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Examining the effects of home literacy and numeracy environment on early reading and math acquisition

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ABSTRACT

The present study examined how the home literacy and numeracy environment in kindergarten influences reading and math acquisition in grade 1. Eighty-two Greek children from mainly middle socio-economic backgrounds were followed from kindergarten to grade 1 and were assessed on measures of nonverbal intelligence, emergent literacy skills, early math concepts, verbal counting, reading, and math fluency. The parents of the children also responded to a questionnaire regarding the frequency of home literacy and numeracy activities. The results of path analyses indicated that parents' teaching of literacy skills predicted reading fluency through the effects of letter knowledge and phonological awareness. Storybook exposure predicted reading fluency through the effects of vocabulary on phonological awareness. Finally, parents' teaching of numeracy skills predicted math fluency through the effects of verbal counting. These findings suggest that both the home literacy and the home numeracy environments are important for early reading and math acquisition, but their effects are mediated by emergent literacy and numeracy skills.

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1. Introduction

It is well documented that early childhood experiences are critical for later academic achievement (e.g., Duncan et al., 2007; Sylva & Roberts, 2010; Torppa et al., 2007). Research has also documented that children come to kindergarten with some knowledge of letters and numbers that is presumed to be the result of parent teaching (e.g., Al Otaiba et al., 2010; Manolitsis & Tafa, 2011; Passolunghi & Lanfranchi, 2012; Sylva et al., 2010). Interactions between parents and their children have also been an integral component of Bronfenbrenner's (1995) bioecological model. The strength of these interactions depends not only on the structural characteristics of the environmental context (e.g., social class), but also on the characteristics of each child. Several researchers have subsumed parent–child interactions under the overarching concept of home-based parental environment that includes facets such as home-learning, warmth/responsivity, and management/discipline (Morrison, 2009; Pomerantz, Moorman, & Litwack, 2007).

The home-learning environment has been found to be a significant predictor of reading and math achievement (Anders et al., 2012; Melhuish et al., 2008; Rodriguez & Tamis-LeMonda, 2011; Sylva et al., 2010). However, because the home-learning environment is broad by its own nature and includes aspects that are conceptually and factor-analytically unrelated to each other (Manolitsis, Georgiou, & Parrila, 2011; Sénéchal, 2006), the possible links between specific aspects of the home-learning environment and reading or math achievement remain unclear. Therefore, the purpose of this longitudinal study was to examine the role of specific home literacy and numeracy experiences on reading and math acquisition. The examination of the effects of these early experiences takes into account not only the children's early cognitive and academic skills, but also mother's educational level, which is used here as an index of the environmental context (to borrow Bronfenbrenner's (1999) terminology).

1.1. Home literacy environment and reading acquisition

Home literacy environment (HLE) has been conceptualized as an umbrella concept that encapsulates all the possible facets of experiences with written speech that children engage in with their parents interactively (Burgess, Hecht, & Lonigan, 2002; Frijters, Barron, & Brunello, 2000; Kirby & Hogan, 2008; Sénéchal, LeFevre, Thomas, & Daley, 1998; Tafa, 2011). Sénéchal et al. (1998) grouped the activities taking place at home into two broad categories: formal and informal literacy activities, which have been found to be independent of each other. A group of studies (Buchs, Welch, Burt, & Knoche, 2011; Schmitt, Simpson, & Friend, 2011; Umek,

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Podlesek, & Fekonja, 2005) has adopted a broader conceptualization of HLE that includes a combination of home literacy activities and contextual variables (e.g., demographic characteristics), child characteristics (e.g., temperament), mother–child interactions (e.g., maternal responsiveness), and parent–child joint activities (e.g., watching TV). In order to be consistent with our previous work on this topic, we used Sénéchal et al.'s (1998) conceptualization of HLE in the present study.

Formal literacy activities are those that directly engage children in print concepts through the teaching of letters or teaching of reading and writing of words. These activities can be found in the literature under different terms such as "parental mediation" (Aram & Levin, 2002) or "zone-of-proximal-development stimulation" (Umek et al., 2005). Several studies have shown that parents' direct teaching contributes to reading ability through the effects of letter knowledge and phonological awareness (Evans, Shaw, & Bell, 2000; Foy & Mann, 2003; Hood, Conlon, & Andrews, 2008; Sénéchal & LeFevre, 2002; Stephenson, Parrila, Georgiou, & Kirby, 2008). In turn, informal literacy activities are those that expose children to print incidentally through activities such as shared book reading and visits to the library. These activities contribute to reading through the effects of vocabulary (Roth, Speece, & Cooper, 2002; Sénéchal & LeFevre, 2002; Torppa et al., 2007). Although previous studies have suggested an indirect relationship between formal/informal literacy activities and reading ability, they have not incorporated both types of home literacy activities in a single statistical model. Doing so would allow us to test the extent to which the hypothesized mediators (letter knowledge, vocabulary, and phonological awareness) explain the relationship between home literacy and subsequent reading.

