills (a combined measure of the children's executive functioning and nonverbal reasoning) predicted children's alphabet transcription as well as their spelling skills in Year 2.
14. The frequency of the primary home learning experiences surveyed were unrelated to children's mathematics and literacy attainment in Years 1 and 2.

15. Parent-child shared reading in Year 1 was related to children's reading abilities in Year 1 and to their word spelling abilities in Year 2. These relationships were not independent of children's language skills.
16. The extent that shared reading is a correlate or causal influence on literacy development remains ambiguous. However given that there are potential benefits, and few if any negatives to shared reading, it can be encouraged.
17. The frequency of parent-child, letter-sound interactions at preschool age predicted children's mathematics and reading attainment in Year 1, although these relationships were not independent of children's preschool language skills. However, these interactions predicted children's word spelling and alphabet transcription skills in Year 2 independently of the children's language skills at preschool age.

Conclusions & Implications

18. Our findings clarify the nature of the preschool home literacy experiences that are most likely to support later academic development. Preschool letter-sound interactions (a subset of code-related literacy experiences that focused on the sounds within words and the links between letters and sounds) had consistently stronger relationships with later mathematics and literacy attainment than either letter activities (code-related literacy experiences with a more limited letter-sound focus) or meaning-related literacy experiences.
19. Given the consistent longitudinal relationships between preschool letter-sound interactions and a range of academic skills, supporting parents to engage in age-appropriate letter-sound interactions with their preschool children is likely to be beneficial.

20. Preschool letter-sound interactions do not need to be formal in nature. The letter-sound interactions scale, utilised in the current study, captured a variety of experiences, including interactions that could be integrated into discussions about toys, books and environmental print.
21. It is important to communicate that integrating letter-sound interactions into preschoolers' play and everyday experiences can be beneficial because discrete formal instruction is unlikely to be age-appropriate for such young children.
22. Parents and early years educators need support in understanding the nature of age-appropriate letter-sound interactions that are likely to be beneficial in laying the foundations for pre-schoolers' later academic development, and ideas for integrating such experiences into everyday activities.

Context and Aims

The aim of the project was to analyse the influence of the Home Learning Environment (HLE), language and cognitive skills on mathematics and literacy attainment in the first years of primary education. There was a particular focus on the role of the HLE in the preschool and primary years.

Predictors of Mathematics and Literacy Attainment in Young Children

A range of preschool factors have been suggested as predictors of early mathematics and literacy attainment once children commence their primary education. Below we provide a brief review of existing evidence that has examined the role of early number skills, language, cognition and the HLE.

Early Number Skills

Early number skills refer to young children's numerical abilities, which often develop prior to formal schooling (e.g., Case & Griffin, 1990; Gelman & Gallistel, 1978; LeFevre et al., 2010; Sarnecka & Carey, 2008; Siegler, 1991; Spelke, 2000; Wynn, 1992). These abilities include:

Counting: Sequential counting refers to the ability to recite the number-word sequence and acknowledge the position of a number-word in this sequence without necessarily understanding its cardinal meaning (Fuson, 1992; Gelman & Gallistel, 1978). Gradually, children develop the ability to apply their knowledge of the number-word sequence to enumerate sets (Gelman et al., 1986; Wynn, 1992). This serial quantification process is referred to as cardinal counting and requires mapping each number-word onto each item in a set in one-to-one correspondence to acknowledge the exact number of items in a collection (Fuson, 1988, 1992; Gelman & Gallistel, 1978).

Number transcoding: The establishment of a relationship between the different symbolic forms that represent the same number (e.g., number-words, Arabic numerals or non-symbolic quantities) including the ability to convert from one type of numerical representation to another (Deloche & Seron, 1987; Lopes-Silva et al., 2014).

Calculation skills: The understanding that quantities can be composed and decomposed into different quantities (Krajewski & Schneider, 2009b). Many pre-schoolers can complete nonverbal calculations where the quantities are represented by objects (Barth et al., 2005; Huttenlocher et al., 1994; Jordan et al., 1992; Levine et al., 1992; Rasmussen & Bisanz, 2005; Starkey & Gelman, 1982; Zur & Gelman, 2004), however fewer are able to perform formal calculations involving number-words or symbols. Proficiency with formal calculations increases dramatically during the first years of schooling (Jordan et al., 1992; Levine et al., 1992; Rasmussen & Bisanz, 2005).

Children's counting, number transcoding and calculation skills at school entry have been repeatedly associated with their later mathematics attainment (Aubrey & Godfrey, 2003; Aubrey et al., 2006; Aunio & Niemivirta, 2010; Aunola et al., 2004; Byrnes & Wasik, 2009; Duncan et al., 2007; Jordan et al., 2008; Krajewski & Schneider, 2009a,b; LeFevre et al., 2009; Lepola et al., 2005; Östergren & Träff, 2013; Passolunghi & Lanfranchi, 2012; Purpura et al., 2011; Romano et al., 2010; Stock et al., 2009a,b; Tobia et al., 2015). In this report we examine whether pre-schoolers' counting, number transcoding and calculation skills predict their mathematical attainment two years later when they have received formal instruction in primary school.

Early Language Skills

Language abilities include both phonological awareness and vocabulary. These language abilities are solid predictors of children's literacy attainment (see Castles et al., 2018

for a review). Theoretical models of early mathematics development have also identified language abilities as an important precursor of early mathematical skills (Krajewski & Schneider, 2009b; LeFevre et al., 2010). Phonological awareness is proposed to underpin early numeracy development by supporting the development of language-symbol associations when acquiring the names of number symbols (LeFevre et al., 2010) and because numerical tasks such as counting and calculating require the retrieval and usage of verbal codes (see Simmons & Singleton, 2008; Soto-Calvo et al., 2015). Vocabulary skills are proposed to underpin early numeracy development through the acquisition and understanding of mathematical vocabulary (Moll et al., 2015; Purpura & Logan, 2015; Purpura & Reid, 2016; Toll & Van Luit, 2014). This body of research suggests that phonological and vocabulary skills support the development of verbally mediated aspects of early mathematics. Young children's phonological awareness and vocabulary correlate with their performance on mathematical attainment tests (Hecht et al., 2001; Leather & Henry, 1994; LeFevre et al., 2010; Simmons et al., 2008; Soto-Calvo et al., 2015).

Cognitive Factors

Cognitive skills include executive functioning (EF) and reasoning skills. EF is an overarching term for the cognitive processes that control goal-directed behaviour. These processes include the updating of working memory, inhibitory control (IC) and the shifting of the attentional focus (Wiebe et al., 2011). EF has been identified as a precursor of early literacy (Bierman et al., 2008; Davidse et al., 2011; Foy & Mann, 2012; Valiente et al., 2010) and numeracy (see Raghubar & Barnes, 2017 for a review). Reasoning abilities have been shown to predict very early reading (Bowey, 1995; de Jong & van der Leij, 1999) and is a predictor of mathematics attainment, although in secondary and older primary-aged children (e.g., Allen et al., 2019; Caviola et al., 2014; Deary et al., 2007; Donolato et al., 2019),

suggesting that nonverbal reasoning may have a stronger role in later rather than early mathematical skills.

The Influence of the Home Learning Environment

The HLE is a broad term that encompasses parental attitudes towards learning, the availability of home learning resources, as well as the quality and quantity of home experiences that promote learning. The association between a more enriched HLE and young children's more advanced academic skills is well established (e.g., Melhuish et al., 2008; Sammons et al., 2015). However, there is now increasing interest in identifying which aspects of the HLE underpin these associations. One area of particular focus is the relative influence of early home numeracy and literacy experiences on both mathematics and literacy skills. A *within-domain relationship* refers to the link between aspects of the home literacy environment and literacy skills or between aspects of the home numeracy environment and numeracy skills. *A cross-domain relationship* refers to the link between aspects of the home literacy environment and number skills or the influence of aspects of the home numeracy environment on literacy skills. Recent studies have examined both, within- and cross-domain relationships between home literacy and home numeracy experiences and young children's early literacy and mathematics skills.

Within-domain Influences: Home Literacy Experiences and Early Literacy Skills

The Home Literacy Model (HLM) (Sénéchal et al., 1998; Sénéchal, 2006; Sénéchal et al., 2017; Sénéchal & LeFevre, 2002, 2014) classifies home literacy experiences as either code-related or meaning-related. Experiences that focus on the code of written print and its relationship to oral language (e.g., teaching a child to read words, teaching a child letter-sound links) are described as code-related. Experiences where the primary focus is sharing

the meaning conveyed by the text are described as meaning-related[1]. The quintessential meaning-related experience is parent-child shared reading. Within the HLM, code-related home literacy experiences are proposed to support emergent literacy skills, including letter-sound knowledge, which in turn support later word reading. In contrast, meaning-related home literacy experiences are proposed to support semantic oral language skills, which in turn support later reading comprehension.

The predictions of the HLM have been largely supported, with studies reporting links between code-related literacy experiences and early decoding skills (e.g., Chen et al., 2010; Evans et al., 2000; Hood et al., 2008; Huntsinger et al., 2016; Inoue et al., 2018; Manolitsis et al., 2013; Levy et al., 2006; Martini & Sénéchal, 2012; Puglisi et al., 2017; Sénéchal, 2006; Sénéchal & LeFevre, 2002, 2014; Skwarchuk et al., 2014; Shahaeian et al., 2018; but cf. Kim, 2009; Manolitsis et al., 2011; Silinskas et al., 2010, Silinskas et al., 2012; Silinskas et al., 2013; Stephenson et al., 2008) and also between meaning-related home literacy experiences and children's vocabulary or wider semantic language skills (Chen et al., 2010; Frijters et al., 2000; Hamilton et al., 2016; Hood et al., 2008; Inoue et al., 2018; Kalia & Reese, 2009; Kim, 2009; Manolitsis et al., 2013; Sénéchal, 2006; Sénéchal et al., 2008; Sénéchal & LeFevre, 2002, 2014; Shahaeian et al., 2018; Skwarchuk et al., 2014, but cf. Evans et al., 2000). In contrast, shared reading does not have a direct relationship with emerging decoding skills (Chen et al., 2010; Hamilton et al., 2016; Hood et al., 2008; Puglisi et al., 2017; Sénéchal & LeFevre, 2002, 2014; Skwarchuk et al., 2014).

[1] Earlier versions of the HLM used 'formal' rather than code-related and 'informal' rather than meaning-related. However for consistency and to avoid confusion we use code- and meaning-related throughout.

The vast majority of studies examining the predictions of the HLM have operationalised code-related experiences using a small number of items that focus on direct teaching (e.g., Chen et al., 2010; Hamilton et al., 2016; Inoue et al., 2018; Manolitsis et al., 2011; Martini & Sénéchal, 2012; Puglisi et al., 2017; Sénéchal, 2006; Sénéchal & Lefrevre, 2002, 2014; Silinskas et al., 2020; Stephenson et al., 2008). They do not survey the broad range of potential code-related experiences. However, in line with recent conceptualisations of the HLM (Krijnen et al., 2020; Sénéchal et al., 2017) we operationalised code-related home literacy experiences more broadly, including a range of items that involved engagement with print and words in everyday contexts.

