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Examining Associations Between Preschool Home Literacy Experiences, Language, Cognition And Early Word Reading: Evidence From A Longitudinal Study

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ABSTRACT

Research Findings: The study investigated whether preschool code-related home literacy experiences had direct associations with regular and irregular word reading in the first year of primary school as well as exploring whether there were indirect associations between these experiences and later word reading via children's language skills or inhibitory control. The parents of 274 preschool children completed a home learning questionnaire at time 1 (M_{age} = 3:11). At time 2, the children completed phonological awareness, vocabulary, inhibitory control and nonverbal reasoning assessments (M_{age} = 4:3) and at time 3 a word reading assessment (M_{age} = 5:3). Letter-sound interactions (a code-related home literacy index that included discussions about letter-sound associations) bore significant associations with children's word reading, whereas letter activities (a code-related index that was less focussed on letter-sound links) did not. Path analyses indicated that letter-sound interactions directly predicted regular word reading and predicted regular and irregular word reading indirectly via children's phonological awareness. These findings highlight that different aspects of code-related home literacy experiences are differentially associated with later word reading skills. *Practice and Policy*: The findings suggest that parents' integration of interactive, age-appropriate discussions that focus on letter-sound associations into children's everyday experiences may support emerging word decoding skills.

Research suggests that home literacy experiences, where children engage with books and written print, support the development of language and literacy skills (Sénéchal, 2006; Sénéchal et al., 2017). This study considers the type of home literacy experiences that are most strongly associated with early word reading skills, and explores the extent that associations between home literacy experiences and word reading are direct or indirect via children's language and cognitive abilities.

The Home Literacy Model

The home literacy model (HLM; Sénéchal, 2006; Sénéchal & LeFevre, 2002; Sénéchal et al., 2017) classifies home literacy experiences into two broad categories. Experiences where the primary focus is the written print are described as code-related (e.g., teaching a child to decode words, identifying letters on signs, practicing sight words). Experiences where the primary focus is the meaning conveyed by the text are described as meaning-related.[1] Shared reading is often presented as the archetypal

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meaning-related home literacy experience. However, other experiences that focus on the meaning of language (e. g. predicting what will happen next in a story, discussing the information in a nonfiction book) would also be classified as meaning-related. Within the HLM, code-related experiences are proposed to support word reading skills. In contrast, meaning-related experiences are proposed to support semantic language skills (e.g., vocabulary and listening comprehension), which support later reading comprehension.

The core predictions of the HLM (Sénéchal, 2006; Sénéchal & LeFevre, 2002; Sénéchal et al., 2017) have largely been supported. Numerous studies report associations between code-related literacy experiences and early decoding skills (e.g., Evans et al., 2000; Hood et al., 2008; Huntsinger et al., 2016; Manolitsis et al., 2013; Puglisi et al., 2017; Sénéchal, 2006; Sénéchal & LeFevre, 2002; Skwarchuk et al., 2014; Shahaeian et al., 2018, but cf. Kim, 2009; Krijnen et al., 2020; Manolitsis et al., 2011; Silinskas et al., 2012, 2013; Stephenson et al., 2008). Many studies also report associations between shared reading, children's semantic language skills and later reading comprehension (e.g., Hamilton et al., 2016; Hood et al., 2008; Kim, 2009; Manolitsis et al., 2013; Sénéchal, 2006; Sénéchal et al., 2008; Sénéchal & LeFevre, 2002; Shahaeian et al., 2018; Skwarchuk et al., 2014; Ehmig et al., 2020, but cf. Evans et al., 2000). In contrast, shared reading does not have a direct association with emerging decoding skills (Hamilton et al., 2016; Hood et al., 2008; Puglisi et al., 2017; Sénéchal & LeFevre, 2002; Skwarchuk et al., 2014). Although the core predictions of the HLM (Sénéchal, 2006; Sénéchal & LeFevre, 2002; Sénéchal et al., 2017) have received substantive empirical support, some issues merit further exploration.

The Development of Grapheme-Phoneme Correspondence via Home Experiences

Studies suggest that code-related home literacy experiences develop knowledge of grapheme-phoneme correspondence (GPC) and that this knowledge at least partially mediates the association between the code-related home literacy skills and word reading (Hamilton et al., 2016; Stephenson et al., 2008). As code-related experiences play a role in the development of GPC knowledge, such experiences may have a differential impact on the development of regular and irregular word reading. Regular words (e.g., cat) include frequent GPCs with many regular words using the same orthographic form to represent the rime. In contrast, irregular words (e.g., you) include infrequent or unique GPCs with few, if any, words using the same orthographic form to represent the rime (see Castles et al., 2018; Steacy et al., 2017 for further discussion of the characteristics of regular and irregular words). As relying solely on the application of frequent GPCs is more likely to result in the successful decoding of a regular than irregular word (see Castles et al., 2018 for a discussion), the association between code-related experiences and regular word reading may be stronger than with irregular word reading.

Home Literacy Experiences, Phonological Awareness and Word Reading

Phonological awareness is defined as "the ability to perceive and manipulate the sounds of spoken words" (Castles & Coltheart, 2004, p. 78). Both phonological awareness and vocabulary are consistent correlates of reading attainment (Castles et al., 2018; Hulme & Snowling, 2016) with phonological awareness rather than vocabulary identified as an independent predictor of early word reading when the two are entered simultaneously into longitudinal models (e.g., Hulme et al., 2015; Muter et al., 2004). Early versions of the HLM (Sénéchal, 2006; Sénéchal & LeFevre, 2002) neither integrated phonological awareness into the model nor proposed an association between code- or meaning-related experiences and phonological awareness. However, a more recent discussion of the model (Sénéchal et al., 2017) suggests that there may be an indirect association between code-related experiences and phonological awareness since the development of GPC knowledge and early decoding skills are associated with improvements in phonological skills (Morais & Kolinsky, 2005; Suortti & Lipponen, 2016). It is also plausible that code-related home experiences that include a focus on phonology (e.g., emphasizing rhyme or alliteration when discussing words) could directly support the development of phonological awareness. Empirical findings examining the association between code-related experiences and phonological awareness are mixed. Positive associations have been reported (Foy & Mann, 2003; Hamilton et al., 2016; Stephenson et al., 2008), with some studies noting that the association is not independent of emerging literacy skills (Sénéchal & LeFevre, 2002). However, other studies have failed to identify a significant association (Evans et al., 2000; Hood et al., 2008; Napoli & Purpura, 2018) or have reported a negative association (Kim, 2009; Manolitsis et al., 2011).

Given that some studies have reported positive associations between phonological awareness and code-related experiences (Foy & Mann, 2003; Hamilton et al., 2016; Stephenson et al., 2008) and consistent evidence that phonological awareness predicts word reading attainment (Castles et al., 2018; Hulme & Snowling, 2016), it is plausible that code-related home literacy experiences support the development of phonological awareness, which in turn supports the development of word reading skills. The present study explores the extent to which the association between code-related home literacy experiences and later word reading skills is mediated by phonological awareness.

Home Literacy Experiences, Executive Function and Word Reading

Executive functioning (EF) is an overarching term for the cognitive processes that control goal-directed behavior. These processes include the updating of working memory, the inhibition of predominant responses and the shifting of the attentional focus (Wiebe et al., 2011). EF, including specific measures of inhibition, are correlates of early word reading and letter-sound knowledge with some studies demonstrating that inhibition predicts growth in early reading skills (Bierman et al., 2008; Cartwright, 2012; Davidse et al., 2011; Foy & Mann, 2013; Haft et al., 2019; Valcan et al., 2020; Valiente et al., 2010; Zhang et al., 2017). Experiences that support the development of EF may therefore indirectly support the development of word reading.

Although EF has not been incorporated into the HLM, recent research has considered whether home literacy experiences could support EF. It has been suggested that home literacy experiences offer a broad array of opportunities for EF skills to develop (Blair & Raver, 2015; Devine et al., 2016; Korucu et al., 2020). For example, when sharing a book with a child a parent may encourage the child to focus their attention on different aspects of the story and different pictures (requiring attentional shifting). A parent may also ask the child to wait until the end of a section before contributing (requiring inhibition) or encourage the child to use their memories of the story when discussing it (requiring updating). Similarly, code-related experiences such as "sounding out" a word involve EF (see Haft et al., 2019 for a discussion of EF involvement in early word decoding). The child needs to sequentially focus on each letter (requiring attentional shifting), inhibit alternative sounds to produce the sound associated with a target letter (requiring inhibition) and retain multiple sounds within working memory when blending together to form a word (requiring updating).

EF abilities may enable children to successfully engage with home literacy experiences, alternatively, or additionally, home literacy experiences may support the development of EF abilities that in turn support later reading skills. Although there are plausible explanations for an association between EF abilities and home literacy experiences, empirical investigations into the association between EF and home literacy experiences are scarce and the findings inconsistent. Korucu et al. (2020) report a significant association between a general home literacy index and EF. They suggest that home literacy experiences may support EF development, which in turn can support children's ability to benefit from literacy instruction. In contrast, Segers et al. (2016) reported null associations between EF measures and meaning-related indices of the home literacy environment. Given the scarcity of research in this area and the inconsistent findings, the extent that home literacy experiences are associated with EF and the extent to which this association underpins the association between home literacy experiences and word reading warrants further exploration.