Most of the existing studies have assessed HLE at the end of kindergarten (Evans et al., 2000; Foy & Mann, 2003; Hood et al., 2008; Manolitsis et al., 2011), which is problematic for two reasons: first, the effects of HLE on emergent literacy skills are confounded with instruction that children receive in kindergarten to the point that they become indistinguishable (Galindo & Sheldon, 2012). Second, parents may alter the frequency of teaching specific literacy components, and consequently what they report on the HLE questionnaire, because of the feedback they receive from teachers regarding their children's performance (Kim, 2009; Silinskas, Leppänen, Aunola, Parrila, & Nurmi, 2010).

1.2. Home numeracy environment and math acquisition

Home numeracy environment (HNE) is an umbrella concept that encompasses all the possible facets of experiences with numeracy (e.g., counting, number recognition, logical games) that children engage in with their parents interactively (LeFevre et al., 2009). LeFevre et al. (2009) grouped HNE activities into two broad categories: direct and indirect numeracy activities. For consistency purposes, in the present study, we will use the terms formal HNE to refer to the direct activities and informal HNE to refer to the indirect HNE activities. Formal HNE involves activities that engage children in explicit teaching of numbers and counting skills. In turn, informal HNE involves incidental exposure to numeracy through "real-world tasks" (LeFevre et al., 2009) such as card games, measuring cooking materials, counting money, or playing with calculators. Similar to HLE activities, the two types of HNE activities are assumed to be independent of each other. Historically, HNE activities have been provided to the children less frequently than the HLE activities (Anders et al., 2012; LeFevre et al., 2009; Skwarchuk, 2009; Tudge & Doucet, 2004).

Compared to the relatively long history of research on HLE, research examining the role of HNE on math acquisition is still in its infancy. Recently, Anders et al. (2012) found that HNE practices predicted the children's numeracy skills at the age of 3 and that an early advantage of children with high HNE was maintained until the age of 5. To our knowledge, only three studies have examined the role of specific aspects of HNE on math acquisition (LeFevre et al., 2009; LeFevre, Polyzoi, Skwarchuk, Fast, & Sowinski, 2010; LeFevre et al., 2009; Skwarchuk, 2009) and have provided mixed findings. For example, LeFevre et al. (2009), in a cross-sectional study that covered the developmental period from kindergarten to grade 2, examined whether formal and informal HNE experiences were related to children's math performance. They found that informal HNE activities accounted for a significant amount of variance in math knowledge and math fluency skills, even after controlling for the effects of vocabulary, working memory and home literacy environment. In contrast, working with a group of Greek and Canadian kindergarten children, LeFevre et al. (2010) found that informal HNE activities were infrequent and they did not correlate significantly with the early numeracy skills. In both studies, however, formal HNE contributed significantly to early numeracy, after controlling for the effect of cognitive skills or parents' education.

A group of studies has also demonstrated that broader aspects of the home-learning experiences are associated with early math skills (LeFevre, Clarke, & Stringer, 2002; Melhuish et al., 2008; Stylianides & Stylianides, 2011). For example, Melhuish et al. (2008) found that a general measure of the home-learning environment predicted numeracy achievement at the age of five and underachievement in mathematics at the age of seven. In addition, some studies have reported that math skills are associated with home literacy experiences at least as strongly as with home numeracy experiences (Anders et al., 2012; LeFevre et al., 2009; LeFevre et al., 2010). These counterintuitive findings have been explained in terms of the language skills that are necessary for solving math tasks and the limited numeracy activities taking place at the preschoolers' home (Anders et al., 2012).