Within-domain Influences: The Home Numeracy Experiences and Early Number Skills

The influence of home learning experiences on mathematics attainment has been subjected to less scrutiny than that of reading attainment. Many studies examining within-domain associations between children's home numeracy experiences (i.e., experiences which have a mathematical or numerical component) and their early mathematics attainment or numerical competence report positive associations (e.g., Anders et al., 2012; Del Río et al., 2017; Hart et al., 2016; Huntsinger et al., 2016; Skwarchuk et al., 2014; Sonnenschein et al., 2016; Zippert & Ramani, 2017). Although null findings have also been reported (e.g., Blevins-Knabe et al., 2000; Missall et al., 2015). It has been proposed that home numeracy experiences that are more formal in nature and directly involve the symbolic number system, as well as those that are more advanced for the age-group under study, are more strongly related to children's numerical competences (Elliott & Bachman, 2017; Thompson et al., 2017; Skwarchuk et al., 2014).

Cross-domain Influences

Aside from the within-domain relationship reported in HLE studies for both maths and literacy, an additional role for home literacy experiences supporting numeracy has been suggested (see Anders et al., 2012; Napoli & Purpura, 2018, for discussions). Language skills such as phonological awareness and vocabulary have been associated with the development of number skills (De Smedt et al, 2010; Koponen et al., 2009; Moll et al., 2015; Purpura et al., 2011; Romano et al., 2010; Simmons et al., 2008; Soto-Calvo et al., 2015). Consequently, there is an argument that the home literacy environment could support mathematics attainment via the development of phonological and vocabulary skills. Both positive (e.g., Anders et al., 2012; Baker, 2014; Barnes & Puccioni, 2017) and null (e.g., Huntsinger et al., 2016; LeFevre et al., 2009; LeFevre et al., 2010; Segers et al., 2015) relationships between indices of the home literacy environment and early mathematics skills in young children have been reported. These contrasting results may be due to the extent that these studies included code- and meaning-related items in their home literacy indices. Recent studies that have examined the relative contribution of both code- and meaning-related literacy experiences to children's mathematical attainment suggest that this relationship is stronger for code- than for meaning-related literacy experiences (Manolitsis et al., 2013; Napoli & Purpura, 2018; Soto-Calvo et al., 2020a, b).

The Present Study

We extended the existing body of research in three key ways:

1. We examined the relationships between aspects of the home numeracy and the home literacy environment, and later mathematics and literacy attainment in a UK sample. Whilst the majority of existing research has been conducted with samples

from continental Europe and North America, the educational context is different in the UK where children start their primary school education somewhat earlier.

2. We considered diverse aspects of the home literacy environment. The majority of studies of the HLM have used a small number of direct teaching-focused items (e.g., Chen et al., 2010; Hamilton et al., 2016; Inoue et al., 2018; Manolitsis et al., 2011; Martini & Sénéchal, 2012; Puglisi et al., 2017; Sénéchal, 2006; Sénéchal & LeFrevre, 2002, 2014; Silinskas et al., 2020; Stephenson et al., 2008), consequently there has been limited exploration as to the extent that different types of code-related items impact on early literacy development (although see Krijnen et al., 2020 and Skwarchuk et al., 2014 for studies using a broader conceptualization of home literacy experiences).
3. We have included a wider array of literacy outcomes. Whilst the majority of studies have focused on the relationships between the home literacy experiences and children's reading accuracy and reading comprehension (see Sénéchal et al., 2017 for an overview), we have also examined the influence of the HLE on children's writing skills including alphabet transcription, spelling and text production. Research examining the HLE aspects that underpin children's early writing skills is very scarce and deserves further attention (although see Guo et al., 2020 and Puranik et al., 2018).

Our study enabled the analysis of the influence of preschool early number skills, language and cognitive factors on mathematics and literacy skills in the first years of primary school as well as the examination of the influence of children's HLE during primary school mediating this relationship. The core aims of the present report are summarised in our three research questions:

1. To what extent do preschool early number skills, language and cognitive skills predict mathematics and literacy outcomes in Key Stage 1?
2. To what extent does the preschool HLE predict mathematics and literacy outcomes in Key Stage 1?
3. To what extent does the primary HLE predict mathematics and literacy outcomes in Key Stage 1? Does the primary HLE modify any influence of the preschool HLE?

Methodology

Design and Procedure

The study had a longitudinal design following a sample of children from the spring term of preschool (the academic year that children turn four years of age) to the autumn term of Year 2 (the academic year that children turn seven years of age). At the start of the study, we contacted a range of preschool settings across the counties of Merseyside, Cheshire and Lancashire. A total of 41 early years settings responded and provided consent to participate in the study. We supplied copies of the preschool HLE questionnaire in the spring term of the preschool year (T1a) to these preschool settings and they distributed them to the parents of children registered in their setting who were born between the 1st of September 2012 and the 31st of August 2013. The questionnaire assessed the frequency of home numeracy experiences, code-related home literacy experiences and meaning-related home literacy experiences. It also included a book title checklist to assess shared reading. Alongside these indices of the HLE, the questionnaire gathered information on demographic and SES factors. We received questionnaires relating to children born within the specified age-bracket from 40 Early Years settings. During the spring term of preschool (T1b) we also assessed the early number skills of 274 children whose parents had returned a completed

questionnaire in time for the assessments to be scheduled. We revisited these children in the summer term of preschool (T2) to assess their language and cognitive skills.

The primary school settings that the participating children were attending for Year 1 were invited to take part in a follow-up phase of the project. A total of 63 primary schools gave consent for the study to continue in their setting. Subsequently, the parents who gave initial consent to participate in the study at preschool (T1a) and whose children were attending a primary school that consented for the study to continue, were invited to continue to take part in the study. Parents were asked to complete a primary HLE questionnaire in the spring term of the Year 1 (T3). We received a total of 120 completed questionnaires from 50 of these primary school settings. This questionnaire assessed the frequency of home numeracy experiences, code-related home literacy experiences, meaning-related home literacy experiences and home writing experiences. It also included two book exposure measures to assess shared reading. Children for whom we received a parental primary HLE questionnaire and consent to continue to take part in the study were visited at their primary schools in the summer term of Year 1 (T4) and had their language, mathematics and reading skills assessed. We revisited these primary schools in the autumn term of Year 2 (T5) when the participating children completed spelling and writing assessments. A final data collection time-point was scheduled for the summer term of Year 2 (T6,) to re-assess these children's language, mathematics, reading, spelling and writing skills. However, this data collection had to be cancelled due to school closures amid the Covid-19 pandemic. All child assessments were conducted individually by trained researchers in a quiet area of the child's preschool or primary school. Table 1 summarises the data gathered and sample size at each time point.

Table 1. Data Gathered, Sample Size and Composition at Each Time Point

	Spring Term Preschool		Summer Term Preschool	Spring Term Year 1	Summer Term Year 1	Autumn Term Year 2
Time point	T_{1a}	T_{1b}	T_2	T_3	T_4	T_5
Sample size[1]	274 (146)	274 (146)	241 (116)[3]	120 (63)	119 (62)	119[3] (62)
Mean age[2]	3:11 (3.6)	4:0 (3.63)	4:3 (3.62)	6:0 (3.8)	6:3 (3.8)	6:7 (3.7)
Measures administered	Preschool HLE Questionnaire	Early Number Skills Assessments	Language and Cognitive Assessments	Primary HLE Questionnaire	Language, Mathematics and Reading Skills	Writing Skills

Notes. [1]Children with valid data at this time point. Number of females shown in brackets. [2]Standard deviation shown in brackets. [3]Includes children with full or partial data. Four additional children completed writing assessments at T_5 time point.

Sample

The Parents

A total of 274 parents (254 females) completed the preschool HLE questionnaire (T1a). The postcode deprivation decile for each household was obtained from the English indices of deprivation 2015 online open data of the United Kingdom (Department for Communities and Local Government, http://imd-by-postcode.opendatacommunities.org/). The mean deprivation level was close to the national average (M = 5.42, SD = 3.32). Three respondents did not supply their postcodes. Parental qualifications were coded according to the UK National Qualification framework (https://www.gov.uk/what-different-qualification-levels-mean/list-of-qualification-levels). This scale levels qualifications from 1 (qualifications equivalent to a lower grade GCSE, typically taken by 16-year-olds) to 8 (doctoral level qualifications). Parental highest level of education was diverse, with a mean which was broadly equivalent to two years of post-secondary education (M = 4.75, SD = 2.00). Four respondents did not report their qualifications.

A total of 120 parents (110 females) completed the primary HLE questionnaire (T3). According to our previous records from the preschool HLE questionnaire, the mean deprivation level of this sample was close to the national average (*M* = 5.69, *SD* = 1.19). One retained respondent had not supplied their household postcode. The children's parental highest level of education was diverse, with a mean which was broadly equivalent to two years of post-secondary education (*M* = 4.92, *SD* = 1.92).

The Children

Within the preschool HLE questionnaire (T1a) parents were asked to report the ethnicity of their child, which was coded according to the categories used in the 2011 UK Census. A total of 249 (90.9%) of the children were white, 17 (6.2%) were of mixed/multiple

ethnic heritage, four (1.5%) were Asian, three (1.1%) were Black and one (0.4) was classified as 'other' (a category that includes any ethnicity other than white, mixed/multiple, Asian or Black). Twenty-three children (8.4%) spoke a language in addition to English at home. A range of European, Asian and African languages were reported. Two children could use sign language in addition to spoken English to communicate. A total of 15 children (5.5%) were described by their parents as having a special educational need or disability (SEND) or as being referred for, or undergoing, investigations because such a need was suspected. A range of needs were reported including speech and language impairments, autism and physical disabilities. These 15 children were included in the sample as they were judged able to comprehend the tasks and responded appropriately during the practice items. Including children with SEND in the sample is a more accurate reflection of the population of children attending mainstream preschools in the UK than excluding them.

Of the sample retained for the primary phase of the project (T_3) a total of 110 (92.4%) children were white, eight (6.7%) were of mixed/multiple ethnic heritage and one (0.8%) was classified as 'other'. Nine children (7.6%) spoke a language in addition to English at home and one child could use sign language in addition to spoken English to communicate. Six children (5%) were described by their parents (in the primary questionnaire) as having SEND. Of these six children, four (3.36%), received SEND support at school or had an Education, Health and Care plan in place. These six children were included in the sample as they were judged able to comprehend at least some of the tests and responded appropriately during the practice items. Overall, there were minimal changes in the demographics of the original and retained samples of parents and children.

Measures

The HLE Questionnaires

The HLE questionnaires included a section on child characteristics, demographic and SES factors, a home learning experiences section asking parents to report the frequency that their child experienced certain age-appropriate home learning experiences on a 6-point Likert scale ranging from never to several times a day, and a book exposure section that consisted of checklists used to index parental familiarity with book titles and book authors. These checklists are commonly used in studies of the home literacy environment as a measure of parent-child shared reading (see Dilnot et al., 2017; Hamilton et al., 2016; Hume et al., 2015; Puglisi et al., 2017; Skwarchuk et al., 2014; Sénéchal et al., 1998; Sénéchal et al., 2008).