Exploring the Nature of Code-related Experiences

When reviewing the HLM, Sénéchal et al. (2017) emphasized that the core distinction within the model was between experiences that focused on the code of written language and experiences that focused on the meaning of written language. They acknowledge that both code- and meaning-related experiences can be playful, informative or didactic. Despite this broad conceptualization, the vast majority of studies (e.g., Hamilton et al., 2016; Inoue et al., 2018; Manolitsis et al., 2011; Puglisi et al., 2017; Sénéchal, 2006; Sénéchal & LeFevre, 2002; Silinskas et al., 2020; Stephenson et al., 2008) have operationalized code-related experiences using a small number of items that emphasize the direct teaching of lexical or sub-lexical code (e.g., "I teach my child to read words," "I teach my child letters"). Only a small number of studies have utilized a wider range of code-related items and explored the extent that *different types* of code-related experiences differentially impact on word reading development.

Skwarchuk et al. (2014) conducted a factor analysis to determine whether code-related experiences cohered into a single factor. The code-related experiences fractionated into two factors. They labeled the first factor, consisting of two items ("I help my child to read words," "I ask my child to point to words/letters when we read"), as "advanced." The second factor, consisting of three items ("I introduce new words and their definitions to my child," "I help my child to sing/recite the alphabet," "We make up rhymes in songs"), was labeled "basic." The "advanced" factor was more strongly associated with reading skills than the "basic" factor. Although Skwarchuk et al. used this evidence to suggest that "advanced" experiences had a stronger impact on early literacy than "basic" ones, it may be that the print focus of the advanced items underpinned their association with early decoding skills (none of the "basic" items relate directly to print).

Krijnen et al. (2020) proposed a more fine-grained model for classifying home literacy experiences. They suggested that home literacy experiences can be characterized in terms of two independent axes. The first represents the type of skills addressed (i.e., the code and meaning distinction emphasized in the HLM). The second represents the extent that the activity reflects exposure or direct teaching. Direct teaching experiences are viewed as more discrete and didactic with the main, or only, focus of the activity being the teaching of literacy. Exposure experiences are considered to be more playful and less didactic with the literacy experiences integrated into play or everyday experiences. Within Krijnen et al.'s model, a code-related activity could have a teaching focus (e.g., practising sight words using flashcards, teaching letter-sound links) or an exposure focus (e.g., playing letter games, pointing out letters on packaging when shopping). Krijnen et al. conducted a factor analysis using a broad range of both meaning- and code-related items to assess their model. Consistent with their model, meaning-related items fractionated into a teaching and an exposure factor. However, the code-related items cohered into a single factor which included both teaching and exposure items. All three factors were related to children's semantic oral language skills, but, contrary to the majority of research that has used solely teaching-focused items to assess code-related experiences (e.g., Hamilton et al., 2016; Manolitsis et al., 2011; Puglisi et al., 2017; Silinskas et al., 2020), the code-related factor did not predict GPC knowledge.

Previous research exploring the nature of code-related home experiences has considered how "advanced" the experiences are (Skwarchuk et al., 2014) and the exposure/teaching distinction (Krijnen et al., 2020). In the present study we explore an additional dimension, the emphasis on phonology and GPC within code-related experiences. Given the substantive evidence that phonological awareness and knowledge of GPC provide the foundations for the development of word reading (Hulme et al., 2012, 2015; Hulme & Snowling, 2016) and evidence that school-based reading instruction emphasizing GPC supports early reading progress (Castles et al., 2018), there are strong reasons to hypothesize that code-related home literacy experiences which emphasize phonology and GPC will provide stronger support for early word reading skills than code-related experiences that do not.

The Present Study

The present study examined the associations between preschool home literacy experiences, children's language and cognitive abilities, and their word reading skills. Parents completed a home literacy questionnaire when their children were in preschool. The questionnaire included a code-related experiences scale, a meaning-related experiences scale, and a book exposure checklist (that was used as an index of shared reading). We have previously reported (Soto-Calvo et al., 2020a) that the code-related index fractionated into two subscales: letter-sound interactions and letter activities. The majority of the experiences within the letter-sound interactions subscale involved parent-child interactions which emphasized phonology or letter-sound associations (GPC). Although the experiences within the letter activities subscale also involved letters, the majority placed little emphasis on letter-sound associations (GPC). Comparing these two code-related subscales enabled us to evaluate whether interactive experiences that focus on GPC and phonology have a stronger association with later word reading skills than other types of code-related experiences. When the children were in preschool they completed a range of language and cognitive assessments. At the end of the first year of primary school, they completed a word reading assessment. We used these data to address four interlinked research questions.

(1) *Do code-related home literacy experiences with greater letter-sound emphasis have stronger associations with word reading and phonological awareness than code-related experiences with a more limited letter-sound emphasis?*

School-based phonics instruction that emphasizes GPC results in greater progress in early word reading than alternative reading instruction (Castles et al., 2018), therefore we hypothesized that letter-sound interactions (home experiences with greater emphasis on GPC and phonology) would have a stronger association with early word reading than letter activities (which have a more limited emphasis on GPC and phonology). Although previous studies examining the association between code-related home literacy experiences and phonological awareness report inconsistent findings (Evans et al., 2000; Foy & Mann, 2003; Hamilton et al., 2016; Hood et al., 2008; Kim, 2009; Manolitsis et al., 2011; Napoli & Purpura, 2018; Sénéchal & LeFevre, 2002; Stephenson et al., 2008), school-based teaching and interventions that develop GPC and explicitly discuss phonology have been shown to develop phonological awareness alongside reading skills (Hatcher et al., 2004; Hulme et al., 2012). Furthermore, the association between GPC knowledge and phonological awareness is iterative (Morais & Kolinsky, 2005; Suortti & Lipponen, 2016). We therefore hypothesized that the frequency of letter-sound interactions would be significantly associated with phonological awareness and that this association would be stronger than the association between the frequency of letter activities and phonological awareness.

(2) *Do code-related related home literacy experiences have a stronger association with regular than irregular word reading skills?*

We hypothesized that the association between code-related experiences (specifically letter-sound interactions) and reading would be stronger for regular than irregular word reading because code-related home literacy experiences have significant associations with GPC knowledge (Hamilton et al., 2016; Stephenson et al., 2008) and GPC knowledge is likely to provide greater support for regular word reading than irregular word reading in the early stages of reading development (Castles et al., 2018). Previous studies have not explored whether code-related experiences have differential associations with regular and irregular word reading.

(3) *Is the association between code-related home literacy experiences and reading fully or partially explained by associations between code-related home literacy experiences and children's language abilities?*

Code-related home literacy experiences may impact directly on the development of early reading skills and they may impact indirectly via the development of language skills (particularly phonological awareness). Previous studies have reported code-related experiences predicting word reading independently of children's language skills (Sénéchal & LeFevre, 2002; Skwarchuk et al., 2014; Stephenson et al., 2008). However, as outlined above, there are arguments to suggest that letter-sound interactions will support the development of phonological awareness, which in turn supports word reading skills (Hulme et al., 2015; Muter et al., 2004). We therefore hypothesized that the association between code-related home literacy experiences and later word reading would be partially, but not fully explained by the associations between code-related home literacy experiences and children's phonological awareness.

(4) *Is there an association between code-related home literacy experiences and inhibition? Is the association between code-related home literacy experiences and reading fully or partially explained by associations between code-related home literacy experiences and children's inhibition?*

Previous findings examining the association between home literacy experiences and executive functions such as inhibition are limited and inconsistent. Korucu et al. (2020) report a positive association between EF and a general index of the HLE, whereas Segers et al. (2016) report null associations between meaning-related indices and EF. We extend these findings by exploring whether code- and meaning-related experiences are differentially related to inhibition (an aspect of EF) and by evaluating whether any association between code-related home literacy experiences and inhibition could partially or fully explain the association between code-related experiences and word reading. Given the paucity of research in this area we did not make specific hypotheses.

Method

Participants

The sample at time 1 (T_1) consisted of 274 parent–child dyads. The children (146 females, M_{age} = 3:11, SD_{age} = 3.6 months) attended 40 preschool settings in England. At T_1, the parents (254 females) completed a questionnaire that included the home literacy scales and questions relating to demographic characteristics. Parents were asked to report their postcode and the postcode deprivation decile for each household was employed as an index of SES. The deciles were obtained from the English indices of deprivation online open data database (Ministry of Housing communities and Local Government, 2015). Postcode indices of deprivation indicate the relative deprivation of the local area. They are calculated using a broad range of measures that relate to income, employment, health, crime and housing (see Ministry of Housing communities and Local Government, 2019 for a detailed discussion of how indices of deprivation are calculated). Deprivation levels within the sample ranged from 1 to 10 with the mean close to the national average of 5 (M = 5.42, SD = 3.32). Three respondents did not supply their postcodes.

Parental qualifications were coded according to the United Kingdom (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 ranged from 0 to 8, 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.

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 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. These 15 children were included in the sample as they were judged able to comprehend the tasks and responded appropriately during the practice items. Inclusion of children with SEND in the sample provides a more accurate reflection of the population of children attending mainstream preschools in the UK than would excluding them.

At time 2 (T_2), 265 children (141 females, M_{age} = 4:3, SD = 3.67 months) were retained and at time 3 (T_3), 231 children (127 females, M_{age} = 5:3, SD = 3.64 months) were retained. Attrition was higher from T_2 to T_3 because the children moved from their preschool settings to primary schools. At T_3 the primary schools into which 26 children had transferred did not consent for the study to continue and the primary school placements of 10 children could not be traced. Additionally, four children moved away, two were persistently absent and one withdrew assent.