Previous studies on HNE have at least three limitations. First, with one exception (Anders et al., 2012), none of the studies examining the role of HNE on math acquisition was longitudinal. Thus, it is difficult to draw any conclusions on the developmental relationship between the HNE activities and math acquisition. Second, although several studies have reported that early numeracy skills are robust predictors of later math ability (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Krajewski & Schneider, 2009; Stock, Desoete, & Roeyers, 2009), none of the HNE studies has examined if the effects of the HNE activities on math acquisition are indirect through the effects of early numeracy skills (that would mimic the relationships observed with the HLE activities). Finally, despite the strong relationship between nonverbal intelligence and mathematics (e.g., Fuchs et al., 2010; Kyttälä & Lehto, 2008), none of the HNE studies has controlled for the effects of nonverbal intelligence.

1.3. The present study

The purpose of the present longitudinal study was to examine how HLE and HNE activities – assessed at the beginning of kindergarten – predict reading and math achievement in grade 1in Greek. Because 'time' is a significant factor that may influence the effects of home-learning environment on early literacy and math acquisition (Bronfenbrenner, 1999), we purposely chose to assess HLE and HNE before children's exposure to any systematic reading or math instruction at school. In addition, we used reading fluency measures in grade 1 as reading outcomes because reading accuracy reaches ceiling by the end of grade 1 in Greek due to the transparency of the orthography (95% consistent in the direction of reading; Protopapas & Vlachou, 2009). To our knowledge, this is the first study to test a mediational model of the relationship between HNE and math acquisition. This model is rooted to empirical findings showing that (a) early mathematical skills in kindergarten predict mathematics ability in grades 1 and 2 (Aunola et al., 2004; Stock et al., 2009),

(b) formal HNE predicts early mathematical skills in kindergarten (Anders et al., 2012; LeFevre et al., 2010) and (c) formal HNE predicts mathematics ability in grade 1 (LeFevre et al., 2009; Melhuish et al., 2008).

We sought to examine the following hypotheses:

(1) Formal literacy activities will predict reading fluency in grade 1 through the effects of letter knowledge and phonological awareness.
(2) Informal literacy activities will predict reading fluency in grade 1 through the effects of vocabulary and phonological awareness.
(3) Formal numeracy activities will predict math fluency in grade 1 through the effects of early math concepts and verbal counting. Because the informal numeracy activities were not assessed in the present study (see below for reasons), we did not formulate a hypothesis regarding their role.
(4) Formal literacy activities will predict math fluency in grade 1 through the effects of early math concepts and verbal counting.

The present study makes four important contributions to the literature: first, we examined the effects of HLE and HNE on reading and mathematics in grade 1, after controlling for the effects of early reading ability (assessed at the end of kindergarten). This responds to the call of previous studies for a more conservative test of the effects of HLE on future reading (Manolitsis et al., 2011) and also takes into account recent evidence showing that reading measures are significant predictors of future mathematics ability (Purpura, Hume, Sims, & Lonigan, 2011). Second, we examined whether the two types of HLE activities would predict early math skills. This would be expected given that solving math tasks requires some level of language processing (Anders et al., 2012) and on the basis of findings showing that early math acquisition is influenced by broader home-learning experiences (Melhuish et al., 2008). Third, the inclusion of math outcomes in our study serves as a control to the possible effects of orthographic transparency on reading. In other words, if the contribution of HLE on reading in Greek is minimized because of orthographic transparency, then the effect of HLE on math should not be affected because math is minimally influenced by the orthographic characteristics of a language. Finally, we examined the effects of HLE and HNE on reading and mathematics, after taking into account the effects of nonverbal intelligence and mother's educational level.

According to the parental investment model (Haveman, Wolfe, & Spaulding, 1991), mother's education is associated with the children's literacy skills, because it enables parents to build their children's human capital by providing increased resources, services, and time for interaction in stimulating activities. A number of studies have shown that HLE mediated the influence of parents' socioeconomic status (educational level and income) on early literacy skills (Foster, Lambert, Abbott-Shim, McCarty, & Franze, 2005; Silinskas, Parrila et al., 2010; Yeung, Linver, Brooks-Gunn, 2002). In addition, there are findings suggesting that mother's education may be differently related to the two facets of HLE; higher-educated mothers choose to provide a more 'child-centered' approach of HLE (e.g., reading books; see Evans et al., 2000; Hartas, 2011; Umek et al., 2005), because they feel they act as role models infusing the value of reading to their children (Saracho, 1997). In contrast, lower-educated mothers choose a more 'traditional' approach of HLE (e.g., direct teaching of letters; Phillips & Lonigan, 2009; Stipek, Milburn, Clements, & Daniels, 1992; Tracey & Young, 2002), because they have fewer resources to provide to their children (e.g., buy fewer books) or less opportunities to access educational services (e.g., infrequent visits to libraries with large book collections; Hartas, 2011; Neuman & Celano, 2001; Silinskas, Leppanen et al., 2010). In the present study, we used mother's education as a control variable and not as a predictor of HLE or HNE, in order to be able to compare our findings to those of previous studies that used similar measures and tested similar hypotheses (Gest, Freeman, Domitrovich, & Welsh, 2004; LeFevre et al., 2010; Roberts, Jurgens, & Burchinal, 2005; Sénéchal, 2006; Silinskas, Leppanen et al., 2010).