Preschool HLE Questionnaire (T1a). The preschool home learning experiences section consisted of a list of 32 home experiences (listed in Appendix 1). There were eight number experiences, eight meaning-related literacy experiences and seven code-related literacy experiences. In addition, there were nine domain non-specific filler items that were not analysed (e.g., rides a scooter, balance bike or bike). The different types of items were randomly ordered within this section. Shared reading was assessed with a book title checklist consisting of fifteen real and six made-up titles (these are listed in Appendix 2). Parents were asked to indicate which book titles were real children's books. They were given three choices; 'real', 'made-up' and 'don't know'. The number of correctly identified real titles and falsely identified made-up titles was recorded.

The Primary HLE Questionnaire (T3). The Primary Home Learning Experiences section consisted of a list containing 36 home experiences (listed in Appendix 3). There were six number experiences, six code-related literacy experiences, six meaning-related literacy

experiences and six writing experiences. In addition, there were 12 non-domain specific fillers that were not analysed (e.g., rides a scooter, balance bike or bike). The different types of items were randomly ordered within this section. The primary book exposure section consisted of two checklists; a book title checklist and a book author checklist. The book title checklist (Hamilton, 2014) consisted of a list of 32 titles (23 were real children's book titles and 9 foils). Parents had to indicate which book titles were real children's books and given three choices; 'real', 'made-up' and 'don't know'. The number of correctly identified real titles and falsely identified made-up titles was recorded. The children's author checklist (Hamilton, 2014) contains 40 names of children's authors and 40 foils. Respondents were asked to indicate which names were real authors of children's storybooks. The number of correctly identified real authors and falsely identified made-up names was recorded. See Hamilton (2014) for the titles and authors used in the checklists.

Preschool Assessments

Early Number Skills (T1b). There was one sequential counting measure, two measures of cardinal counting (give me X and counting objects), two measures of number transcoding (numeral reading and numeral recognition) and two measures of calculation (addition and subtraction). In the sequential counting task children were asked to count out loud to a cuddly toy starting from one to as high as they could. The highest number recited in the correct order was recorded. In the give me X task the child was asked to place a specific number of toy animals (that they had to select from a larger set) onto a drawing of a farm or into a house (e.g., "Can you put two ducks in the pond?", "Can you put ten teddies in the house?"). This task consisted of three blocks of five items. In the counting objects task the children were asked to count animal pictures presented on a card (e.g., "How many bears are there?"). There were 20 cards with pseudo-randomly distributed pictures of animals on each

card. The cards were grouped into four blocks each consisting of five items. In the numeral recognition task the researcher asked the child to point at a specific number (e.g., "Can you point to number five?"). This task consisted of four blocks of five items. In the numeral reading task children were asked to name the printed numerals that the researcher pointed at on a sheet of card. Each card displayed five numerals. This task consisted of four blocks of five items. In the addition and subtraction tasks the experimenter presented each problem to the child in the form of story (e.g., "If you put two horses on the path and you add one more, how many horses would there be?"). Animal toys and a drawing of a farm or a house were available to help the child complete the calculation. The child was asked to provide a verbal response. These tasks consisted of three blocks of four items. See Table 2 for children's performance on these early number skills tasks at Time 1b.

Table 2. Children's Performance on the Early Number Skills Measures Administered in Preschool (T1b)

	N	Maximum[1]	M	SD
Sequential counting	274	-	16.57	14.23
Counting objects	274	20	5.14	2.72
Give me x	274	15	3.17	2.47
Numeral recognition	274	20	6.41	5.32
Numeral reading	274	20	5.07	3.99
Addition	274	12	1.69	2.25
Subtraction	274	12	2.23	2.23

Notes. [1]Maximum possible score.

Cognition and Language assessments (T2). Two subtests from the Preschool and Primary Inventory of Phonological Awareness (PIPA, Dodd et al., 2000) were administered to assess children's phonological awareness. In the Alliteration Awareness subtest children had to identify the word (from a choice of four) that did not start with the same sound as the

others. In the Rhyme Awareness subtest children had to identify the word (from a choice of four) that did not rhyme with the others. Both of these tests consisted of two practice items and 12 experimental items. Vocabulary was assessed with two standardised measures. In the Naming Vocabulary subtest from the British Ability Scales III (BAS-3, Elliott & Smith, 2011) the child had to name a picture presented to them. In the Receptive Vocabulary subtest from the Wechsler Preschool and Primary Scale of Intelligence - Fourth UK Edition (WIPPSI-IV-UK, Wechsler, 2013) the child had to point at the picture (from a choice of four) that best matched the word said by the researcher. Nonverbal reasoning was assessed with two standardised measures. In the Matrices subtest from the BAS-3 (Elliott & Smith, 2011) the child had to choose the shape (from a choice of 4) that best completes the pattern. In the Picture Similarities subtest from the BAS-3 (Elliott & Smith, 2011) the child had to choose which picture best fitted with the set presented. Executive functioning was assessed with two experimental measures, which had been used previously with preschool children. The Fish/Shark task (Wiebe et al., 2012) was a response inhibition task presented on a laptop computer. The children had to press a key when they saw a fish (to catch it) but inhibit this response when they saw a shark. The d' index was calculated (this is a sensitivity index, which represents how accurately the child detects the fish and rejects the sharks). In the Big-Little Stroop (adapted from Kochanska et al., 2000) the child was shown the large outline of an animal with smaller animal outlines presented within it. The large outline appeared briefly first (priming effect). The child's task was to inhibit naming the larger animal and state what the smaller animals within the outline were. Children's performance was indexed by the percentage of incongruent trials (where the larger outline differed from the smaller ones within it) responded to correctly. See Table 3 for children's performance on the language and cognitive measures at Time 2.

Table 3. Children's Performance on the Predictor Measures Administered in Preschool (T2)

	N[3]	Mean	SD
Alliteration Ability	263	3.73	2.80
Alliteration Standard[1]	263	9.87	2.92
Rhyme Awareness Ability	254	4.36	2.71
Rhyme Awareness Standard[1]	254	9.66	2.73
Expressive Vocabulary Ability	265	127.12	15.09
Expressive Vocabulary Standard[2]	265	52.59	9.83
Receptive Vocabulary Ability	257	16.99	4.77
Receptive Vocabulary Standard[1]	257	10.08	3.12
Big/Little Stroop %	251	75.70	26.71
Fish/Shark d	242	1.74	1.12
Picture Similarities Ability	256	92.60	12.36
Picture Similarities Standard[2]	256	48.15	14.28
Matrices Ability	265	57.92	18.39
Matrices Standard[2]	265	43.40	9.59

Notes. Age standardised scores given for all standardised measures. [1]Standardised mean of 10. [2]Standardised mean of 50. [3] Fish/Shark d indexes could not be calculated for 8 children due to their random response pattern. All other missing data on this and the other measures is due to child absence during the testing schedule.

Primary Child Assessments

Language assessments (T4). Two vocabulary tests were administered to assess children's vocabulary. In the Naming Vocabulary test from the BAS-3 (Elliott & Smith, 2011) the child is presented with a picture of an item and has to name it. In the Receptive Vocabulary test from the Wechsler Preschool and Primary Scale of Intelligence - Fourth UK Edition (WIPPSI-IV-UK, Wechsler, 2013) the child has to point at the picture (from a choice of four) that matches the word said by the researcher. Two standardised tests from the York

Assessment of Reading for Comprehension Early Reading (YARC, Hulme et al., 2009) consisting of 12 experimental items each were administered to assess children's phonological awareness. In the Sound Isolation test the child has to produce the first or last sound of a word said by the researcher. This test includes six practice items for which feedback is provided. In the Sound Deletion test the child has to produce only part of the word said by the researcher by omitting a sound in that word. This test includes seven practice items for which feedback is provided. See Table 4 for children's performance on the language measures at Time 4.

Table 4. Children's Performance on the Predictor Measures Administered in Year 1 (T4)

Test	N	Mean	SD
Expressive Vocabulary Ability	119	156.10	16.69
Expressive Vocabulary T	119	58.32	10.36
Receptive Vocabulary Standard	119	10.51	2.53
Sound Deletion Ability	119	72.70	16.05
Sound Deletion Standard	119	109.65	12.58
Sound Isolation Ability	119	87.99	14.22
Sound Isolation Standard	119	109.55	10.50

Mathematics (T4). The Number Skills Scale from the BAS-3 (Elliot & Smith, 2011) was administered. This measure covers a broad range of mathematical concepts that are relevant to the children's age.

Reading (T4). In the Passage Reading test from the YARC Passage Reading (Snowling et al., 2011) the child has to read aloud two short passages and is asked eight questions about each passage immediately after it had been read. The number of reading errors made is recorded to calculate a reading accuracy score. One point is given for each question about

the passage answered correctly, providing a reading comprehension score. See Table 5 for children's performance on the mathematics and reading measures at Time 4.

Table 5. Children's Performance on the Mathematics and Reading Measures Administered in Year 1 (T4)

	N	M	SD
Mathematics Ability	119	90.18	27.24
Mathematics Standard	119	107.43	14.29
Passage Reading Accuracy Ability	119	39.24	11.57
Passage Reading Accuracy Standard	119	110.13	11.76
Passage Reading Comprehension Ability	118[1]	42.34	12.11
Passage Reading Comprehension Standard	118	106.70	12.49

Note.[1]The reading accuracy score of one participant did not meet the accuracy threshold to allow comprehension questions to be administered.

Spelling (T5). In the Spelling test from the BAS-3 (Elliot & Smith, 2011) the child has to write words spoken by the researcher. See Table 6 for children's performance on the spelling measure at Time 5.

Alphabet Transcription (T5). Children's alphabet transcription was assessed with an adapted version of the alphabet writing test of the Wechsler Individual Achievement Test (WIAT–II UK, Wechsler, 2005). In this task the child was presented with lined paper on which the first letter of the alphabet was printed in lower case and then asked to continue writing the letters of the alphabet, in sequence, for 15 seconds. The number of letters produced was recorded. Raters credited each letter that was judged identifiable and could be distinguished from the other letters formed. See Table 6 for children's performance on the alphabet transcription measure at Time 5.

Writing (T5). Children's writing abilities were assessed with two tasks assessing their writing production skills (i.e., sentence generation test and narrative generation test). In the

sentence generation test (adapted from Arfe et al., 2016; Dockrell et al., 2019) the child has to generate and write sentences. In a practice trial, the child was presented with a lined sheet of paper at the top of which was printed the word pair 'child-car'. The experimenter explained that they wanted the child to play a game where they made up as many sentences as they could which included these two words and write them down. The experimenter spoke two such sentences aloud and modelled writing them. The child was then told it was their turn and they should try to write as many sentences as they could using the words 'man-dog'. The child was encouraged to continue writing sentences for five minutes. This task reflects children's ability to generate ideas in written sentences and represents translation processes in writing at the sentence level (Arfé et al, 2016; Dockrell et al., 2019). Semantically and syntactically correct sentences that contained both targets were awarded two points. Sentences considered to be only minimally semantically or syntactically different from previous sentences, were awarded one point. Errors in punctuation, capitalisation or misspellings were ignored. The number of points awarded to each sentence was summed to provide the sentence generation total score. In the narrative generation test (adapted from Kim et al., 2011; Puranik & Al Otaiba, 2012) the child was asked to compose an extended text to the prompt "At school I like…". Each child was given two minutes before writing to discuss with the experimenter a set of four pictures showing children engaging in typical primary school activities (e.g., working in class and playing in the playground). They were then provided with a sheet of lined paper on which the prompt was printed and asked to write about the things they liked doing at school. The child was encouraged to write for five minutes, after which time the task was stopped, though they were allowed to finish any sentence they had already started when the time elapsed. This task assesses children's ability

to produce text beyond the sentence level. See Table 6 for children's performance on the spelling and writing measures at Time 5.