Materials

The Home Literacy Questionnaire

Parents reported the frequency of children's home literacy experiences as part of a larger home learning questionnaire (see Soto-Calvo et al., 2020a). They responded using a 6-point Likert scale ranging from never (0) to several times a day (5). Seven items referred to code-related literacy experiences. These items covered a broad range of experiences that involved the orthographic or phonological aspects of language. Eight items referred to meaning-related literacy experiences. These experiences involved sharing the meaning of oral or written language. The code- and meaning-related items are shown in Tables 1 and 2.

Additionally, a book exposure checklist was included to assess shared reading. Shared reading is viewed as a core meaning-related experience within the HLM (Sénéchal, 2006; Sénéchal & LeFevre, 2002; Sénéchal et al., 2017), with parental book exposure checklists typically used to index the amount of shared reading a child experiences. Within the checklist, parents were presented with a list of potential preschool book titles and asked to indicate which they believed were real. They were given the options "real," "made up" and "don't know." Of the 21 book titles 15 were real and six were made up. See Table 3 for a full list of titles. The book exposure checklist was based on similar checklists that have successfully assessed shared reading in previous studies (e.g., Hamilton et al., 2016; Puglisi et al., 2017; Skwarchuk et al., 2014). A book exposure index was computed using the same formula as

Table 1. Descriptive statistics and factor loadings for exploratory factor analysis using the principal axis method of the home code-focused experiences items.

Item	Mean	SD	Missing Responses	Factor 1 loading	Factor 2 loading
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?")	3.21	1.50	1	.82	
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'?"	3.28	1.40	2	.81	
Is taught the names or sounds of letters or how to "sound out" words	3.64	1.32	0	.52	
Forms or traces letters or writes their name	2.78	1.53	3	.42	
Plays with puzzles or games involving letters	2.68	1.30	1		.80
Sings or recites the alphabet	2.93	1.51	4		.67
Completes activities involving letters or sounds in magazines or workbooks	1.89	1.33	4		.61
Letter-sound interactions[a]	3.24	1.10			
Letter activities[b]	2.50	1.14			

Notes. n = 267, cases deleted listwise (from 274 respondents).
[a]The mean response to the items contained in the letter-sound interactions scale.
[b]The mean response to the items contained in the letter activities scale. Letter-sound interactions α =.76. Letter activities α = .74.

Table 2. Descriptive statistics and factor loadings for exploratory factor analysis using the principal axis method of the home meaning-focused literacy experiences items.

Item	Mean	SD	Missing Responses	Factor loading
Discusses stories with an adult (e.g., "What do you think happens next? Do you think the bunny is frightened?")	3.70	1.08	3	.70
Is encouraged to point out or identify pictures in books (e.g., "Can you point to the elephant?")	3.88	1.07	2	.66
Is encouraged to choose books that interest them to look at with an adult	3.78	1.03	1	.63
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)	2.24	1.35	3	.58
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")	3.62	1.42	4	.51
Looks at factual books (e.g., books about animals, space or transport)	2.90	1.27	1	.49
Has stories read to them [a]	4.14	0.78	0	
Makes up songs, stories or rhymes [b]	3.72	1.41	3	
Meaning-focused literacy experiences [c]	3.50	0.74		

Notes. n = 266, cases deleted listwise (from 274 respondents). α = .76.
[a]Item excluded from the EFA due to lack of variability in scores (operationalized as a mean item score within 1 point of the maximum).
[b]Item excluded from EFA due to low inter-item correlations within the scale.
[c]The mean response to the items contained in the meaning-focused literacy scale.

Table 3. Parents' responses to the items in the book exposure checklist.

Item	Identified as Real (%)
Real titles	
The very hungry caterpillar	251 (91.6)
Kipper	227 (82.8)
Dear zoo	211 (77)
That's not my monkey	202 (73.7)
Aliens love underpants	195 (71.2)
The snail and the whale	193 (70.4)
Giraffes can't dance	172 (62.8)
Maisy's bedtime	161 (58.8)
Not now, Bernard	149 (54.4)
Each peach, pear, plum	129 (47.1)
Princess Smartypants	105 (38.3)
Dogger	89 (32.5)
Gorilla	68 (24.8)
Would you rather . . .	66 (24.1)
Oscar got the blame	57 (20.8)
Made-up titles	
Grandmother Windmill	7 (2.6)
Belinda Brown takes charge	15 (5.5)
The peg dolly	19 (6.9)
Sally-Anne drives the van	19 (6.9)
What's after bedtime?	25 (9.1)
The wand that wouldn't work	43 (15.7)

Notes. n = 268 (six parents did not complete this section of the questionnaire), α = .77 (real titles only). Percentages are provided in brackets.

Skwarchuk et al. (2014) [(Story books titles correctly identified – Foils identified as real books)/total number of actual books x 100]. This procedure reduced the influence of guessing. Descriptive statistics for the resulting book exposure index are shown in Table 5. Details of the items, instructions and response choice for the home literacy experiences and the book exposure checklist are reported in Appendices A and B.Table 4

Table 4. Descriptive statistics for the language, cognitive and reading measures.

	Mean (non-standardized)	*SD (non-standardized)*	Range (non-standardized)	*Mean (age-standardized)*	*SD (age-standardized)*	Range (standardized)	*n*	α
Rhyme awareness	4.36	2.71	0–11	9.66	2.73	5–17	254	.83[b]
Alliteration awareness	3.73	2.80	0–12	9.87	2.92	6–17	263	.84[b]
Naming vocabulary	127.12	15.09	78–178	52.59	9.83	20–80	265	.73[b]
Receptive vocabulary	16.99	4.77	1–28	10.08	3.12	2–19	257	.89[b]
Matrices	57.92	18.39	10–97	43.40	9.59	24–73	265	.75[b]
Picture similarities	92.60	12.36	56 –133	48.15	14.28	28–80	256	.79[b]
Big/Little Stroop	75.70	26.71	0–100	-	-	-	251	.77[c]
Fish/Shark d′	1.74	1.12	−0.85–3.77	-	-	-	242[a]	.95, .94[d]
Word Reading	15.18	7.63	0–30	115.87	12.92	72–131	231	.98[b]

Notes. Non-age standardized scores for the vocabulary, matrices and picture similarities measures are non-age standardized ability scores (see respective manuals for details). For the reading and phonological measures they are raw scores. The mean scores for the normative samples for the phonological measures and receptive vocabulary are 10, for matrices, picture similarities and naming vocabulary are 50 and for the reading measure 100. d′ indexes could not be calculated for 8 children for the Fish/Shark measure 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. [b] Inter-tem reliability of the standardization sample. [c] Inter-tem reliability of older preschool sample (Kochanska et al., 2000). [d] Inter-tem reliability of the preschool sample for "Go" and "No go" items respectively (Howard & Melhuish, 2016).

Table 5. Correlations among the socio-economic indices, the home literacy scales and reading.

	1	2	3	4	5	6	7	8
1.SES	-	.04	−.15*	.05	.23**	.11	.16*	.15*
2.Letter-sound interactions scale		-	.72***	.50***	.19**	.29**	.19**	.26**
3.Letter activities scale			-	.43***	−.02	.12	.10	.12
4.Meaning-focused scale				-	.12	.03	−.08	−.03
5.Book exposure					-	.00	.03	.02
6.Regular word reading						-	.71**	.92**
7.Irregular word reading							-	.94**
8.Total word reading								-
n	225	225	225	224	225	231	231	231
Mean	−0.26	−0.17	0.00	−0.02	53.66	10.57	4.60	15.18
Std. Deviation	0.84	0.93	0.93	0.86	21.10	3.89	4.37	7.63
Minimum	−1.85	−2.62	−2.30	−2.70	0	0	0	0
Maximum	1.35	1.52	1.97	1.70	93	15	15	30

Notes. *$p < .05$, ** $p < .01$, ***$p < .001$. Descriptive statistics presented for the children who completed the T_3 reading assessment. n = 212 for all correlations, cases deleted listwise.

Child Assessments

Phonological awareness. Two measures from the Preschool and Primary Inventory of Phonological Awareness (Dodd et al., 2000) were administered. In *Alliteration Awareness*, the child had to identify the word from a set of four that started with a different sound. In *Rhyme Awareness*, the child had to identify the word from a set of four that did not rhyme with the others. Both tests comprised 2 practice items and 12 experimental items.

Vocabulary. Two vocabulary measures were administered. In the *Naming Vocabulary* subtest from the British Ability Scales III (BAS-3, Elliot & Smith, 2011) the child had to name pictures 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 set of four that best matched the word said by the researcher.

Inhibition. Two experimental computerized tasks previously used with pre-schoolers were administered. In the *Fish/Shark* task (Wiebe et al., 2012) the child had to press a key when shown a fish (75% of the trials) but inhibit this response when shown a shark (25% of the trials). The *d'* index was calculated by subtracting the *z*-score value of the hit rate right-tail *p* value from the *z*-score value of the false alarm rate right-tail *p* value (Macmillan & Creelman, 2005; Wiebe et al., 2012). This sensitivity index represents how accurately the child detects fishes and rejects sharks. In the *Big/Little Stroop* task (modified from Kochanska et al., 2000) the child saw a large outline of an animal with smaller animal outlines presented within it. The large outline appeared briefly first for 750 ms. The child had to name the smaller animals within the outline. The trials were equally split between congruent trials (where the outline animal matched the smaller ones within it) and incongruent trials (where the outline animal differed from the small ones within it). The number of correct responses to the incongruent trials was recorded. We chose our two inhibition measures because they both capture variance in this age group effectively and have demonstrated strong associations with other measures of EF (Clark et al., 2014; Howard & Melhuish, 2016; Kochanska et al., 2000; Wiebe et al., 2012).