2. Method

2.1. Participants

Ninety-nine Greek kindergarten children (63 males and 36 females; Mean age = 64.32 months, SD = 3.23, at the first time of measurement) from Heraklion, a typical urban city in Greece, were followed from kindergarten to grade 1. The children were randomly selected from six kindergarten schools (serving children ages 5–6 years old), which were, in turn, selected with a stratified randomized approach in order to represent a range of demographics. The children were native speakers of Greek, Caucasian, and 57 percent had attended pre-kindergarten (serving children ages 4–5 years old). The children were assessed three times during the study: at the beginning and end of kindergarten, and at the end of grade 1. By grade 1, the sample consisted of 90 children. Nine children (9.09% of the initial sample) withdrew from the study. The attrition was due to the fact that the children and their families moved to a different district and could not be located (n = 7) or to withdrawal of parental consent (n = 2). In order to examine if the performance of the children who withdrew from the study differed significantly from the rest of the children, we performed t tests on their kindergarten performance scores and on the HLE scores. None of the t tests reached significance (all ps > .15). Furthermore, eight children had missing data on the home literacy and numeracy questionnaire (the parents did not return the questionnaire). Because the focus of this study was on home literacy and numeracy environment, we excluded these children from further analyses. Thus, the final sample consisted of 82 children (53 males and 29 females; Mean age = 64.67 months, SD = 3.26, at the first time of measurement) for whom a full dataset was available across time.

The home literacy and numeracy questionnaire was filled out by 70 mothers, two fathers, and 10 families where parents responded together. Mother's educational level was as follows: 7.4% of the mothers attended only elementary school, 11.1% attended only junior high school, 39.5% obtained a high school degree, 24.4% obtained a college degree, 14.6% obtained a university degree, and 2.4% had completed graduate studies. Based on the National Statistics of Greece (National Statistical Service of Greece, 2007), the mother's educational level in our study was representative of the selected region.

2.2. Beginning of kindergarten measures

2.2.1. Home literacy environment

Home literacy environment was assessed with five Likert-scale questions adapted from Stephenson et al. (2008; see Kirby & Hogan, 2008, for similar questions). Parents were asked (1) how often their child was taught to identify letters; (2) how often their child was taught letter sounds; and (3) how often their child was taught to read words when the child was 2–4 years of age. In addition, they were asked (4) how often their child is read to at home, and (5) how many children's books are in the home. For questions one to four, the six-point Likert-scale ranged from *never* to *more than once a day*. For question five, the Likert-scale ranged from *less than 10* to *more than 200*. Finally, mothers were asked to select their highest achieved educational level among six options (completed elementary school, completed junior high school, completed high school, completed college, completed university, and completed graduate studies). The reliability coefficient is provided in Section 3.

2.2.2. Home numeracy environment

Home numeracy environment was assessed with five Likert-scale questions, which were adapted in Greek from LeFevre et al. (2009). Parents were asked (1) how often their child was taught to identify the names of written numbers (e.g., bus number); (2) how often their child was taught to count different objects; (3) how often their child was taught to sort different objects according to their size and shape; (4) how often their child was taught to count in a number line (e.g., 1, 2, 3, 4); and (5) how often their child was taught to do simple calculations (e.g., 1 + 1, 2 − 1). The six-point Likert-scale ranged from *never* to *more than once a day*. Questions on informal numeracy activities (e.g., how often their child was playing with number fridge magnets, how often their child was playing with calculators, how often their child was using calendars, and how often the parents were talking about money when shopping) were used in a pilot study and showed floor effects (more than 80% of the parents selected "never" as their answer to each question). Similar floor effects for the informal numeracy activity questions were reported in LeFevre et al.'s (2010) study. For this reason, the questions on informal numeracy environment were excluded from the present study. The reliability coefficient is provided in Section 3.