Table 6. Children's Performance on the Spelling, Alphabet Transcription and the Writing Measures Administered in Year 2 (T5)

	Mean	SD	N
Alphabet transcription	4.78	2.64	121
BAS Spelling [a]	105.84	14.04	121
SG. Total score	7.72	4.10	120
SG. Number of words	33.45	14.42	120
SG. % Spelled correct	.86	.14	120
SG. Number of T-units	5.01	2.27	120
SG. MLT-units	6.77	2.20	118
SG. Number of Clauses	5.22	2.46	120
SG. Clause density	1.04	0.11	118
TP. Number of words	24.18	12.75	121
TP. % Spelled correct	.71	.25	121
TP. Number of T-units	2.31	2.39	121
TP. MLT-units	7.61	2.85	74
TP. Number of Clauses	3.05	3.16	121
TP. Clause density	1.40	0.52	74

Notes. SG = Sentence Generation, TP = Text Production, MLT-units = Mean Length of T-units. Four additional children, who were not included in the preschool HLE analyses completed the writing assessments. These children were not included in the core correlation analyses, but were included in the factor analyses that confirmed the structure of the writing skills.

Analysis Strategy and Key Findings

Data Reduction

The Home Learning Environment: Home Learning Experiences and Shared Book Reading (T1a & T3)

Preschool Home Learning Experiences (T1a). We created preschool home experiences scales from the number, code-related literacy and meaning-related literacy items contained in the preschool HLE questionnaire. First, we removed items with limited variability then we conducted a Principal Axis Factoring (PAF) analysis on each scale separately. While the home numeracy experiences and the meaning-related home literacy experiences formed a single scale, the code-related home literacy experiences fractionated into two scales. One contained experiences that were more interactive and focused on sounds or the links between letters and sounds. We therefore labelled this scale *Letter-sound interactions*. The second contained activities that were less interactive and less focused on the link between letters and their sounds. We therefore labelled this scale *Letter activities*. The final items that were contained in these scales are shown in Table 7. Full details of this analysis, and each of the scale items, can be found in Soto-Calvo et al. (2020a).

Table 7. Items Within the Final Preschool HLE Scales (Time 1a)

Number	Meaning-related Literacy	Code-related Literacy	
		Letter-sound Interactions	Letter Activities
Is encouraged to point out or identify numbers in books or the environment (e.g. "What number is on the bus? Can you see a number 8?")	Discusses stories with an adult (e.g. "What do you think happens next? Do you think the bunny is frightened?")	Talks about letter sounds with an adult (e.g. "What sound does snake start with?", "Can you think of any other words starting with 's'"?	Plays with puzzles or games involving letters
Is taught the names of numbers (e.g. "This is number 8")	Is encouraged to point out or identify pictures in books (e.g. "Can you point to the elephant?")	Is taught the names or sounds of letters or how to 'sound out' words	Sings or recites the alphabet
Writes or traces numbers	Is encouraged to choose books that interest them to look at with an adult	Forms or traces letters or writes their name	Completes activities involving letters or sounds in magazines or workbooks
Completes number activities in magazines or workbooks	Is encouraged to use books to follow-up interests or experiences they have (e.g. looking at a space book because that had talked about space at preschool)	Is prompted to identify letters in books or the environment (e.g. "Can you see a's' on the sign?", "What letter does the word cat begin with?")	
Plays games that involve number cards, dice or a number spinner	Discusses with an adult how things work or what they mean (e.g. "Why do you think the ice lolly is melting?", "Nocturnal animals sleep in the day")		
Discusses numbers or quantity with an adult (e.g. "How many blocks are there?", "Who has more sandwiches?")	Looks at factual books (e.g. books about animals, space or transport)		

Preschool Shared Book Reading (T1a). The mean score for real book titles correctly identified was 8.49 (*SD* = 3.19). Six respondents did not complete this section. Parental responses to the preschool book title checklist were used to create a book exposure variable using the same formula as Skwarchuk et al. (2014), which corrects for guessing [(books titles correctly identified - foils identified as real books) / total number of actual books] x 100). The mean score for the computed preschool book title checklist was 53.41% (SD = 21.63), reflecting that on average parents could correctly identify approximately half of the real book titles. See Soto-Calvo et al. (2020a) for the parental responses to the individual items utilised in the preschool book exposure checklist.

Primary Home Learning Experiences (T3). We created primary home experiences scales from the number, code-related literacy, meaning-related literacy and writing literacy from the items contained in the primary HLE questionnaire using the same methodology as for the preschool home experiences scales. The final items that were contained in these scales are shown in Table 8.

Table 8. Items Within the Final Primary HLE Scales (T3)

	Literacy		
Number	Meaning-related	Code-related	Writing
Is encouraged to practice calculations (these could be addition, subtraction, multiplication or division). The calculations might involve concrete objects or be completed mentally	Is encouraged to choose books that interest them to look at with an adult	Practices reading individual words (sometimes called key words/high frequency words/'tricky' words)	Is encouraged to use writing in practical tasks (e.g. making notes, lists)
Is encouraged to practice reading numbers or ordering numbers	Is encouraged to use books to follow-up their interests or experiences (e.g. looking at a space book because they had discussed space at school)	Is encouraged to attempt to spell unfamiliar words	Engages in independent writing
Rehearses number facts (e.g. number bonds or times tables)	Discusses stories with an adult (e.g. "What do you think happens next?")	Reads aloud to an adult (this could be books supplied by yourself or school reading books)	Is encouraged to use correct punctuation (e.g. capital letters) when writing
Practices counting forwards or backwards in 1s, 2s, 5s, or 10s	Looks at factual books (e.g. books about animals or transport)	Is encouraged to sound out unfamiliar words or 'alien' words	An adult reads and discusses child's writing
Discusses numbers or quantity with an adult (e.g. "Can you share out the sweets equally?", "How much flour do we need for the cake?")	Discusses with an adult how things work or what they mean (e.g. "Why do you think the ice lolly is melting?")	Practices the sounds that a letter or letters make (e.g. 's', 'sh', 'igh')	Writes about or labels pictures they have drawn
Plays games that involve number cards, dice or a number spinner		Practices spelling words	Adult and child engage in writing tasks together

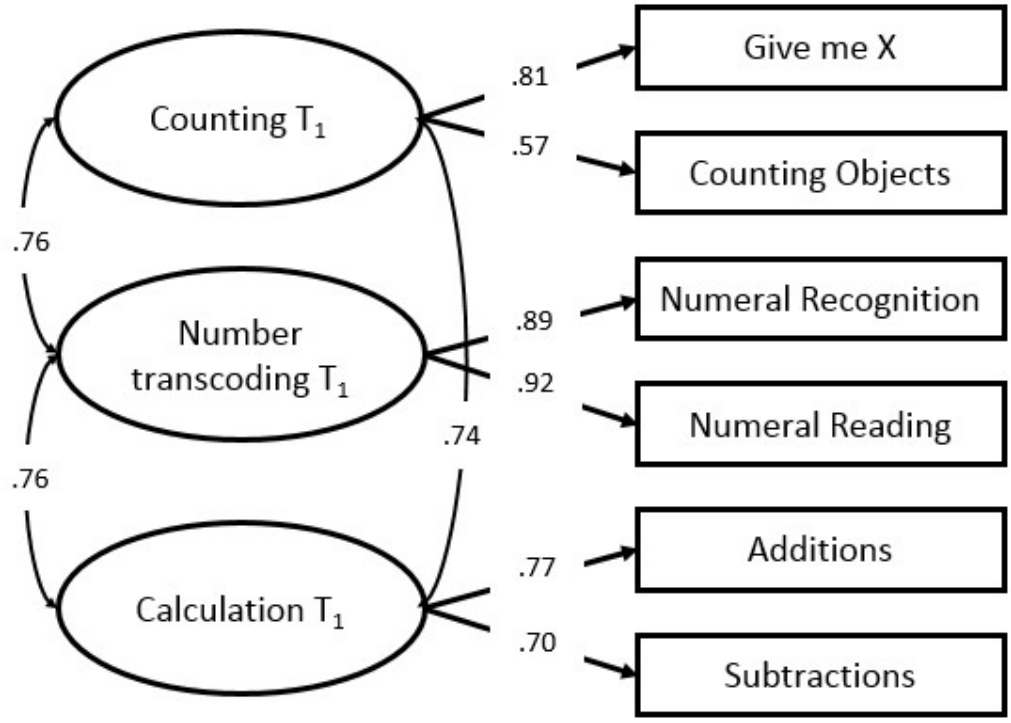
Primary Shared Book Reading (T4). Parental responses to the primary book title checklist and the primary book author checklist were used to create two primary book

exposure variables respectively, using the same formula as Skwarchuk et al. (2014) which corrects for guessing, i.e., [(books titles correctly identified - foils identified as real books) / total number of real books] x 100) and [(authors correctly identified - foils identified as real authors) / total number of actual authors] x 100). The mean score for the computed primary book titles checklist was 32.10% (SD = 23.83), reflecting that on average parents could correctly identify approximately one third of the real book titles. The mean score for the computed primary book author checklist was 25.77% (SD = 16.94), reflecting that on average parents could correctly identify approximately a quarter of the real authors. A composite variable for primary book exposure was then created from the mean of the z-scores of these two primary shared reading computed scores.

Early Number Skills (T1b)

We used Confirmatory Factor Analysis (CFA) to confirm that our number skills measures loaded onto the three factors we hypothesised (i.e., counting, number transcoding and calculation). This three-factor structure was a good fit for the data for six of the core tests. However, sequential counting could not be accommodated in the model either as a single observed measure or as part of the counting factor since it reduced the fit of the model. Consequently, it was dropped from subsequent analyses. The preferred model of early number skills assessed at T1 is shown in Figure 1 below. This analysis is reported in full in Soto-Calvo et al. (2020a).

Figure 1. The Relationships Between the Preschool Early Number Skills Measures and the Early Number Skills (T1b)



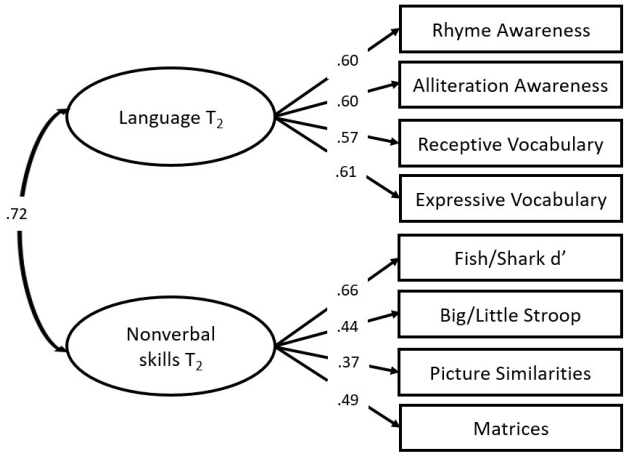
In order to conduct the subsequent analyses we created composite scores consistent with the factor structure confirmed by the CFA. These composites were created from the mean of the z-scores of the component variables. Counting was created from give me x and counting objects, number transcoding from numeral reading and numeral recognition, and calculation from addition and subtraction.