Nonverbal reasoning. Two measures from the British Ability Scales III (BAS-3, Elliot & Smith, 2011) were administered. In the *Matrices* subtest, the child had to select the picture from a set of four that best completed a four-picture pattern. In the *Picture Similarities* subtest, the child had to place a card under a picture from a set of four that best matched the picture on the card.

Reading. In the *Early Word Recognition* Test from the York Assessment of Reading for Comprehension (Hulme et al., 2009) children had to read aloud 15 regular and 15 irregular words. The total words read correctly for each word type was recorded.

Procedure

Ethical approval was granted by the university research ethics panel and written consent was gained from the educational settings and parents. At T_1 the questionnaire, a parental information sheet and a consent form were distributed to the parents of pre-schoolers in the participating settings for parents to complete. Parents were given the option of returning the consent form and completed questionnaire in a sealed envelope to the preschool setting (where it was kept securely), or posting it directly to the university. Children's data were collected via individual assessment sessions in a quiet area of their preschool (T_2) and school (T_3). Each session lasted approximately 15 minutes. At T_2 the children completed the vocabulary, phonological awareness, inhibition and nonverbal reasoning assessments in three sessions. At T_3 the children were administered the word reading test, as part of a larger battery of attainment tests that are not reported here. At both time points verbal assent was requested from the children before an assessment session commenced.

Analysis

Correlations and regressions were utilized to address research questions 1 and 2. To address question 1 we determined whether the strength of the correlations between letter-sound interactions and word reading and phonological awareness differed from the strength of the correlations between letter activities and word reading and phonological awareness. To address question 2 we determined whether the correlations between letter-sound interactions and regular and irregular word reading differed significantly. Steiger's test of the difference between two correlations was employed (Steiger, 1980). Additionally, two-step hierarchical regressions, with the SES, cognitive and language measures entered at step 1 and the home literacy indices at step 2, were used to assess whether associations between the home literacy indices and regular and irregular word reading were independent of the children's SES, language and cognitive skills.

The R program (R Core Team, 2014) with the "lavaan" library (Rosseel, 2012) was used to conduct path analyses to address research questions 3 and 4. In the path models, letter-sound interactions and letter activities were entered as the indices of code-related experiences. We tested direct and indirect paths (via cognitive and language abilities) to regular and irregular word reading. Two models were tested. In model 1, the language and cognitive variables were organized as four composites (phonological awareness, vocabulary, non-verbal reasoning and inhibition). This model enabled an assessment of whether phonological awareness or inhibition mediated any association between the code-related indices and later regular or irregular word reading, and thus addressed research questions 3 and 4 directly. In model 2, we grouped the language and cognitive variables as two composites (language and non-verbal abilities). The same pattern of direct and indirect paths was assessed. The models tested are illustrated in Figure 1 (model 1) and Figure 2 (model 2).

Although we do not propose that home literacy experiences would influence the development of non-verbal reasoning ability in the same way as they may influence language and inhibition abilities, we included reasoning abilities within the path models because reasoning abilities are associated with early word reading skills (see Bowey, 2005 for a review). Home literacy experiences may be more frequent in the homes of children with higher reasoning abilities even if they do not directly influence reasoning development. By including reasoning abilities within the models we can exclude the possibility that any direct associations between home literacy experiences and reading are underpinned by associations between the frequency of home literacy experiences and reasoning abilities.

The models were initially tested with traditional path analyses utilizing listwise deletion where there were missing data (models 1a and 2a). We tested the significance of the direct and indirect effects using bootstrapping procedures. Unstandardized indirect effects were computed for each of 10,000 bootstrapped samples, and the 95% confidence interval was computed by determining the effects at the 2.5th and 97.5th percentiles. Following traditional path analyses, multilevel path analyses were employed (models 1b and 2b). The between level was the same as tested in the traditional path analyses. The within level model accounted for the nested structure of the data (with children being situated within different preschool settings). In the

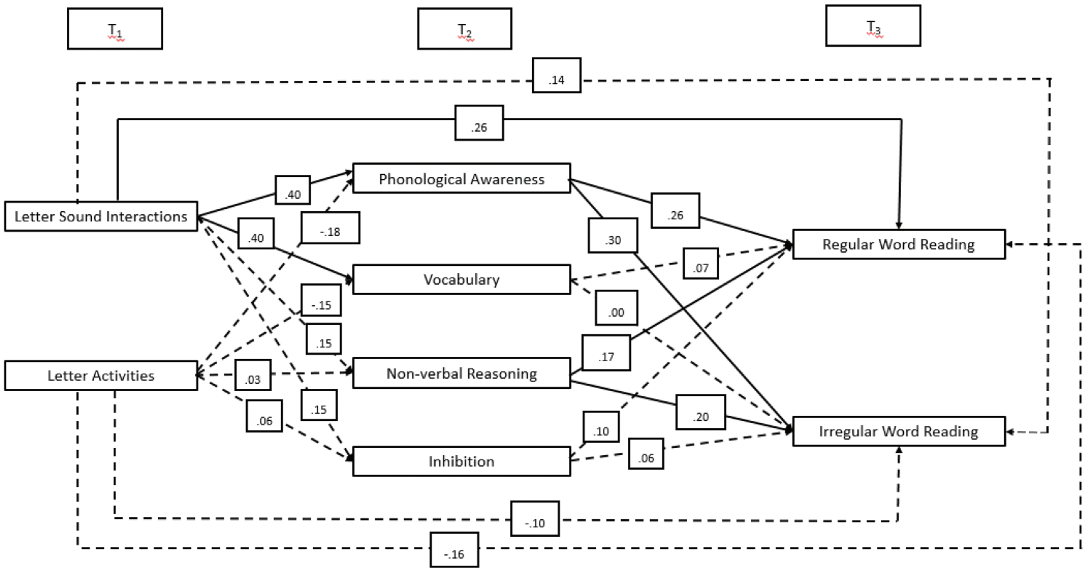

Figure 1. Path model 1a assessing direct and indirect associations between code-related experiences and regular and irregular word reading (four factor composites). *Notes*. Statistically significant paths solid lines ($p < .05$), not statistically significant paths ($p > .05$) dotted lines. Covariances between measures were tested but are not illustrated for clarity of presentation. Model 1a presented conducted with listwise deletion (n = 196). See for full details of all direct and indirect effects including confidence intervals.

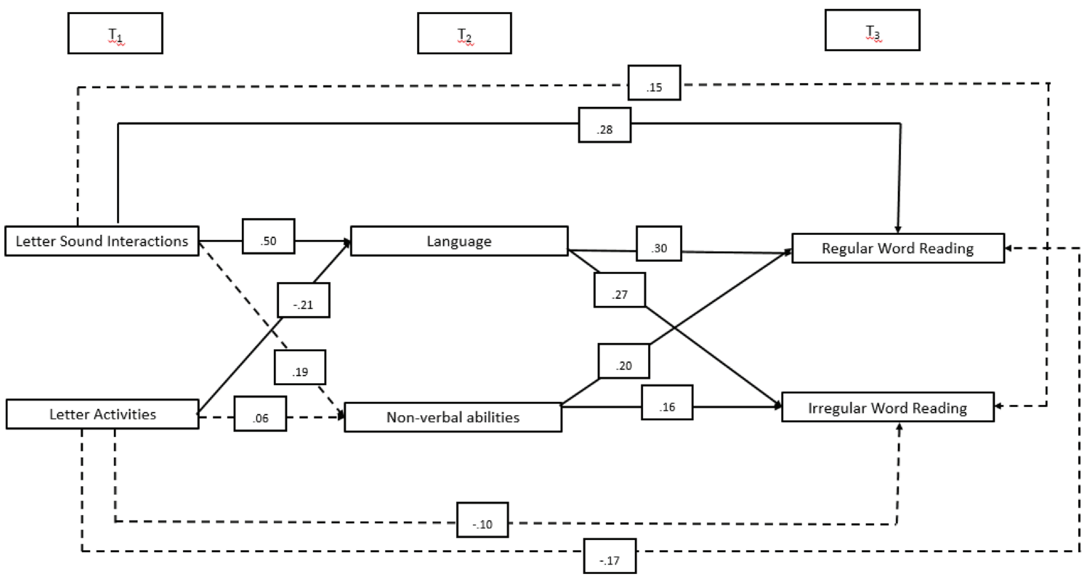

Figure 2. Path model 2a assessing direct and indirect associations between code-related experiences and regular and irregular word reading (two factor composites). *Notes*. Statistically significant paths solid lines ($p < .05$), not statistically significant paths dotted lines ($p > .05$). Covariances between measures were tested but are not illustrated for clarity of presentation. Model 2a presented conducted with listwise deletion (n = 196) See for full details of all direct and indirect effects including confidence intervals.

within level, intercepts were considered as random effects (see Rosseel, 2017 for further details). Finally, the traditional path models were reassessed using the full information maximum likelihood (FIML) method of accounting for missing data (models 1 c and 2 c).