2.2.3. Nonverbal cognitive ability

The Matrices test from the Das-Naglieri Cognitive Assessment System (CAS; Naglieri & Das, 1997; Greek standardization: Papadopoulos, Georgiou, Kendeou, & Spanoudis, 2008) was used to assess nonverbal cognitive ability. This test required participants to select one of six options that best completed a matrix with a part missing. The items in this task are organized in terms of difficulty. The task was discontinued after four consecutive errors. A participant's score was the number of correctly completed items (max = 33). Cronbach's alpha reliability coefficient in our sample was .90.

2.2.4. Vocabulary

The vocabulary test was adapted in Greek from Dyslexia Early Screening Test (DEST) battery (Nicolson & Fawcett, 2004; Greek standardization: Papadopoulos, Georgiou, & Kendeou, 2008). In this task, the experimenter said a word and the children were asked to point to the picture among four alternative options that corresponded to the word. The task consisted of 15 items and was discontinued after four consecutive errors. Cronbach's alpha reliability coefficient in our sample was .78.

2.2.5. Initial sound identification

This task was adapted in Greek (see Manolitsis, 2000) from the work of Wallach, Wallach, Dozier, and Kaplan (1977) and was used to assess phonological awareness. Children were provided with the picture of a target word (e.g., /kota/ → chicken) and were then asked to choose one of three words that alliterated with it (e.g., /γata/, /molivi/, /kalaθi/ → cat, pencil, basket). The task consisted of 10 items and it was preceded by two practice items. Cronbach's alpha reliability coefficient in our sample was .81.

2.2.6. Syllable segmentation

This task was adapted in Greek (see Manolitsis, 2000) from the work of Liberman, Shankweiler, Fisher, and Carter (1974) and was used to assess phonological awareness. Children were asked to segment words into syllables by saying and clapping each syllable of the word. The task consisted of 10 items and it was preceded by two practice items. Cronbach's alpha reliability coefficient in our sample was .80.

2.2.7. Letter knowledge

The participants were asked to provide the sound of each of the 24 uppercase and lowercase Greek letters. The letters were arranged randomly on A4 paper. The maximum score was 48. Cronbach's alpha reliability coefficient in our sample was .95. Letter name knowledge was not assessed because the children are not taught the letter names (e.g., alpha, beta) before the end of grade 1.

2.2.8. Basic math concepts

Basic math concepts were assessed with four tasks adapted from the Test of Early Mathematics Ability (TEMA-3; Ginsburg & Baroody, 2003). The first task assessed the *cardinality rule* and required children to count how many stars they saw in a given picture. The task included one practice item (2 stars) and two test items (3 stars, 5 stars). The second task assessed *seriation of numbers* and required children to say what number comes after 3 (practice item), 8, 6, and 9. The third task assessed *naming of single-digit numbers* and required children to name the numbers 2 (practice item), 3, 7, and 9. The fourth task assessed *number comparison* and required children to choose what number is greater than the other (e.g., 10 or 1 (practice item), 4 or 3, and 8 or 7). The score on basic math concepts was the sum of the scores in the four tasks (max = 10). Cronbach's alpha reliability coefficient in our sample was .77.

2.2.9. Verbal counting

In this task, the children were asked to count from 1 up to the highest number they could. The children were asked to stop counting, when they reached 50. The children's score depended on the maximum number they could count without skipping any numbers. They received one point if they could count continuously from 1 to 5, two points from 6 to 10, three points from 11 to 15, four points from 16 to 20, five points from 21 to 25, six points from 26 to 30, seven points from 31 to 35, eight points from 36 to 40, nine points from 41 to 45, and ten points from 46 to 50.

2.3. End of kindergarten measures

At the end of kindergarten, the children were administered the same letter knowledge, vocabulary, initial sound identification, and early numeracy measures. In addition, they were administered a phoneme elision task, and a word-reading accuracy task. In the *Phoneme Elision* task, they were given a word and they were then asked to delete a part of the word and say what was left. The task was adapted in Greek from the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999; see Georgiou, Parrila, & Papadopoulos, 2008, for information on the adaptation procedure). Children were asked to delete (a) a word from a compound word (2 items), (b) a syllable from a two- or three-syllable word (5 items), and (c) a phoneme from a one- or two-syllable word (22 items). Testing was discontinued after three consecutive errors. The children's score was the number of correct responses (max = 29). Cronbach's alpha reliability coefficient in our sample was .91. In the *word-reading accuracy* task, the children were shown 10 simple words (e.g., /to/(the); /pita/(pie)) and were asked to read them aloud. The children's score was the number of words read correctly. Cronbach's alpha reliability coefficient in our sample was .87.