Language and cognition (T2)

We used CFA to determine an appropriate factor structure for the language and cognitive factors. Our original intention was to create four factors (vocabulary, phonological awareness, executive functioning and nonverbal reasoning), however this model did not provide an appropriate fit of the data because executive functioning and nonverbal reasoning measures were too highly related. Consequently, we produced two further models. In the first three-factor model, phonological awareness and vocabulary remained separate factors

with a single nonverbal abilities factor. In the second we created a two-factor model with language abilities (encompassing both phonological awareness and vocabulary) and nonverbal abilities (encompassing both nonverbal reasoning and executive skills). Both these models provided an adequate fit of the data. However, the model comprising two factors, language skills and nonverbal abilities, was taken forward for subsequent analyses (illustrated in Figure 2) because it provided a better fit of the data. Furthermore, within the alternative three-factor model the separate phonological awareness and vocabulary factors were highly correlated which is problematic when entered as simultaneous predictors within longitudinal analyses. The full analysis is reported in Soto-Calvo et al. (2020b).

Figure 2. The Relationships Between the Preschool Language and Cognitive Measures and the Language and Nonverbal Factors (T2)



In order to conduct the subsequent analyses we created composite scores consistent with the structure confirmed by the CFA. These composites were created from the mean of the z-scores of the component variables. The language composite was created from Alliteration awareness, Rhyme awareness, Receptive vocabulary and Naming vocabulary. The nonverbal composite was created from Matrices, Picture similarities, Big/Little Stroop and Fish/Shark d'.

Language (T4)

In our CFA analysis of the preschool language and nonverbal abilities the model comprising two factors, language and nonverbal abilities, was taken forward for subsequent analyses because it provided a better fit of the data than separate vocabulary and phonological awareness factors (see Figure 2). We conducted Exploratory Factor Analysis (EFA) using the PAF method with a Promax rotation and Kaiser normalization with the language variables assessed in Year 1 (T4) to confirm the existence of one language factor. Results from this analysis indicated again that a single language factor rather than separate phonological and vocabulary factors provided a better fit of the data. We therefore created a language composite measure from the mean of the Z scores of all four language measures administered at Time 4. Individual item loadings are shown in Table 9.

Table 9. Factor Loadings for Exploratory Factor Analysis using PAF of the Phonological and Vocabulary Measures Administered in Year 1 (T4).

Measure	Factor loadings
Receptive Vocabulary	.70
Sound Deletion	.60
Expressive Vocabulary Ability	.57
Sound Isolation	.53

Writing (T5)

Exploratory Factor Analysis (EFA) initiated with Principal Components Analysis (to confirm the orthogonal status of the factors) subsequently applying the Varimax rotation with Kaiser normalisation, evaluated the factor structure of the microstructural measures (i.e., word and sentence features) derived from children's sentence and text production. The following variables were included in the analyses to index productivity and complexity at the word and sentence level; the total number of words, T-units, the proportion of correctly spelled words, the MLT-units and clause density in both sentence generation and text production. The

Kaiser-Meyer-Otkin value of .54, being above .5 was considered to be acceptable confirming the adequacy of the sample with Bartlett's test of sphericity also significant (x^2 (45) = 386.31, p<.001). Four factors emerged with Eigenvalues > 1. Factor 1 (Eigenvalue = 3.30) explained 32.96 % of the variance with Factor 2 (Eigenvalue = 1.90) accounting for an additional 18.90%, Factor 3 (Eigenvalue = 1.46) a further 14.62 %, and Factor 4 (Eigenvalue = 1.07) an additional 10.71 % of the variance. The loadings of variables on this four factor structure (suppressing loadings below .4) is displayed in Table 4. The loadings of variables on this four-factor structure (suppressing loadings below .4) is displayed in table 10. We interpreted Factor 1 as an index of writing productivity, Factor 2 as an index of writing complexity in text production, Factor 3 as an index of spelling ability and Factor 4 as an index of writing complexity in sentence generation. This structure follows almost exactly that identified by Arfé and colleagues (2016) except that the absence of accuracy measures (gender agreement being minimal in English) resulted in a factor of text spelling. Combined, the factors accounted for 77.78% of the variation in writing performance.

Table 10. Factor Loadings for Exploratory Factor Analysis Using Principal Component Analysis with Varimax Extraction of the Indices of Writing Performance in Year 2 (T5)

Measure	Productivity	TP Complexity	Text Spelling	SG Complexity
TP. Number of Words	.84			
SG. Number of Words	.81			
TP. T-units	.76			
SG. T-units	.70	-.50		
TP. MLT-units		.90		
TP. Clause Density		.88		
SG. % Spelled Correct			.89	
TP. % Spelled Correct			.85	
SG. MLT-units				.85
SG. Clause Density				.69

Note. SG = Sentence Generation, TP = Text Production, MLT-units = Mean Length of T-units.

Correlation Analyses

Correlations among the SES indices (postcode deprivation and parental qualification), the preschool HLE scales obtained at Time 1a, the children's preschool language and nonverbal abilities assessed at Time 2, the primary HLE scales obtained at Time 3, and the children's primary language abilities assessed at Time 4 are shown in Table 11.

Table 11. Correlations Among the SES Indices, the Preschool and Primary HLE Scales, and the Language and Cognitive Measures

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. PD T1a	-														
2. PQ T1a	.42***	-													
3 N EXP T1a	-.03	-.01	-												
4. L MEA T1a	.01	.08	.51***	-											
5. LS INT T1a	.02	.01	.73***	.50***	-										
6. L ACT T1a	-.11	-.16**	.72***	.42***	.70***	-									
7. BTC T1a	.19**	.21**	.17**	.14*	.18**	.03	-								
8. LANG T2	.06	.09	.20**	.09	.31***	.16*	.12	-							
9. N-VERB T2	-.06	-.02	.16*	.03	.20**	.21**	.11	.49***	-						
10. N EXP T3	.16	.09	-.46***	-.40***	-.34***	-.35***	.09	-.11	-.11	-					
11. L MEA T3	-.01	-.06	-.44***	-.45***	-.43***	-.34***	-.02	-.17	-.17	.66***	-				
12. L CODE T3	-.02	-.18*	-.36***	-.54***	-.32***	-.23*	-.13	-.09	-.09	.54***	.68***	-			
13. L WRI T3	-.02	.06	-.44***	-.44***	-.48***	-.39***	-.00	-.12	-.12	.56***	.50***	.66***	-		
14. BOOK EXP T3	.32**	.32**	.21*	.15	.18	.00	.44***	.21*	.05	-.02	-.14	-.18	-.03	-	
15. LANG T4	.38***	.31**	.21*	.17	.35***	.21*	.08	.53***	.40***	-.01	-.16	-.21*	-.19*	.29**	-

Note. PD = Postcode Deprivation; PQ = Parental Qualifications; N EXP = Number Experiences; L MEA = Meaning-related Experiences; LS INT = Letter-sound interactions; L ACT = Letter activities; BTC = Book title checklist; LANG = Language abilities; N-VERB = Nonverbal abilities; L CODE = Code-related experiences; L WRI = Writing experiences; BOOK EXP = Book Exposure.
Cases excluded pairwise. * p<.05, ** p<.01, *** p<.001.

The preschool home experiences scales are positively related to each other and so are the primary home experiences scales. However, the preschool experiences scales are negatively related to the primary ones. The preschool and primary book exposure indices are positively related to each other and to both of the SES indices, and whilst the preschool book xposure index is positively related to the preschool home experiences scales (with the exception of the letter activities scale), neither the preschool nor the primary school book exposure index are related to the primary home experiences. The preschool nonverbal abilities and the preschool and primary language abilities are related to each other and to the preschool home learning experiences scales (with the exception of the meaning-related literacy experiences scale). Primary language abilities are negatively related to the primary home literacy code-related and writing scales.

Correlations among the predictor variables and the mathematics and reading attainment measures administered in Year 1 (T4) are shown in Table 12.

Table 12. Correlations Between the Predictor Variables and the Mathematics and Reading Measures in Year 1 (T4)

	Mathematics	Reading Accuracy	Reading Comprehension
1. PD T1a	.16	.18	.09
2. PQ T1a	.09	.26**	.18*
3 N EXP T1a	.16	.20**	.12
4. L MEA T1a	-.02	.07	.08
5. LS INT T1a	.27**	.27**	.19*
6. L ACT T1a	.13	.15	.12
7. BTC T1a	-.14	-.02	.07
8. LANG T2	.30**	.40***	.47***
9. N-VERB T2	.18	.26**	.35***
10 N EXP T3	-.12	-.02	.04
11. L MEA T3	-.03	-.12	-.14
12. L CODE T3	-.16	-.15	-.13
13. L WRI T3	-.23*	-.22*	-.12
14. BOOK EXP T3	.06	.24*	.17
15. LANG T4	.55***	.68***	.71***

Note. PD = Postcode Deprivation; PQ = Parental Qualifications; N EXP = Number Experiences; L MEA = Meaning-related Experiences; LS INT = Letter-sound interactions; L ACT = Letter activities; BTC = Book title checklist; LANG = Language abilities; N-VERB = Nonverbal abilities; L CODE = Code-related experiences; L WRI = Writing experiences; BOOK EXP = Book Exposure. Cases excluded pairwise. * $p<.05$, ** $p<.01$, *** $p<.001$.

The preschool home letter-sound interactions scale and the children's preschool and primary language abilities were significant positive correlates of their mathematics performance in Year 1. Parental qualifications, the preschool home number and letter-sound interactions scales, the children's preschool and primary language abilities, their nonverbal abilities at preschool and the primary book exposure scale were all were significant positive correlates of their reading accuracy in Year 1. Parental qualifications, the preschool home letter-sound interactions scales, the children's preschool and primary language abilities and

their nonverbal abilities at preschool were all significant positive correlates of their reading comprehension in Year 1. Finally, the primary home literacy writing scale was a negative correlate of children's mathematics and reading accuracy in Year 1.

Correlations among the predictor variables and the spelling and writing measures administered in Year 2 (T5) are shown in Table 13.

Table 13. Correlations Between the Predictor Variables and the Spelling and Writing Measures in Year 2 (T5)

	Word Spelling	Alphabet transcript.	Productivity	TP Complexity	Text Spelling	SG complexity
1. PD T1a	.20*	.26**	.15	-.02	-.02	-.01
2. PQ T1a	.22*	.15	.06	.05	.11	.02
3 N EXP T1a	.21*	.19*	.01	-.02	.01	-.10
4. L MEA T1a	.07	.03	.04	-.07	-.12	-.17
5. LS INT T1a	.28**	.25**	.12	-.01	.11	-.09
6. L ACT T1a	.18	.07	.11	-.03	.03	-.13
7. BTC T1a	.03	-.10	.01	-.02	.11	.08
8. LANG T2	.41***	.22*	.28**	.13	.30**	-.21
9. N-VERB T2	.36***	.14	.16	.27*	.41**	-.05
10. N EXP T3	-.00	.04	-.01	-.02	.01	-.10
11. L MEA T3	-.15	-.16	-.01	-.02	.01	-.10
12. L CODE T3	-.13	-.11	.01	-.02	-.01	.11
13. L WRI T3	-.21*	-.13	.01	-.02	.01	-.10
14. BOOK EXP T3	.19*	.02	-.01	.05	.26*	-.16
15. LANG T4	.66***	.37***	.20	.24*	.54***	-.14

Notes. Alphabet transcript. = Alphabet Transcription; PD = Postcode Deprivation; PQ = Parental Qualifications; N EXP = Number Experiences; L MEA = Meaning-related Experiences; LS INT = Letter-sound interactions; L ACT = Letter activities; BTC = Book title checklist; LANG = Language abilities; N-VERB = Nonverbal abilities; L CODE = Code-related experiences; L WRI = Writing experiences; BOOK EXP = Book Exposure. Cases excluded pairwise. *p <.05, **p <.01, ***p <.001.