Results

Preliminary Analyses: the Home Literacy Scales

Analysis of the home literacy scales has been reported previously (Soto-Calvo et al., 2020a). In the present study, the factor analysis was repeated using listwise deletion for missing items, rather than mean imputation which was used previously. This was to avoid mean imputation reducing the variability of the dataset. Items were excluded from the factor analysis if there was limited variability in responses or low correlations with the other items in the scale. The factor analyses utilized the Principal Axis Factoring (PAF) method, with a Promax rotation and Kaiser normalization. This assessed whether the items relating to code-related and meaning-related experiences formed reliable and internally consistent scales. Prior to the factor analyses, Bartlett's test of sphericity was used to test the null hypothesis that the correlation matrix is an identity matrix. Small values of the significance level ($p < .05$) indicate that a factor analysis can be usefully employed with the data (Field, 2005). For both factor analyses $p < .001$ indicating that factor analysis can be meaningfully employed Descriptive statistics for the individual items within the code- and meaning-related scales, item factor loadings and scale reliabilities are reported in Tables 1 and 2.

Barlett's test of sphericity for the code-related experiences was significant $\chi^2(21) = 554.64$, $p < .001$. Kaiser-Meyer-Olkin (KMO) was very good (KMO = .82) confirming the adequacy of the sample. Two factors emerged with Eigenvalues > 1. Factor 1 (Eigenvalue = 3.29) explained 40.05% of the variance. Factor 2 (Eigenvalue = 1.08) explained an additional 8.91% of the variance. All but one of the experiences that loaded onto factor 1 either explicitly or implicitly referred to phonology or GPC. Furthermore, all but one item involved adult-child interaction. We therefore refer to this scale as letter-sound interactions. The items that loaded onto factor 2, did not explicitly mention adult-child interaction or phonology. GPC was only mentioned in one item that loaded onto factor 2. We therefore refer to this scale as letter activities. Barlett's test of sphericity for the meaning-related literacy experiences was significant $\chi^2(15) = 349.97$, $p < .001$. Only one factor emerged with an Eigenvalue > 1 (Eigenvalue = 2.77). This explained 46.24% of the variance. KMO was very good (KMO = .80) confirming the adequacy of the sample. We refer to this scale as meaning-related experiences.

The factor structure for both the code- and meaning-based scales reported here is the same as previously reported when mean imputation was employed (Soto-Calvo et al., 2020a), with the same items loading onto the same factors. There were only minimal changes to the factor loading values.

Preliminary Analyses: the Language and Nonverbal Abilities and SES

identifies the descriptive statistics for the reading, language and nonverbal ability measures. The mean standard scores for the nonverbal, vocabulary and phonological variables are all broadly consistent with standardization samples. However, the mean standard score for word reading was elevated. This is likely to be influenced by an increase in English children's word reading skills since the publication of the test (see Department for Education, 2018 for an analysis of the rise in English children's word reading skills over the past decade). Similar elevated standardized word reading scores have been reported recently in large UK samples (e.g., Russell et al., 2018).

Confirmatory factor analyses (CFAs) to examine the factorial structure of the language and nonverbal variables have been reported previously (Soto-Calvo et al., 2020b), but are summarized below. In the first CFA we organized the measures into four factors, phonological awareness (*Rhyme awareness* and *Alliteration awareness*), vocabulary (*Naming vocabulary* and *Receptive vocabulary*), inhibition (*Fish/Shark d'* and *Big/Little Stroop*) and nonverbal reasoning (*Matrices* and *Picture similarities*). The first model reflects four factors that are viewed as theoretically distinct within individual differences research into reading and mathematics development (Castles et al., 2018; Hulme et al., 2012; Moll et al., 2015; Muter et al., 2004). The fit of this model was not strong. A two factor model, with language (*Rhyme awareness, Alliteration awareness, Naming vocabulary* and *Receptive vocabulary*) and nonverbal ability (*Fish/Shark d', Big/Little Stroop, Matrices* and *Picture similarities*) factors was also assessed. The second model reflects the broader verbal and non-verbal organization of cognitive skills within psychometric assessments of children's abilities (e. g. Wechsler, 2013). This two-factor structure had a better fit (see Soto-Calvo et al., 2020b for further statistical details relating to these CFAs).

We created two sets of composite scores (by calculating the mean of the z-scores of the relevant variables) to utilize in the subsequent regressions and path analyses. The first set was consistent with the four factor model and the second set was consistent with the two factor model. Moving forward our primary analyses were conducted with the four factor composite scores (phonological awareness, vocabulary, inhibition, nonverbal reasoning). Although the CFA (Soto-Calvo et al., 2020b) indicated the four factor model was statistically weaker, vocabulary, phonological awareness, inhibition and reasoning are theoretically distinct and moreover, have different associations with the development of different aspects of reading (see Castles et al., 2018). Furthermore, these composites enabled specific hypotheses relating to phonological awareness and inhibition to be assessed. We completed complimentary analyses with the two factor composites (language and nonverbal reasoning) to determine whether the organization of the composites altered the pattern of results.

A composite variable indexing SES was created by converting postcode deprivation decile and parental education level to z-scores and the calculating the mean.

Correlations

Table 5 shows the correlations between the home literacy and reading measures. The correlations between meaning-related experiences and all the word reading measures, and between book exposure and all the word reading measures were very weak (all $r < .1$) and not statistically significant. There were small but significant correlations between letter-sound interactions and regular, irregular and total word reading. In contrast, the correlations between letter activities and these reading measures were weaker and not statistically significant. One-tailed tests of the difference between correlations (Lee & Preacher, 2013; Steiger, 1980) indicated that the association between letter-sound interactions and word reading was significantly stronger than the association between letter activities and word reading ($z = 2.77$, p .003). Furthermore, the association between letter-sound interactions and regular word reading was significantly stronger than the association between letter-sound interactions and irregular word reading ($z = 1.97$, $p = .02$).

Table 6 shows the correlations between the language and cognitive composites and the home literacy and reading scores. Phonological awareness, vocabulary, inhibition and non-verbal reasoning all correlated with all the word reading measures at a statistically significant level. The correlations between the phonological awareness and vocabulary composite and all the word reading measures were of medium size. The correlations between the nonverbal reasoning composite and total and regular word reading were medium in size and the correlation with irregular word reading was small. All the correlations between the inhibition composite and the word reading measures were small.

Letter-sound interactions had a small but significant correlation with phonological awareness. The other home literacy indices had very weak correlations with phonological awareness that were not statistically significant. One-tailed tests of the difference between correlations (Lee & Preacher, 2013; Steiger, 1980) indicated that the association between letter-sound interactions and phonological awareness was significantly stronger than the association between letter activities and phonological awareness ($z = 2.85$, $p = .002$). As expected, vocabulary had a small, but significant correlation with book exposure. The inhibition and non-verbal reasoning composites had small but significant correlations with the code- although not the meaning-related home literacy experiences.

Regressions

Two-step hierarchical regressions (see Table 7) were conducted to determine whether preschool home literacy experiences could predict later regular and irregular word reading skills when SES, phonological awareness, vocabulary, inhibition and nonverbal reasoning were accounted for. Together SES, language and cognitive skills predicted medium-sized, significant variance in both regular [$R^2 = .25$, F(5, 190) = 12.69, $p < .001$] and irregular [$R^2 = .20$, $F(5, 190) = 9.49$,

Table 6. Correlations among the home literacy scales, language and cognitive composites, and reading.

Composite		*M* (*SD*)	Range	Letter-sound interactions	Letter activities	Meaning-related experiences	Book exposure	Word reading	Regular Words	Irregular words
Language		0.00 (0.72)	−1.58–2.07	.31***	.16*	.07	.16*	.43***	.45***	.37***
	Phonological awareness	0.00 (0.85)	−1.47–2.52	.24***	.10	.07	.12	.42***	.41***	.36***
	Vocabulary	0.01 (0.83)	−2.38–2.71	.30***	.17*	.05	.16*	.33***	.37***	.26***
Nonverbal skills		0.02 (0.67)	−2.11–1.47	.20**	.23**	.05	.11	.35***	.36***	.29***
	Inhibition	0.10 (0.80)	−2.42–1.36	.17*	.20**	.06	.09	.24**	.26**	.19**
	Non-verbal reasoning	0.01 (0.79)	−2.42–1.90	.16*	.18**	.02	.11	.34***	.36***	.29***

Notes. *$p < .05$, ** $p < .01$, ***$p < .001$. $n = 203$ for all correlations with the reading measures, $n = 225$ for all other measures.

Table 7. Linear regressions models predicting regular and irregular word reading (T_3) from SES, home literacy experiences (T_1), and phonological awareness, vocabulary, inhibition and nonverbal reasoning (T_2).