2.4. End of grade 1 measures

2.4.1. Reading fluency

Reading fluency was assessed with two measures: a word-reading fluency and a nonword-reading fluency task. Reading fluency measures were administered because reading accuracy reaches ceiling by the end of grade 1 in Greek (Papadopoulos, Georgiou, & Kendeou, 2009). Both reading fluency measures were adapted in Greek from the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999, see Georgiou et al., 2008, for details on how the tasks were adapted in Greek). In the word-reading fluency task, the children were asked to read as fast as possible a list of 104 words increasing in difficulty, divided into four columns of 26 words each. The words were selected from the children's grade 1–6 language textbooks. In the nonword reading fluency task, the children were asked to read as fast as possible a list of 63 nonwords increasing in difficulty. The nonwords were developed by substituting letters in real words with some others or by changing the position of existing letters in words. A short, 8-word/nonword practice list was presented before each subtest. In each task, children's score was the number of correct words/nonwords read within a 45-s time limit. Test–retest reliability coefficient has been reported to be .94 for word-reading fluency and .86 for nonword-reading fluency (Georgiou et al., 2008).

2.4.2. Math fluency

Math fluency was assessed with two measures: *Number Sets* and *calculation fluency*. Number sets was adopted from Geary, Bailey, and Hoard (2009). The child's task was to determine as quickly and accurately as possible if pairs or trios of object sets, Arabic numerals, or a combination of these matched a target number (5 and 9). The object sets or numerals were combined to create domino-like rectangles. The target numbers were listed in a large font (36 point) at the top of each page. On each page, 18 items matched the target, 12 were larger than the target, 6 were smaller than the target, and 6 contained 0 squares or an empty square. Two items matching a target number of 4 were first explained for practice. The child was instructed to move across each line of the page from left to right and to circle any groups that could be put together to make the target number (5 or 9). Using a stopwatch, the child was given 60 and 90 s per page for the targets 5 and 9, respectively. We chose to time the task to avoid ceiling effects and because a timed measure should provide an assessment of fluency in recognizing number combinations (Geary et al., 2009). The child's score on each page was the difference in the *z*-score for hits and false alarms. To obtain a single score for the whole task, we averaged the scores for 5 and 9. Cronbach's alpha reliability coefficient in our sample was .85.

The calculation fluency task was adopted from Aunola and Räsänen (2007). The children were asked to do simple calculations (e.g., 3 + 4, 9 − 2) within a 3-min time limit. The children's score was the number of correct calculations performed within the time limit. The maximum score was 28. Cronbach's alpha reliability coefficient in our sample was .89.

2.5. Procedure

All participants were tested individually in their respective schools during school hours by the third author and a graduate student who had experience in psychological testing. In kindergarten, testing lasted roughly an hour and was completed in two sessions of 30 min each. The order of the tasks within each session was counterbalanced to avoid practice effects. In grade 1, testing lasted roughly 20 min. Parents' written consent was obtained prior to testing at each measurement occasion.

2.6. Statistical analyses

Path analysis was used to test our hypotheses (Loehlin, 2003). The analysis was performed in AMOS 16. In total, five models were tested with reading and math fluency in grade 1 as the dependent variables (see Section 3 for more details). To evaluate the model fit, chi-square values and a set of fit indexes were used: (a) the Comparative Fit Index (CFI); (b) the Goodness of Fit Index (GFI); and (c) the Root Mean Square Error of Approximation (RMSEA). A non-significant chi-square value and CFI and GFI indexes above .95 suggest model acceptance (Hu & Bentler, 1999). In addition, RMSEA values below or at .05 indicate a close fit, but values as high as .07 are regarded as acceptable (Browne & Cudeck, 1993). In addition, to examine the statistical significance of the mediation paths between HLE/HNE and reading/mathematics, we used the bootstrapped procedure with biased-corrected confidence intervals (Warner, 2012).

3. Results

3.1. Preliminary data analyses

The descriptive statistics for the home literacy and numeracy questionnaire are presented in Table 1. The home literacy questionnaire indicated that, on average, parents in the present study reported having between 25 and 99 children's books at home, that storybook reading occurred at home a couple of days a week, and that children were taught to read words a few times a month. In turn, the home numeracy questionnaire indicated that, on average, parents taught their children to identify the names of written numbers or sort objects a few days a week, count once a day, and do simple calculations a few times a month.