Both SES indices (parental qualifications and postcode deprivation), the preschool home number and letter-sound interactions scales, the primary book exposure scale, the children's nonverbal abilities and their preschool and primary language abilities were

significant positive correlates of their word spelling in Year 2. Postcode deprivation, the preschool home number and letter-sound interactions scales, and the children's preschool and primary language abilities were significant positive correlates of their alphabet transcription skills in Year 2. Preschool nonverbal abilities and the children's preschool and primary language abilities were significant positive correlates of their text spelling skills in Year 2. Children's preschool language abilities and preschool nonverbal abilities were significant correlates of their productivity and text production complexity in Year 2, respectively. Lastly, sentence generation complexity did not correlate significantly with any of the predictor variables.

Regression Analyses

We conducted a series of hierarchical linear regression models to examine our core research questions.

Examining the Extent that Preschool Early Number (T1b), Language and Nonverbal Abilities (T2) Predict Mathematics and Literacy Outcomes in Key Stage 1 (T4 & T5)

Do preschool number skills predict primary mathematics attainment?

Children's performance on the three early number skills was significantly correlated to their performance on the standardised mathematics test administered in Year 1 (T4) ($r_{\text{Counting}} = .42$, $p < .001$; $r_{\text{Number transcoding}} = .65$, $p < .001$ and $r_{\text{Calculation}} = .52$, $p < .001$). Therefore, we first addressed the question of whether preschool early number skills (T1b) predict mathematics outcomes in Year 1 (T4). We conducted a linear regression model predicting mathematics in Year 1 from the three preschool early number skills entered simultaneously in a single step (see table 14).

Table 14. Linear Regression Model Predicting Mathematics in Year 1 (T4) from the Preschool Early Number Skills (T1b)

	Mathematics (T4)	
	β	R^2
1.Early Number Skills		
Counting	.08	
Number transcoding	.50***	
Calculation	.18*	
		.46***

*p <.05, **p <.01, ***p <.001.

The children's counting, number transcoding and calculation skills in preschool explained a significant 46% of the variance in their mathematics attainment in Year 1 (T4), with number transcoding and calculation skills explaining a unique significant proportion of variance.

Do preschool language and nonverbal abilities predict primary mathematics and reading attainment?

We conducted three linear regression models predicting Mathematics, Reading Accuracy and Reading Comprehension in Year 1 from the preschool language and nonverbal skills, respectively. The two predictor variables were entered simultaneously in a single step in the regression model (See Models 1 to 3 inTable 15).

Table 15. Linear Regressions Models Predicting Mathematics, Reading Accuracy and Reading Comprehension in Year 1 (T4) from the Preschool Language and Nonverbal Skills (T2).

	Mathematics			Reading Accuracy			Reading Comprehension		
Predictor	Model	β	Δ R^2	Model	β	Δ R^2	Model	β	Δ R^2
1.LANG & N-VERBAL	1			2			3		
LANG		.22*			.33**			.41***	
N-VERB		.07			.09			.14	
			.07*			.15***			.25***

Notes. LANG = Language abilities; N-VERB = Nonverbal abilities.
*p <.05, **p <.01, ***p <.001.

All three models indicate that preschool language abilities were a unique significant predictor of children's mathematics, reading accuracy and reading comprehension in Year 1, but preschool nonverbal abilities were not.

Do preschool language and nonverbal abilities predict primary spelling and writing attainment?

We conducted six linear regression models predicting Word Spelling, Alphabet transcription, Writing Productivity, Text Production Complexity, Text Spelling and Sentence Generation Complexity in Year 2 from the preschool language and nonverbal abilities, respectively. The two predictor variables were entered simultaneously in a single step in the regression models (See Models 4 to 9 in Table 16).

Table 16. Linear Regressions Models Predicting Word Spelling, Alphabet Transcription, Writing Productivity, Text Production Complexity, Text Spelling and Sentence Generation Complexity in Year 2 (T5) from the Preschool Language and Nonverbal Abilities (T2)

	Word Spelling			Alphabet Transcript.			Productivity			TP Complexity			Text Spelling			SG complexity		
	Model	β	R^2	Model	β	R^2	Model	β	R^2	Model	β	R^2	Model	β	R^2	Model	β	R^2
Preschool LANG & N-verbal	4			5			6			7			8			9		
LANG		.24*			.19			.23			.12			.13			-.26	
N-VERB		.24*			.05			.06			.22			.35**			.06	
			.18***			.05			.07			.05			.18**			.06

Notes. Alphabet Transcript. = Alphabet Transcription, SG = Sentence Generation; TP = Text Production; LANG = Language abilities; N-VERB = Nonverbal abilities.

* p <.05, ** p <.01, *** p <.001.

Significant variance in both spelling measures was predicted by preschool abilities. Nonverbal abilities was a unique predictor of both word and text measures of spelling. Additionally, language abilities was a unique predictor of word spelling. Significant variance in the other writing measures was not explained by the preschool ability measures.

Examining the Extent that Aspects of the Preschool HLE (T1a) Predict Mathematics, Literacy, and Writing Outcomes in Key Stage 1 (T4 & T5)

Which aspects of the preschool HLE predict primary reading and mathematics?

Examination of Table 12 revealed that only the preschool number experiences scale was a correlate of children's Reading Accuracy in Year 1 and that only the preschool letter-sound interaction scale was a correlate of children's Mathematics, Reading Accuracy and Reading Comprehension in Year 1. We therefore conducted three linear regression models predicting Mathematics, Reading Accuracy and Reading Comprehension in Year 1 from the preschool HLE scales that were significant correlates, respectively. When there was more than one predictor, the predictor variables were entered simultaneously in a single step in the regression models (See Models 10 to 12 in Table 17).

Table 17. Linear Regressions Models Predicting Mathematics, Reading Accuracy and Reading Comprehension in Year 1 (T4) from the Preschool HLE Scales (T1a)

		Mathematics			Reading Accuracy			Reading Comprehension	
Predictor	Model	β	R^2	Model	β	R^2	Model	β	R^2
1.HLE Preschool	10			11			12		
N EXP		-			-.03			-	
LS INT		.27**			.29**			.19*	
			.07**			.07*			.04*

Notes. HLE = Home Learning Environment; N EXP = Number Experiences; LS INT = Letter-sound interactions. *p <.05, **p <.01, ***p <.001.

All three models predicted a significant proportion of the variance, the preschool letter-sound interactions scale was a unique significant predictor of children's Mathematics, Reading Accuracy and Reading Comprehension in Year 1.

Which aspects of the preschool HLE predict primary writing and spelling skills?

Examination of Table 13 revealed that only the preschool letter-sound interactions scale was a significant correlate of children's Word Spelling and Alphabet Transcription in Year 2 (T5). We therefore conducted two linear regression models predicting Word Spelling and Alphabet Transcription in Year 2 from the preschool letter-sound interactions scale, respectively (Models 13 and 14 in Table 18).

Table 18. Linear Regression Models Predicting Alphabet Transcription and Word Spelling in Year 2 (T5) from the Preschool Letter-sound Interactions Scale (T1b)

	Word Spelling			Alphabet transcription		
	Model	β	R^2	Model	β	R^2
1.HLE Preschool LS INT	13	.28**	.08**	14	.25**	.06**

Notes. HLE = Home Learning Environment; LS INT = Letter-sound interactions. *p <.05, **p <.01, ***p <.001.

Both models predicted a small but significant proportion of the variance, the preschool letter-sounds interaction scale was a unique significant predictor of children's Alphabet Transcription and Word Spelling in Year 2.

Examining the Extent That Relationships Between Preschool HLE (T1a) and Mathematics and Literacy Attainment in Key Stage 1 (T4 & T5) Are Independent of Preschool Language and Nonverbal Abilities

Do preschool letter-sound interactions predict primary literacy and mathematics attainment independently of preschool language and nonverbal abilities?

We first conducted three hierarchical regression models predicting Mathematics, Reading Accuracy and Reading Comprehension in Year 1 from the preschool language and nonverbal abilities and the preschool letter-sound interaction scale, respectively. We entered preschool language and nonverbal abilities together in a single first step and the preschool letter-sound interactions scale in the second step of the regression models (See Models 15 to 17 in Table 19).

Table 19. Hierarchical Linear Regressions Models Predicting Mathematics, Reading Accuracy and Reading Comprehension in Year 1 (T4) from the Preschool Language and Nonverbal Abilities (T2) and the Preschool Letter-sound Interactions Scale (T1a)

		Mathematics			Reading Accuracy			Reading Comprehension	
Predictor	Model	β	Δ R^2	Model	β	Δ R^2	Model	β	Δ R^2
1.LANG & N-VERBAL	15			16			17		
LANG		.22**			.33**			.41***	
N-VERB		.07			.09			.14	
			.22*			.15***			.25***
2.HLE Preschool LS INT		.18			.16			.14	
			.03			.02			.02

Notes. LANG = Language abilities; N-VERB = Nonverbal abilities; HLE = Home Learning Environment; LS INT = Letter-sound interactions.
*p <.05, **p <.01, ***p <.001.

In all three regression models the letter-sound interaction scale fails to predict unique significant variance over and above children's preschool language and nonverbal abilities.

Predicting Spelling, Alphabet Transcription and Writing in Key Stage 1 (T5).

We first conducted two hierarchical regression models predicting Alphabet Transcription and Word Spelling in Year 2 from the preschool language and nonverbal abilities and the preschool letter-sound interactions scale. We entered preschool language and nonverbal abilities together in a single first step and the preschool letter-sound interactions scale in the second step of the regression models (See models 18 and 19 in Table 20).

Table 20. Hierarchical Linear Regression Models Predicting Alphabet Transcription and Word Spelling in Year 2 (T5) from Preschool Language and Nonverbal Abilities (T2) and the Preschool Letter-sound Interactions Scale (T1a)

		Alphabet Transcription			Word Spelling	
	Model	β	Δ R^2	Model	β	Δ R^2
1.Preschool LANG & N-VERBAL	18			19		
LANG		.19			.24*	
N-VERBAL		.05			.24*	
			.05			.18**
2.Preschool HLE LS INT		.25*			.21*	
			.06*			.05*

Notes. LANG = Language abilities; N-VERB = Nonverbal abilities; LS INT = Letter-sound interactions.
*p <.05, **p <.01, ***p <.001.

The letter-sound interaction scale predicts a small but significant proportion of variance in children's alphabet transcription and word spelling over and above the preschool language and nonverbal abilities.