	Regular Word Reading (T_2)		Irregular Word Reading (T_2)	
Predictor	β	ΔR^2	β	ΔR^2
Step 1.				
SES (T_1)	.06		.12	
Phonological awareness (T_2)	.29***		.30***	
Vocabulary (T_2)	.10		.02	
Inhibition (T_2)	.07		.05	
Nonverbal reasoning (T_2)	.19*		.19*	
		.25***		.20**
Step 2.				
Letter-sound Interactions (T_1)	.16*		.05	
		.02*		.00
Step 2.				
Letter activities (T_1)	.04		.00	
		.00		.00
Step 2.				
Meaning activities (T_1)	.01		−.11	
		.00		.01
Step 2.				
Book Exposure (T_1)	−.04		.01	
		.00		.00

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

$p < .001$], word reading. Letter-sound interactions predicted a small, but significant proportion of additional variance in later regular [R^2 = .02, $F(1, 189) = 5.50$, $p = .02$], but not irregular [R^2 =.00, $F(1, 189) = 0.651$, $p = .44$] word reading. Neither letter activities nor the other meaning-related indices (book exposure and meaning-related experiences) could account for significant additional variance in either reading measure once SES, language and cognitive abilities were accounted for. This pattern of results, where only letter-sound interactions predicted additional, independent variance in regular word reading was sustained when the analyses were repeated using two-factor composites (language and nonverbal abilities) rather than four-factor composites (see Supplementary material Table S1).

Path Analyses

We used path analyses to test whether the association between code-related home literacy experiences and later word reading was mediated by the associations between code-related experiences and children's language and cognitive skills. Composites created using the mean of the relevant z-scores were used within the path analysis to index the cognitive and language variables. The use of z-score composites within path analysis has been successfully employed in previous similar studies (e. g. Hamilton et al., 2016; Moll et al., 2015). This methodology directly addressed whether language skills or inhibition mediated any associations between code-related home learning experiences and later reading (research questions 3 and 4). It also enabled evaluation of whether the structure of the language and cognitive variables (formed into four or two composites) impacted on the significance of any direct paths identified.

In model 1, the language and cognitive variables were grouped as four composites (phonological awareness, vocabulary, inhibition and non-verbal reasoning). Model 1 was first assessed using traditional path analysis and listwise deletion (model 1a, illustrated in Figure 1). The magnitude of all the direct and indirect effects, their significance and the confidence intervals are specified in. Phonological awareness and nonverbal reasoning both significantly predicted regular and irregular word reading. Letter-sound interactions indirectly predicted regular and irregular word reading via phonological awareness (see Table 9). Additionally, there was a direct positive association between letter-sound interactions and regular word reading. The model was saturated, the fit was completely adequate. A large, significant proportion of the variance in both regular word reading (R^2 = .28) and a moderate, significant proportion of the variance in irregular word reading (R^2 = .19) was explained. When the model was reassessed using a multilevel path analysis approach (model 1b) the results were very similar (see Tables 8 and 9). The positive direct association between letter-sound interactions and regular word reading and the indirect associations between letter-sound interactions and regular and irregular word reading remained significant within the multilevel analysis. Additionally, a direct negative association between letter activities and regular word reading (indicating that when the other variables were taken into account more frequent letter activities were associated with lower regular word reading scores) reached statistical significance in model 1b (see Table 8).

In model 2, the cognitive and language variables were grouped into two composites (language and nonverbal abilities). Model 2 was first assessed using traditional path analysis and listwise deletion (model 2a, illustrated in Figure 2). The magnitude of all the direct and indirect effects, their significance and the confidence intervals are specified in Tables 10 and 11. Model 2a was saturated, meaning that the fit is perfect by definition. A large, significant proportion of the variance in both regular (R^2 = .28), and a moderate, significant proportion of the variance in irregular word reading (R^2 = .17) was explained. The pattern of significant paths was very similar to model 1a. Letter-sound interactions continued to have a significant, direct path to regular word reading and significant, indirect paths to both regular and irregular word reading via language abilities. Additionally, a direct negative association between letter activities and language ability reached statistical significance (indicating that when the other variables were taken into account more frequent letter activities were associated with lower language abilities). Model 2 was reassessed using a multilevel path analysis approach (model 2b) and the results were very similar in terms of both statistically significant effects and path magnitude (see Tables 10 and 11). In addition to the significant paths identified in model 2a, in model 2b the negative path between letter activities and regular word reading reached statistical significance.

Finally we reassessed both models 1 and 2 using the full information maximum likelihood method (FIML) rather than listwise deletion to account for the missing data (models 1c and 2c). For model 1c, the magnitude of the direct and indirect effects, their significance and the confidence intervals are specified in Tables S2 and S3 within the supplemental materials. For model 2c, the magnitude of the direct and indirect effects, their significance and the confidence intervals are specified in Tables S4 and S5 within the supplementary materials. When the models were reassessed using FIML, the direct path from letter-sound interactions to regular word reading remained significant within both models 1c and 2c, as did the indirect paths to regular and irregular word reading via phonological awareness (in model 1c) and via language (in model 2c).

Summary of Key Findings

Both hypotheses evaluated in relation to research question one were supported. The correlation between letter-sound interactions and word reading was statistically stronger than the correlation between letter activities and word reading and the correlation between letter-sound interactions and phonological awareness was statistically stronger than the correlation between letter activities and phonological awareness.

Considering research question two, the hypothesis that letter-sound interactions would have a stronger association with regular word reading than with irregular word reading was supported. The correlation between letter-sound interactions and regular word reading was statistically stronger than the correlation between letter-sound interactions and irregular word reading. Furthermore, both the regressions and the path analyses indicated that letter-sound interactions had a positive association with regular word reading that was independent of the children's cognitive and language abilities. The independent association was not significant for irregular word reading.

Table 8. Unstandardized and standardized direct effect estimates for model 1.

		Model 1a						Model 1b (multilevel)					
					95% CIs						95% CIs		
Predictor	Dependent variable	b	SE	p	LL	UL	β	b	se	p	LL	UL	β
Phonological Awareness	Regular Word Reading	1.15	0.28	.000	0.60	1.69	.26	1.19	0.33	.000	0.55	1.84	.27
Vocabulary	Regular Word Reading	0.32	0.35	.360	−0.36	1.04	.07	0.23	0.31	.454	−0.38	0.85	.05
Non-verbal Reasoning	Regular Word Reading	0.80	0.34	.018	0.13	1.47	.17	0.79	0.33	.016	0.15	1.44	.17
Inhibition	Regular Word Reading	0.46	0.32	.150	−0.17	1.06	.10	0.44	0.32	.164	−0.18	1.06	.10
Letter Sound Interactions	Regular Word Reading	1.04	0.39	.007	0.28	1.80	.26	1.25	0.41	.002	0.45	2.04	.32
Letter Activities	Regular Word Reading	−0.64	0.36	.072	−1.34	0.07	−.16	−0.83	0.39	.032	−1.59	−0.07	−.21
Phonological Awareness	Irregular Word Reading	1.51	0.38	.000	0.74	2.23	.30	1.60	0.41	.000	0.79	2.40	.30
Vocabulary	Irregular Word Reading	−0.02	0.45	.958	−0.90	0.87	.00	−0.19	0.37	.605	−0.90	0.53	−.04
Non-verbal Reasoning	Irregular Word Reading	1.05	0.41	.011	0.27	1.86	.20	1.09	0.39	.005	0.32	1.85	.20
Inhibition	Irregular Word Reading	0.28	0.37	.446	−0.45	0.99	.06	0.28	0.39	.470	−0.48	1.04	.05
Letter Sound Interactions	Irregular Word Reading	0.62	0.44	.163	−0.25	1.49	.14	0.75	0.50	.129	−0.22	1.73	.16
Letter Activities	Irregular Word Reading	−0.47	0.42	.262	−1.32	0.35	−.10	−0.60	0.48	.205	−1.54	0.33	−.13
Letter Sound Interactions	Phonological Awareness	0.36	0.08	.000	0.21	0.51	.40	0.36	0.09	.000	0.17	0.54	.40
Letter Activities	Phonological Awareness	−0.16	0.09	.067	−0.33	0.01	−.18	−0.16	0.09	.099	−0.34	0.03	−.17
Letter Sound Interactions	Vocabulary	0.36	0.09	.000	0.19	0.53	.40	0.38	0.10	.000	0.19	0.57	.42
Letter Activities	Vocabulary	−0.14	0.09	.118	−0.31	0.03	−.15	−0.17	0.10	.086	−0.35	0.02	−.18
Letter Sound Interactions	Non-verbal Reasoning	0.13	0.09	.151	−0.04	0.31	.15	0.15	0.09	.121	−0.04	0.33	.17
Letter Activities	Non-verbal Reasoning	0.02	0.09	.791	−0.16	0.19	.03	0.01	0.09	.890	−0.17	0.20	.01
Letter Sound Interactions	Inhibition	0.13	0.10	.189	−0.07	0.33	.15	0.19	0.10	.060	−0.01	0.38	.21
Letter Activities	Inhibition	0.05	0.10	.600	−0.14	0.24	.06	0.00	0.10	.988	−0.19	0.20	.00

Notes. n = 196, listwise deletion.

Table 9. Unstandardized and standardized indirect effect estimates for model 1.