The descriptive statistics for the children measures are presented in Table 2. An examination of the distributional properties of the measures revealed some problems. Word-reading accuracy was positively skewed (63 children (76.8% of the sample) did not read any words, 8 children (9.7% of the sample) read 1–9 words, and 11 children (13.4% of the sample) read all 10 words accurately) and Number Sets was negatively skewed. In the case of word-reading accuracy, we converted the scores to 0 and 1 (0 = children who did not read any words, 1 = children who read at least one word). In the case of Number Sets, we first reflected and then log transformed the scores. This resulted in a normal distribution. In addition, the distributions of Matrices and Letter Knowledge at the beginning of kindergarten were platykurtic. Because none of the transformations improved their distributions, we ran all further analyses with the raw scores.

At the beginning of kindergarten, the children knew, on average, less than half of the letter sounds and their performance improved significantly by the end of kindergarten ($t(81) = 7.59$, $p < .001$). A similar improvement was noted for vocabulary ($t(81) = 4.14$, $p < .01$). Despite the improvement in letter knowledge

Table 1
Descriptive statistics for parents' reports on home literacy and numeracy environment at the beginning of kindergarten.

	M	*SD*	Range
Home Literacy Questionnaire			
Number of children books[a]	2.69	.80	1–5
Frequency of reading to child[b]	3.21	1.06	0–5
Teach to identify letters[b]	2.74	1.43	0–5
Teach letter sounds[b]	2.52	1.53	0–5
Teach to read words[b]	1.66	1.42	0–5
Home Numeracy Questionnaire			
Teach to identify numbers[b]	2.89	1.30	0–5
Teach to count objects[b]	3.47	1.08	1–5
Teach to sort objects[b]	3.12	1.32	0–5
Teach to count (e.g., 1, 2, 3)[b]	3.81	1.05	1–5
Teach simple calculations[b]	1.93	1.46	0–5

Note: $N = 82$.
[a] 1 = less than 10; 2 = 10–24; 3 = 25–99; 4 = 100–199; 5 = more than 200.
[b] 0 = never; 1 = less than once a month; 2 = a few times a month; 3 = a few times a week; 4 = about once a day; 5 = more than once a day.

Table 2
Descriptive statistics for the child measures.

Measures	Beginning of kindergarten		End of kindergarten		Grade 1	
	M	*SD*	*M*	*SD*	*M*	*SD*
Matrices (33)	6.50	3.00				
Vocabulary (15)	11.04	2.19	11.79	1.89		
Initial sound identification (10)	7.46	2.41	7.77	2.24		
Syllable segmentation (10)	8.57	2.10				
Phoneme elision (29)			5.35	6.78		
Letter knowledge (48)	16.28	15.66	23.77	16.34		
Word reading (10)	1.09	2.77	1.77	3.61		
Math concepts (10)	7.22	2.79	8.32	2.22		
Counting (10)	4.61	2.52	5.72	2.37		
WRE (104)					23.45	11.26
PDE (63)					20.00	7.02
Number Sets hits[a]					17.79	7.34
Number Sets false alarms[b]					.06	1.23
Calculations (28)					8.70	3.25

Note: In parenthesis we report the maximum possible score in each measure. WRE = Word Reading Efficiency; PDE = Phonemic Decoding Efficiency.
[a] This represents the mean of the hits across the two items (5 and 9).
[b] This represents the mean of the false alarms across the two items (5 and 9).

and vocabulary, the children were not readers yet, as 76.8% could not read any words at the end of kindergarten.

3.2. Data reduction

In order to examine the predicted relationships between the key constructs in our study, the number of variables was reduced. The home literacy measures were summarized in two composite variables following Sénéchal's (2006) protocol. Principal component analyses with varimax rotation on all five responses of the parents' questionnaire revealed a two-factor solution with eigenvalues above 1: the responses on the question about children's books at home and the question about how frequently parents read to their child loaded on one factor (factor loadings .62 and .89, respectively), and the responses on the other three questions loaded on the second factor (all factor loadings > .77). The first factor was called storybook exposure and represents the informal home literacy activities, and the second factor was called parent literacy teaching and represents the formal home literacy activities. The Cronbach's alpha reliability coefficients were .80 and .67 for the formal and informal HLE activities, respectively. Parent literacy teaching correlated $r = .30$ with storybook exposure. In addition, the five home numeracy questions loaded on one factor (all factor loadings > .66), which we called parent numeracy teaching and represents the formal numeracy activities (Cronbach's $\alpha = .85$). Parent numeracy teaching correlated $r = .75$ with parent literacy teaching and $r = .32$ with storybook exposure. Paired-sample comparisons with Bonferroni correction (alpha level of .05 adjusted to .016 according to three comparisons) indicated that the mean score (3.05) of parent numeracy teaching was significantly higher than the mean score (2.30) of parent literacy teaching ($t(81) = 7.97$, $p < .001$) and higher than the mean score (2.61) of storybook exposure ($t(81) = 3.69$, $p < .001$). The mean scores of the two HLE factors did not significantly differ from each other.