Examining the Extent that the Primary HLE Predicts Mathematics and Literacy Outcomes in Key Stage 1 and Whether it Modifies the Influence of the Preschool HLE on Mathematics and Literacy Outcomes

We first addressed the question of whether aspects of the primary HLE (T3) predict any of the mathematics and/or literacy outcomes in Year 1 (T4) and of the spelling and writing outcomes in Year 2 (T5). Examination of

Table *12* and Table 13 suggest that only primary book exposure was a significant correlate of children's Reading Accuracy in Year 1 (T4) and of their Word Spelling and Text Spelling in Year 2 (T5). We therefore conducted three linear regression models predicting Reading Accuracy, Word Spelling and Text Spelling from the Primary Book Exposure composite variable and the letter-sound interactions preschool scale. In the first set of regression models we entered the primary book exposure scale in the first step and the letter-sound interactions preschool scale in the second step of the regression models (see models 20a to 22a in

Table *21*), then we swap the order of the steps in the second set of regression models (see models 20b to 22b in

Table *21).*

Table 21. Linear Regressions Models Predicting Reading Accuracy in Year 1 (T4), and Word Spelling and Text Spelling in Year 2 (T5) from the Primary Book Exposure Scale (T3) and the Preschool Letter-Sound Interactions Scale (T1a)

		Reading Accuracy			Word Spelling			Text Spelling	
Predictor	Model	β	R^2	Model	β	R^2	Model	β	R^2
1.Primary HLE	20a			21a			22a		
Book Exposure		.24**			.19*			.26*	
			.06**			.04			.07*
2.Preschool HLE									
L-S INT		.23**			.25*			.04	
			.05**			.06*			.00
1.Preschool HLE	20b			21b			22b		
L-S INT		.26**			.28**			.05	
			.07**			.08**			.00
2.Primary HLE									
Book Exposure		.20*			.14			.26*	
			.04*			.02			.07*

Notes. HLE = Home Learning Environment.
* p <.05, **p <.01, ***p <.001.

The preschool letter-sound interactions scale predicts a unique and moderate proportion of variance in children's Reading Accuracy in Year 1 (T4) and Word Spelling in Year 2 (T5), even over and above the primary book exposure scale, however it does not predict any additional variance in Text Spelling in Year 2 (T5) (see Models 20a to 22a). the primary book exposure scale predicts a unique and moderate proportion of variance in children's Reading Accuracy in Year 1 (T4) and Text Spelling in Year 2 (T5), even over and above the preschool letter-sound interactions scale, however it does not predict any additional variance in Word Spelling in Year 2 (T5) (see Models 20b to 22b).

We then conducted three hierarchical regression models predicting Reading Accuracy in Year 1 (T4) and Word Spelling and Text Spelling in Year 2 (T5) from the preschool language and nonverbal abilities and the primary book exposure measure, respectively. We entered preschool language and nonverbal abilities together in a single first step and the primary book exposure measure in the second step of the regression models (See Models 23 to 25 in Table 22).

Table 22. Hierarchical Linear Regressions Models Predicting Reading Accuracy in Year 1 (T4) and Word Spelling and Text Spelling in Year 2 (T5) from the Preschool Language and Nonverbal Abilities and the Primary Book Exposure Scale (T3)

		Reading accuracy			Word Spelling			Text Spelling	
Predictor	Model	β	Δ R^2	Model	β	Δ R^2	Model	β	Δ R^2
1.LANG & N-VERBAL	23			24			25		
LANG		.35**			.24*			.16	
N-VERB		.04			.23*			.29*	
			.14**			.17**			.15*
2.HLE Primary Book Exposure		.19			.19			.25	
			.04			.03			.06

Notes. LANG = Language abilities; N-VERB = Nonverbal abilities; HLE = Home Learning Environment.
* p <.05, ** p <.01, *** p <.001.

The primary book exposure composite does not predict significant variance in children's Reading Accuracy in Year 1 (T4), nor Word Spelling and Text Spelling in Year 2 (T5) when preschool language and nonverbal abilities are accounted for.

We finally conducted three hierarchical regression models predicting Reading Accuracy in Year 1 (T4) and Word Spelling and Text Spelling in Year 2 (T5) from primary language abilities, the preschool letter-sound interactions scale and the primary book exposure measure, respectively. We entered primary language abilities in a single first step, then the preschool letter-sound interactions scale in the second step and the primary book exposure measure in the third and last step of the regression models (See Models 26 to 28 in Table 23).

Table 23. Hierarchical Linear Regressions Models Predicting Reading Accuracy in Year 1 (T4) and Word Spelling and Text Spelling in Year 2 (T5) from the Primary Language Abilities (T4), the Preschool Letter-sound Interactions Scale (T1a) and the Primary Book Exposure Scale (T3)

		Reading accuracy			Word Spelling			Text Spelling	
Predictor	Model	β	Δ R^2	Model	β	Δ R^2	Model	β	Δ R^2
1.Primary LANG	29			30			31		
LANG		.69***			.66***			.53***	
			.48***			.44***			.28***
2.HLE Preschool									
LS INT		.05			.07			-.01	
			.00			.00			.00
3.HLE Primary									
Book Exposure		.05			-.01			.12	
			.00			.00			.01

Notes. LANG = Language abilities; HLE = Home Learning Environment.
*p <.05, **p <.01, ***p <.001.

The primary book exposure composite variable no longer predicts a significant proportion of variance in children's Reading Accuracy in Year 1 (T4), and Word Spelling and

Text Spelling in Year 2 (T5) over and above primary school language abilities and the preschool letter-sound interactions scale.

Key Findings

- Children's early number skills in the last year of preschool predict their mathematical attainment in Year 1.
- Preschool language skills predicted their mathematics and reading attainment in Year 1 and their spelling skills in Year 2.
- Preschool language and nonverbal abilities relate differently to different academic outcomes in primary school, with preschool language abilities predicting a broader range of attainment measures than nonverbal abilities.
- The frequency of preschool home letter-sound interactions predicted children's mathematics and reading attainment in Year 1 and their word spelling and alphabet transcription skills in Year 2.
- The relationships between preschool home letter-sound interactions and later reading and mathematics attainment were not independent of children's preschool language abilities. This may be because there is an indirect route where letter-sound interactions develop language abilities, which in turn support later reading and mathematics. Alternatively, letter-sound interactions may co-vary with language abilities, but have no direct influence on later reading and mathematics attainment.
- The relationships between preschool home letter-sound interactions and later word spelling and alphabet transcription were independent of preschool language and nonverbal abilities. This strengthens the argument that these aspects of literacy are directly supported by these types of interactions in the preschool period.

- There were no significant positive relationships between the frequency of any of the *primary* home learning experiences and any of the primary attainment measures assessed in Year 1 and 2. This suggests that the frequency of the primary home learning experiences indexed in the current study does not influence primary attainment.
- The frequency of home experiences relating to numbers, and to the meaning and code of language at preschool age were *negatively* related to the frequency of home experiences focused on numbers, the meaning and code of language, and writing at primary age. This suggests that parents who do not frequently engage in home learning experiences with their preschool child, engage *more* frequently in home learning experiences with their child once they have commenced primary school.
- The frequency of home shared reading at preschool and at primary age were related, suggesting that parents who frequently read to their preschool child at home continue to engage in shared reading activities with their child in primary school.
- The frequency of parent-child shared reading when their children were in Year 1 predicted their reading accuracy in Year 1 and their word spelling and text spelling abilities in Year 2. The relationships between shared reading in primary school and reading accuracy and word spelling were independent of letter-sound interactions in preschool. However, these relationships were not independent of preschool or primary language abilities. This may be because there is an indirect route where shared reading develops language abilities, which in turn support later spelling and reading. Alternatively, shared reading may co-vary with language abilities, but have no direct influence on later reading and spelling attainment.
- The indices of writing productivity and complexity were not related to the preschool or primary home learning measures. Furthermore they had more limited relationships with

preschool language ability than mathematics or reading. This suggests that these aspects of literacy are largely supported by different preschool abilities and experiences than those indexed in the present study.

Implications for Policy and Practice

The Influence of Preschool Early Number Skills

Our findings demonstrate, in a UK sample, that preschool counting, number transcoding and calculation skills relate to mathematical attainment three years later, after children have undergone over two years of formal primary education. This is consistent with research that has identified a role for early number skills in supporting early numeracy development (Aubrey & Godfrey, 2003; Aubrey et al., 2006; Aunio & Niemivirta, 2010; Aunola et al., 2004; Byrnes & Wasik, 2009; Duncan et al., 2007; Jordan et al., 2008; Johansson, 2005; LeFevre et al., 2010a Krajewski & Schneider, 2009a,b; LeFevre et al., 2010; Lepola et al., 2005; Östergren & Träff, 2013; Passolunghi & Lanfranchi, 2012; Purpura et al., 2011; Romano et al., 2010; Stock et al., 2009a,b; Tobia et al., 2015). However, in our sample counting skills were not a unique predictor of mathematics attainment once number transcoding and calculation skills were taken into account. Counting skills may act as a fundamental building block of early mathematics, but later mathematics attainment may depend to a greater extent on more complex number skills such as number transcoding and calculation (see Krajewski & Schneider, 2009b).

As number transcoding and simple calculation skills (supported by manipulatives) were key predictors of later mathematics, activities and experiences that encourage these skills during the preschool period should be encouraged as they are likely to support later numeracy.

The Influence of Preschool Language Skills

We found that a composite measure comprising preschool phonological awareness and vocabulary skills predicted later reading accuracy, reading comprehension, alphabet transcription, word spelling and mathematics attainment. Our findings further reinforce the message that developing preschoolers' language skills lays a foundation for their future academic development in reading and spelling (e.g., Castles et al., 2018; Caravolas et al., 2001; Puglisi et al., 2017; Sénéchal & LeFevre, 2002). Our findings support theoretical models that propose a role for language skills in early mathematics development (LeFevre et al., 2010; Krajewski & Schneider, 2009b) and studies linking early language skills with later mathematical attainment in young children (Hecht et al., 2001; Leather & Henry, 1994; LeFevre et al., 2010; Simmons et al., 2008; Soto-Calvo et al., 2015). As phonological awareness and vocabulary were key predictors of a wide range of later academic skills including reading, spelling and mathematics, activities and experiences that encourage these skills during the preschool period should be encouraged to provide a firm foundation both for later literacy and numeracy.

The Influence of the Preschool and the Primary Home Learning Environment

Preschool Home Numeracy Experiences and Primary Mathematics.

We have previously reported that home numeracy experiences at preschool age are not an independent predictor of mathematics attainment one year later (Soto-Calvo et al., 2020b). The present study confirmed that preschool home numeracy experiences are also not an independent predictor of mathematics attainment two years later. Our results may differ from studies that have identified a relationship between home numeracy experiences and mathematics (Anders et al., 2012; Del Río et al., 2017; Hart et al., 2016; Huntsinger et al., 2016; Skwarchuk et al., 2014; Sonnenschein et al., 2016; Zippert & Ramani, 2017), due to

the level of challenge of the home numeracy experiences surveyed. Research into the environmental factors supporting early number skills suggest that parent-child advanced home numeracy experiences might be more beneficial than basic ones (see Elliott & Bachman, 2017; Thompson et al., 2017; Skwarchuk et al., 2014). The home numeracy experiences we indexed in our preschool questionnaire may have been too basic to support children's developing mathematics. Surveying a wider range of home numeracy experience, particularly expanding the scale to include activities challenging the upper boundaries of numeracy skills may be a more sensitive tool to further investigate this finding. We would not therefore discount a role for preschool home numeracy experiences based on our findings alone, but rather would suggest further studies need to consider whether more advanced experiences may provide greater support for developing mathematics.