			Model 1a						Model 1b (multilevel)					
						95% CIs						95% CIs		
Predictor →	Mediator →	Dependent variable	b	SE	p	LL	UL	β	b	se	p	LL	UL	β
Letter Sound Interactions	Phonological Awareness	Regular Word Read	.41	0.14	.002	0.18	0.71	.10	0.43	0.16	.008	0.11	0.74	.11
Letter Sound Interactions	Vocabulary	Regular Word Read	.12	0.14	.395	−0.12	0.42	.03	0.09	0.12	.458	−0.15	0.33	.02
Letter Sound Interaction	Non-verbal Reasoning	Regular Word Read	.11	0.09	.231	−0.04	0.31	.03	0.12	0.09	.190	−0.06	0.29	.03
Letter Sound Interactions	Inhibition	Regular Word Read	.06	0.07	.387	−0.04	0.23	.02	0.08	0.07	.261	−0.06	0.23	.02
Letter Activities	Phonological Awareness	Regular Word Read.	−.18	0.11	.093	−0.41	0.01	−.05	−0.19	0.12	.130	−0.43	0.05	−.05
Letter Activities	Vocabulary	Regular Word Read	−.04	0.06	.493	−0.21	0.05	−.01	−0.04	0.06	.488	−0.15	0.07	−.01
Letter Activities	Non-verbal Reasoning	Regular Word Read	.02	0.08	.811	−0.14	0.19	.00	0.01	0.07	.890	−0.14	0.16	.00
Letter Activities	Inhibition	Regular Word Read	.02	0.06	.670	−0.08	0.15	.01	0.00	0.04	.988	−0.08	0.09	.00
Letter Sound Interactions	Phonological Awareness	Irregular Word Read	.54	0.18	.003	0.23	0.94	.12	0.57	0.21	.006	0.17	0.97	.12
Letter Sound Interactions	Vocabulary	Irregular Word Read.	−.01	0.17	.959	−0.34	0.33	.00	−0.07	0.14	.609	−0.35	0.21	−.02
Letter Sound Interactions	Non-verbal Reasoning	Irregular Word Read	.14	0.12	.238	−0.05	0.41	.03	0.16	0.12	.174	−0.07	0.39	.03
Letter Sound Interactions	Inhibition	Irregular Word Read	.04	0.07	.567	−0.08	0.19	.01	0.05	0.08	.499	−0.10	0.20	.01
Letter Activities	Phonological Awareness	Irregular Word Read	−.24	0.15	.110	−0.57	0.01	−.05	−0.25	0.16	.126	−0.57	0.07	−.05
Letter Activities	Vocabulary	Irregular Word Read	.00	0.07	.964	−0.15	0.15	.00	0.03	0.06	.622	−0.09	0.16	.01
Letter Activities	Non-verbal Reasoning	Irregular Word Read	.02	0.10	.808	−0.18	0.24	.01	0.01	0.10	.890	−0.19	0.21	.00
Letter Activities	Inhibition	Irregular Word Read	.01	0.05	.773	−0.07	0.14	.00	0.00	0.03	.988	−0.05	0.05	.00

Notes. n = 196, listwise deletion.

Table 10. Unstandardized and standardized direct effect estimates for model 2.

		Model 2a						Model 2b (multilevel)					
					95% CIs						95% CIs		
Predictor	Dependent variable	b	SE	p	LL	UL	β	b	se	p	LL	UL	β
Language	Regular Word Reading	1.54	0.37	.000	0.84	2.27	.30	1.37	0.38	.000	0.63	2.10	.27
Non-verbal abilities	Regular Word Reading	1.09	0.39	.005	0.35	1.86	.20	1.17	0.40	.003	0.40	1.94	.22
Letter Sound Interactions	Regular Word Reading	1.04	0.40	.008	0.28	1.83	.28	1.20	0.40	.003	0.41	2.00	.33
Letter Activities	Regular Word Reading	−0.64	0.36	.074	−1.34	0.06	−.17	−0.79	0.39	.042	−1.56	−0.03	−.22
Language	Irregular Word Reading	1.61	0.51	.002	0.61	2.61	.27	1.36	0.48	.005	0.41	2.31	.23
Non-verbal abilities	Irregular Word Reading	1.02	0.47	.030	0.12	1.93	.16	1.14	0.49	.020	0.18	2.10	.18
Letter Sound Interactions	Irregular Word Reading	0.61	0.44	.164	−0.26	1.48	.15	0.72	0.50	.149	−0.26	1.71	.17
Letter Activities	Irregular Word Reading	−0.47	0.42	.262	−1.29	0.34	−.10	−0.56	0.49	.249	−1.52	0.39	−.13
Letter Sound Interactions	Language	0.36	0.07	.000	0.23	0.50	.50	0.38	0.08	.000	0.23	0.54	.53
Letter Activities	Language	−0.15	0.07	.046	−0.29	0.00	−.21	−0.17	0.08	.037	−0.33	−0.01	−.23
Letter Sound Interactions	Non-verbal abilities	0.13	0.09	.123	−0.03	0.30	.19	0.16	0.08	.040	0.01	0.32	.25
Letter Activities	Non-verbal abilities	0.04	0.08	.648	−0.13	0.19	.06	0.01	0.08	.923	−0.15	0.16	.01

Notes. n = 196, listwise deletion.

Table 11. Unstandardized and standardized indirect effect estimates for model 2.

			Model 2a						Model 2b (multilevel)					
						95% CIs						95% CIs		
Predictor →	Mediator →	Dependent variable	b	SE	p	LL	UL	β	b	se	p	LL	UL	β
Letter Sound Interactions	Language	Regular Word Reading	0.55	0.17	.001	0.26	0.92	.15	0.52	0.18	.003	0.18	0.87	.14
Letter Sound Interactions	Language	Irregular Word Reading	0.58	0.22	.008	0.20	1.05	.14	0.52	0.21	.014	0.11	0.93	.12
Letter Sound Interaction	Non-verbal abilities	Regular Word Reading	0.14	0.11	.187	−0.04	0.39	.04	0.19	0.11	.094	−0.03	0.42	.05
Letter Sound Interactions	Non-verbal abilities	Irregular Word Reading	0.13	0.11	.239	−0.03	0.40	.03	0.19	0.12	.127	−0.05	0.43	.04
Letter Activities	Language	Regular Word Reading	−0.23	0.13	.075	−0.50	0.00	−.06	−0.23	0.13	.066	−0.48	0.01	−.06
Letter Activities	Language	Irregular Word Reading	−0.24	0.15	.112	−0.59	0.00	−.06	−0.23	0.13	.087	−0.49	0.03	−.05
Letter Activities	Non-verbal abilities	Regular Word Reading	0.04	0.10	.674	−0.16	0.24	.01	0.01	0.09	.923	−0.17	0.19	.00
Letter Activities	Non-verbal abilities	Irregular Word Reading	0.04	0.10	.686	−0.15	0.25	.01	0.01	0.09	.923	−0.17	0.19	.00

Notes. n = 196, listwise deletion.

Considering research question three, the hypothesis that the association between code-related home literacy experiences and later word reading would be partially, but not fully explained by the associations between code-related home literacy experiences and children's phonological awareness was supported. The path analyses indicated that letter-sound interactions had indirect associations with regular and irregular word reading via phonological awareness, and also a direct positive association with regular word reading.

Finally, considering the fourth research question, letter-sound interactions correlated significantly with inhibition. However, the path analyses did not indicate that the association between letter-sound interactions and inhibition underpinned the association between letter-sound interactions and word reading.

Discussion

The results of the current study extend previous findings in three key ways. First, they indicate that letter-sound interactions (that emphasize GPC and phonology) have closer associations with children's phonological awareness and word reading skills than letter activities (that have a more limited emphasis on GPC and phonology). This suggests that not all code-related home literacy experiences are equal in their associations with phonological awareness and word reading skills. Second, they indicate that code-related home literacy experiences are a stronger predictor of regular than irregular word reading. Third, they demonstrate that the association between letter-sound interactions and later regular word reading is partially mediated by phonological awareness, but is not mediated by inhibitory control.

Code-related Experiences and Word Reading

Our findings help to clarify the type of code-related home literacy experiences that are most likely to support children's emerging word decoding skills. Letter-sound interactions had a stronger association with later word reading than letter activities. This suggests that home literacy experiences that are interactive and focus on GPC and phonology are most likely to be beneficial in supporting early word reading skills. The stronger association with regular than irregular word reading is consistent with previous studies reporting associations between code-related home literacy experiences and GPC knowledge (Hamilton et al., 2016; Hood et al., 2008; Sénéchal & LeFevre, 2002) and strengthens the argument that code-related home literacy experiences support the development of word reading skills via the development of letter-sound associations. There is already substantial research indicating that an emphasis on GPC as part of school-based instruction supports early word reading development (Castles et al., 2018). Our findings compliment this research on school-based instruction and suggest that discussing GPC and phonology at home could also support young children's early reading development.

Home Literacy Experiences, Phonological Awareness and Vocabulary

Letter-sound interactions had a significantly stronger association with phonological awareness than letter activities, indicating that code-related discussions and experiences which emphasize GPC and phonology are more closely associated with phonological awareness than experiences that have a more limited emphasis on these areas. Previous studies examining the associations between code-related experiences and phonological awareness present inconsistent findings with only some studies reporting significant, positive associations (Evans et al., 2000; Foy & Mann, 2003; Hamilton et al., 2016; Hood et al., 2008; Kim, 2009; Manolitsis et al., 2011; Napoli & Purpura, 2018; Sénéchal & LeFevre, 2002; Stephenson et al., 2008). Our findings suggest that the extent code-related indices emphasize GPC and phonology impacts on the strength of their association with phonological awareness.