Preschool Letter-sound Interactions and Primary Literacy and Mathematics Attainment. Our letter-sound interactions scale comprising code-related home literacy items that emphasise the links between letters and their corresponding sounds was the strongest environmental predictor we identified. It was the only aspect of the preschool HLE that predicted children's attainment in Year 1 and Year 2. Although our preschool letter-sound interactions scale related to both children's mathematics and reading performance in Year 1, these relationships were not independent of children's preschool language skills. However, the relationship with word spelling and alphabet transcription in Year 2 was independent of preschool children's language and nonverbal abilities.

The direct relationship between preschool letter-sound interactions and spelling and alphabet transcription suggests that these early home experiences continue to influence these important aspects of writing development after formal education has commenced. The longer-term relationships with reading and mathematics are more equivocal. There may

be an indirect route where letter-sound interactions develop language abilities, which in turn support later spelling and reading. Alternatively, letter-sound interactions may co-vary with language abilities, but have no direct influence on later reading and spelling attainment. However, given our previous findings that these interactions influence number skills and reading in the very early stages of primary education (Simmons et al., 2018; Soto-Calvo et al., 2020b) and the current finding that there is a direct, longer-term relationship with spelling, we argue such interactions should be supported. Parents could be encouraged to discuss the sounds within words and their correspondence with letters as part of preschool children's everyday activities. The current findings indicate that the sort of activities which could be advocated would include talking about sounds at the start of words in rhymes or songs, discussing whose name starts with a particular sound, identifying letters and the sounds they make in environmental print or talking about letter sounds when sharing books or toys.

Shared Reading and Primary Literacy. We found that the frequency of parent-child shared reading after school onset predicted children's reading and text spelling ability, with these relationships being independent of the frequency of home letter-sound interactions at preschool age. However, these associations were not independent of children's language skills. Consequently the relationship is ambiguous; shared reading may influence reading via the development of language skills, or alternatively the two factors may simply co-vary (see Puglisi et al., 2017 and Sénéchal & LeFevre, 2014 for discussions of this issue). Given that there are few, if any, negatives to shared reading and significant potential benefits, such experiences can be encouraged within the HLE.

Primary Home Learning Experiences and Primary Attainment. There were no significant relationships between the frequency of any of the primary home experiences

indexed (number, meaning-related, code-related and writing experiences) and primary attainment. This may seem contradictory given the positive significant relationships between preschool home learning experiences and primary attainment. However, reflecting on the relationships between the primary home learning experiences and the other variables within the study and also previous literature helps to elucidate this pattern. The frequency of primary school home learning experiences had significant *negative* relationships with preschool home learning experiences (see Table 11). Some previous research has reported null or negative relationships between primary home learning experiences and attainment (Kim, 2009; Manolitsis et al., 2009; Manolitsis et al., 2011; Silinskas et al., 2012, Silinskas et al., 2013; Stephenson et al., 2008). It has been suggested that once primary school commences, parents adjust the frequency of home learning experiences to the attainment level or abilities of the child, with parents of children who are perceived to be struggling intensifying the frequency of home learning experiences (Krijnen et al., 2020; Sénéchal et al., 2017). This explanation is broadly consistent with our results. Parents who engage in more frequent letter-sound interactions in preschool lay the foundation for early literacy and mathematics when children start primary education (hence the significant positive relationships). However, once primary school commences, children who are struggling with academic work (who typically experienced less frequent preschool letter-sound interactions) may at this stage experience more frequent home learning experiences, as their parents engage in activities at home to support them. Although they do not reach statistical significance, all the correlations between the primary home literacy experiences and the reading and mathematics measures at primary school, in the present study, are negative.

Conclusion

The findings within the current report and from the earlier stages of the project (Simmons et al., 2018; Soto Calvo et al, 2020b) suggest that experiencing letter-sound interactions at preschool age is likely to support attainment in the early years of primary school. Letter-sound interactions are age-appropriate parent-child interactions that focus on the sounds within words (e. g. "Whose name starts with the 's' sound?", "Can you think of another word that starts with 's'?"), and the links between letters and sounds (e. g. "Can you see an 's' on the sign?", "This says cornflakes. Which letter do you think makes the 'c' sound?"). At preschool age, discussions about letters and sounds can be initiated when engaging with books, toys and environmental print such as signs and packaging. These interactions can be integrated into preschoolers' play and everyday activities.

We view the key policy implication of our findings as raising the awareness, of both parents and early years professionals, of the value of letter-sound interactions. It is important to communicate that integrating such interactions into preschoolers' play and everyday experiences could be beneficial, as discreet formal instruction is unlikely to be age-appropriate for such young children. An important next step is investigating how best to support parents in integrating such practices with young children. A key priority for future research would be to assess the value of low-intensity interventions that aim to support parents in including more letter-sound interactions into their preschoolers' everyday experiences.

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Appendix 1: Preschool Home Learning Experiences Items in Presentation Order

Item	Scale
Plays with plasticine, play dough or similar modelling clay	Domain general filler
Is taught the names of numbers (e. g. 'This is a number 8')	Number
Looks at factual books (e. g. books about animals, space or transport)	Meaning
Enjoys colouring or sticker books	Domain general filler
Discusses stories with an adult e. g. What do you think happens next? Do you think the bunny is frightened?	Meaning
Is taught the names or sounds of letters or how to 'sound out' words	Code: Letters and sounds
Recites numbers in order	Number: Excluded from final scale (lack of variability of response)
Rides a scooter, balance bike or bike	Domain general filler
Plays games that involve number cards, dice or a number spinner.	Number
Is prompted to identify letters in books or the environment (e. g. Can you see a's' on the sign? What letter does the word cat begin with?)	Code: Letters and sounds

Item	Scale
Has stories read to them	Meaning: Excluded from final scale (lack of variability of response)
Engages in imaginary play (e. g. pretending to be a fairy, knight or firefighter)	Domain general filler
Is encouraged to point out or identify numbers in books or the environment (e. g. What number is on the bus? Can you see a number 8?)	Number
Is encouraged to choose books that interest them to look at with an adult	Meaning
Plays with toy vehicles (e. g. cars, trucks)	Domain general filler
Is encouraged to point out or identify pictures in books (e. g. Can you point to the elephant?)	Meaning
Sings or recites the alphabet	Code: Letter activities
Draw or paints	Domain general filler
Plays with puzzles or games involving letters	Code: Letter activities
Completes number activities in magazines or workbooks	Number
Watches television	Domain general filler

Item	Scale
Forms or traces letters or writes their name	Code: Letter sound interactions
Discusses with an adult how things work or what they mean (e.g. Why do you think the ice lolly is melting? Nocturnal animals sleep in the day.)	Meaning
Discusses numbers or quantity with an adult (e.g. How many blocks are there? Who has more sandwiches?)	Number
Plays with construction toys (e. g. blocks, Duplo, stickle bricks)	Domain general filler
Completes activities involving letters or sounds in magazines or workbooks.	Code: Letter activities
Makes up songs, stories or rhymes	Meaning: Excluded from final scale (poor inter-item correlations)
Writes or traces numbers	Number
Engages with craft activities (e. g. sticking, cutting, threading beads, making things)	Domain general filler
Sings number songs (e. g. 'Ten little monkeys', 'This old man')	Number: Excluded from final scale due to poor inter-item correlations
Talks about letter sounds with an adult e. g. what sound does snake start with? Can you think of any other words starting with's'?	Code: Letter-sound interactions
Is encouraged to use books to follow-up interests or experiences they have (e. g. looking at a space book because that had talked about space at preschool).	Meaning

Appendix 2: Preschool Book Checklist

Items in presentation order. Underlined items are not real books.

The very hungry caterpillar

Princess Smartypants

Would you rather …

Giraffes can't dance

The snail and the whale

Dogger

Each peach, pear, plum

<u>The wand that wouldn't work</u>

Aliens love underpants

<u>Belinda Brown takes charge</u>

<u>Sally Anne drives the van</u>

Kipper

<u>Grandmother Windmill</u>

Maisy's bedtime

<u>What's after bedtime?</u>

That's not my monkey

<u>The peg dolly</u>

Oscar got the blame

Gorilla

Dear zoo

Not now, Bernard

Appendix 3: Primary School Home learning Experiences Items in Presentation Order

Item	Scale
Plays with plasticine, play dough or similar modelling clay	Domain general filler
Reads aloud to an adult (*this could be books supplied by yourself or school reading books)*	Code
Is encouraged to choose books that interest them to look at with an adult	Meaning
Plays games that involve number cards, dice or a number spinner	Number
Engages in imaginary play *(e. g. pretending to be a fairy, knight or firefighter)*	Domain general filler
Is encouraged to sound out unfamiliar words or 'alien' words	Code
Looks at factual books *(e.g. books about animals or transport)*	Meaning
Plays games on a computer, tablet or phone	Domain general filler
Practices counting forwards or backwards in 1s, 2s, 5s, or 10s	Number
Is encouraged to use writing in practical tasks (e.g. making notes, lists)	Writing
Engages with craft activities *(e.g. sticking, cutting, threading beads)*	Domain general filler
An adult reads and discusses child's writing	Writing
Practices spelling words	Code
Discusses stories with an adult (*e.g. "What do you think happens next?")*	Meaning
Discusses numbers or quantity with an adult *(e.g. "Can you share out the sweets equally?", "How much flour do we need for the cake?")*	Number
Is encouraged to use correct punctuation (*e.g. capital letters*) when writing	Writing

Item	Scale
Is encouraged to draw or paint	Domain general filler
Practices reading individual words *(sometimes called key words/high frequency words/'tricky' words)*	Code
Engages in active outside play	Domain general filler
Is encouraged to attempt to spell unfamiliar words	Code
Discusses with an adult how things work or what they mean *(e.g. "Why do you think the ice lolly is melting?")*	Meaning
Rehearses number facts *(e.g. number bonds or times tables)*	Number
Writes about or labels pictures they have drawn	Writing
Watches television	Domain general filler
Reads comics, magazines or annuals	Meaning: Excluded from final scale (low inter-item correlations)
Enjoys colouring or sticker books	Domain general filler
Engages in independent writing	Writing
Plays with dolls or action figures (*e.g. Barbie, Action Man*)	Domain general filler
Is encouraged to practice calculations (these could be addition, subtraction, multiplication or division). The calculations might involve concrete objects or be completed mentally	Number
Practices the sounds that a letter or letters make *(e. g. 's', 'sh', 'igh')*	Code
Is encouraged to use books to follow-up their interests or experiences *(e.g. looking at a space book because they had discussed space at school)*	Meaning
Plays with construction toys *(e.g. Duplo, Lego)*	Domain general filler
Is encouraged to practice reading numbers or ordering numbers	Number
Participates in formal activities or sports *(e.g. swimming lessons, dance class, football training)*	Domain general filler
Adult and child engage in writing tasks together	Writing
Is encouraged to ride a scooter or bike	Domain general filler