Alongside the significant direct path linking letter-sound interactions to regular word reading, significant, indirect associations between letter-sound interactions and both regular and irregular word reading via children's phonological awareness were identified. Letter-sound interactions may develop children's phonological awareness which in turn supports their word reading development. However, it is also possible that parents modify the frequency of letter-sound interactions in response to their child's phonological awareness (which may at least in part be genetically determined, Christopher et al., 2015). Previous research has demonstrated that parents of school-age children modify home literacy experiences in response to their child's literacy attainment (Inoue et al., 2018; Manolitsis et al., 2011; Silinskas et al., 2012). The parents of pre-schoolers may modify home literacy experiences in response to their child's phonological abilities. Future studies should assess phonological awareness and home literacy experiences at multiple time-points to establish the direction of this association.

The significant correlation between book exposure and vocabulary and the null correlations between book exposure and word reading were consistent with the predictions of the HLM (Sénéchal, 2006; Sénéchal & LeFevre, 2002; Sénéchal et al., 2017) and many previous studies (e.g., Hamilton et al., 2016; Hood et al., 2008; Kim, 2009; Manolitsis et al., 2013; Sénéchal, 2006; Sénéchal & LeFevre, 2002; Sénéchal et al., 2008; Shahaeian et al., 2018; Skwarchuk et al., 2014). However, perhaps surprisingly given the predictions of the HLM, the other meaning-related index (meaning-related experiences) did not correlate significantly with vocabulary. Book exposure checklists are commonly used as an indirect index of the frequency of shared reading (Hamilton et al., 2016; Puglisi et al., 2017; Sénéchal et al., 2017; Skwarchuk et al., 2014), whereas the meaning-related experiences scale incorporated meaning-related discussions that extended beyond shared reading. Future studies could directly assess whether the frequency of shared reading rather than the frequency of meaning-related discussions are more closely associated with children's vocabulary abilities.

Code-related Experiences, Inhibition and Word Reading

A significant correlation between inhibition and word reading was identified. This was consistent with previously reported associations between EF and word reading (Bierman et al., 2008; Davidse et al., 2011; Foy & Mann, 2013; Haft et al., 2019; Valiente et al., 2010; Zhang et al., 2017). Furthermore, inhibition abilities correlated with code- but not meaning-related home literacy experiences. This extends the findings of Korucu et al. (2020) and Segers et al. (2016) by identifying code-related experiences as more closely associated with inhibition than meaning-related experiences. However, the path analyses do not support the proposal that inhibition abilities underpin the association between home literacy experiences and early reading skills (Blair & Raver, 2015; Korucu, 2020). Within model 1, there were no significant indirect paths from the code-related home literacy experiences to word reading via inhibition. The associations between code-related experiences and inhibition and between inhibition and word reading should not be considered to be independent of children's language and non-verbal reasoning abilities.

Limitations and Future Directions

The current study identified a direct association between the frequency of letter-sound interactions and later regular word reading. The broad range of language and cognitive variables included in the study increases the likelihood that these interactions are supporting children's emerging decoding skills (rather than simply being a correlate of them). However, we acknowledge that causal links cannot be concluded solely on the basis of individual differences data. Administering both the home literacy questionnaire and the reading, language and cognitive measures at multiple time points within a longitudinal study would enable cross-lagged models to be evaluated. Such models can clarify the direction of the associations identified. However, to unambiguously conclude that there is a causal relationship between the frequency of letter-sound interactions and later reading skills, intervention studies are required. Extending existing intervention research that assesses the impact of supporting and modifying the home learning environment (see Justice & Ezell, 2000; Sénéchal, 2014; Sénéchal et al., 2017), would determine whether increasing the frequency of the specific experiences indexed within the letter-sound interactions scale results in improvements in young children's emerging decoding skills.

The current study explored the interrelationships between home literacy experiences and a wider range of cognitive factors than is typical. However, we acknowledge that utilizing a wider range of EF measures would have improved the study further. We used two inhibitory control measures as our index of EF. These measures were chosen because they effectively capture individual differences in preschool children and have strong associations with other EF measures (Clark et al., 2014; Kochanska et al., 2000; Wiebe et al., 2012). Although statistical analyses suggest that EF does not fractionate in pre-schoolers (Wiebe et al., 2012), it is possible that using a wider range of EF measures including indices of updating and shifting may result in stronger associations between EF and both the home literacy experiences and word reading.

In common with many studies of the home literacy environment (e.g., Hood et al., 2008; Huntsinger et al., 2016; Manolitsis et al., 2013; Puglisi et al., 2017; Sénéchal, 2006; Sénéchal & LeFevre, 2002; Skwarchuk et al., 2014), the current study employed parent-report questionnaires to index the frequency of home literacy experiences. We acknowledge that self-report measures may be influenced by social desirability bias and the accuracy of parental recall. However, emerging observational findings align with our conclusions. Bergman Deitcher et al. (2021) demonstrated that parental references to written print during shared reading (e.g., pointing out the links between print and letter-sounds or spoken words) were associated with children's letter knowledge, whereas references to the meaning of the text or the illustrations were not. Further studies that utilize a range of methodologies (e. g., questionnaires, observations, prompted real-time activity reports) will triangulate the findings and have the potential to strengthen the conclusions that can be drawn.

Although there are exceptions (e.g., Silinskas et al., 2020), research into the HLM during preschool has typically been conducted with moderate sample sizes ranging from 100 to 300 (e.g., Hamilton et al., 2016; Hood et al., 2008; Korucu et al., 2020; Puglisi et al., 2017; Sénéchal & LeFevre, 2002). Many studies recruit from multiple educational settings resulting in a low participant to setting ratio (e.g., Hamilton et al., 2016; Korucu et al., 2020; Puglisi et al., 2017). The present study is typical of this approach, having a moderate sample size recruited from multiple preschools. Using multiple settings is advantageous as the variety of preschool settings within society can be represented within the sample. However, it is important to recognize that recruitment from multiple settings results in nested data. Our key predictor variable – the frequency of letter-sound interactions – may be associated with the preschool setting attended. It could be that some settings encourage parents to engage in such interactions at home, and thus that attendance at a particular type of setting is the direct predictor of later reading attainment. We utilized multilevel path analyses to explore whether the findings remained significant when the variance attributed to the preschool settings was accounted for. The core findings remained significant within the multilevel path analyses. However, we recognize that to fully exclude preschool setting as a potential confounding factor, further studies with a larger sample size are required. This would enable a large number of settings to be sampled and increase the participant: setting ratio. A larger sample would also enable complex structural equation models (SEMs) to be effectively constructed, with latent variables accounting for measurement error. Utilizing a SEM approach would further strengthen the conclusions that could be drawn.

Conclusion and Implications

Although further intervention studies are required to confirm a causal link, the findings of the present study are consistent with an account in which preschool interactions at home that focus on phonology and GPC support children's emerging word reading skills. There is an understandable reticence to advocate parents attempting to teach preschool children formally, as such activities may be stressful for the child and their parents. However, the items within the letter-sound interactions scale include age-appropriate discussions about letters and sounds that could occur when informally exploring toys, environmental print and books. Although shared reading in itself is a meaning-related experience, complimentary code-related interactions can occur within this context. Parent-child interactions that focus on print and letter-sound links have been reported when parents share alphabet books (Bergman Deitcher et al., 2021), and can be encouraged when sharing storybooks (Justice & Ezell, 2000; Justice et al., 2002). Letter-sound interactions do not have to be discrete, formal activities, but can be integrated into shared reading, everyday experiences and play. Parents talking about the sounds within words and their associations with letters in a sensitive and responsive manner could support preschoolers in developing the foundations of reading.Funding

Note

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.

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Appendix A: Home Literacy Experiences Questionnaire Items

Instructions: *Listed below is a variety of activities. We would like you to rate how often your child experiences the different types of activities at home. Please only include experiences they have at home. Do NOT include experiences that your child may have at preschool or nursery. My child:*

Code-related items (Letter-sound interactions)

- 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?”)
- 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’?”
- Is taught the names or sounds of letters or how to “sound out” words
- Forms or traces letters or writes their name

Code-related items (Letter activities)

- Plays with puzzles or games involving letters
- Sings or recites the alphabet
- Completes activities involving letters or sounds in magazines or workbooks

Meaning-related items

Underlined items were excluded from the final scale.

- Discusses stories with an adult (e.g., “What do you think happens next? Do you think the bunny is frightened?”)
- Is encouraged to point out or identify pictures in books (e.g., “Can you point to the elephant?”)
- Is encouraged to choose books that interest them to look at with an adult
- 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)
- 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”)
- Looks at factual books (e.g., books about animals, space or transport)
- Has stories read to them
- Makes up songs, stories or rhymes

Response choices: *Several times a day, About once a day, Several times a week, About once a week, Occasionally, Never*

Appendix B: Book Title Checklist

Instructions: *In this section we want to discover how familiar you are with different types of children’s books. Below is a list of titles. Some are real books for preschool children. Some are titles that we have made-up. Please indicate which titles you think are real and which you think are made-up. Try not to guess – if you are not sure if a title is a real book or not please tick “Don’t know.”*

Titles (Made-up titles underlined)
The very hungry caterpillar
Princess Smartypants
Would you rather . . .
Giraffes can’t dance
The snail and the whale
Dogger
Each peach, pear, plum
The wand that wouldn’t work
Aliens love underpants
Belinda Brown takes charge
Sally-Anne drives the van
Kipper
Grandmother Windmill
Maisy’s bedtime
What’s after bedtime?
That’s not my monkey
The peg dolly
Oscar got the blame
Don’t know Gorilla
Dear zoo Real
Not now, Bernard

Response choices: *Real, Made-up, Don’t Know*