In addition, we calculated composite scores for phonological awareness, reading fluency, and math fluency. At the beginning of kindergarten, the phonological awareness score was derived by averaging the *z* scores of initial sound identification and syllable segmentation and, at the end of kindergarten, by averaging the *z* scores of initial sound identification and phoneme elision. In grade 1, the reading fluency score was obtained by averaging the *z* scores of word-reading fluency and nonword-reading fluency and the math fluency score by averaging the *z* score of Number Sets and calculations.

3.3. Correlations between the measures

Table 3 presents the zero-order correlations among all the variables involved in the present study. Pre-kindergarten attendance (dummy coded variable: 1 = attended pre-kindergarten and 0 = did not attend pre-kindergarten) did not correlate significantly with any of the measures and was left out from further analyses. As was expected, parent literacy teaching correlated only with letter knowledge (at the beginning of kindergarten) and storybook exposure correlated only with vocabulary. In turn, both letter knowledge and vocabulary correlated significantly with phonological sensitivity. All emergent literacy skills correlated significantly with word-reading accuracy in kindergarten and reading fluency in grade 1. Both parent literacy and numeracy teaching correlated with counting at the beginning of kindergarten. Finally, all of the emergent literacy and reading skills correlated significantly with the early numeracy and math skills.

3.4. Predicting reading ability

Next, we performed path analysis to examine the predictors of reading ability in grade 1. Only statistically significant paths are included in the final model (see Fig. 1). The model fit the data very well and accounted for 44% of the variance (see Table 4 for the fit indexes). The results indicated, first, that storybook exposure predicted vocabulary and parent literacy teaching predicted letter knowledge at the beginning of kindergarten. In turn, vocabulary and letter knowledge predicted phonological awareness. Second, letter knowledge, phonological awareness, and vocabulary were stable from the beginning of kindergarten to the end of kindergarten. Finally, beyond the contribution of mother's education, phonological awareness and letter knowledge at the end of kindergarten predicted reading fluency in grade 1.

We then examined the model in Fig. 1, after partialling out the effects of word-reading accuracy (binary coded variable) on reading fluency in grade 1. Before conducting this analysis, reading fluency was residualized for word-reading accuracy and the unstandardized residuals were used in the place of the reading fluency factor scores. The model fitted the data very well and accounted for 16% of the variance (see Table 4 for the fit indexes). Only mother's education continued to predict the residualized reading fluency scores in grade 1 ($\beta = .331$). The contribution of phonological awareness ($\beta = -.044$) and letter knowledge ($\beta = .166$) was no longer significant.

Table 3
Zero-order correlations between home literacy, home numeracy and child cognitive measures.

		2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
1.	PAT	−.01	.16	.12	−.15	.12	.07	.18	.00	−.15	−.01	−.01	.03	.10	.03	.07	.18	.10	.00
2.	Mother's education		.28	−.03	.21	.13	.32	.10	.18	.21	.25	.38	.18	.16	.20	.19	.14	.43	.16
3.	Matrices			.13	.14	.20	.52	.45	.38	.41	.44	.45	.42	.24	.29	.41	.25	.33	.37
4.	PLT				.30	.75	.23	.15	.19	.02	.25	.15	.11	.13	.11	.04	.05	.02	−.04
5.	Storybook exposure					.32	.16	.14	.33	.02	.19	.20	.15	.25	.20	.14	.11	.05	.05
6.	PNT						.13	.16	.11	.09	.28	.11	.03	.07	.02	.14	.01	.04	−.02
7.	LK_T1							.51	.46	.62	.66	.84	.54	.40	.78	.54	.62	.59	.50
8.	PA_T1								.43	.51	.46	.42	.54	.42	.43	.42	.41	.39	.41
9.	Vocabulary_T1									.45	.42	.42	.52	.68	.41	.48	.51	.32	.48
10.	Math concepts_T1										.54	.66	.67	.30	.47	.77	.60	.47	.51
11.	Counting_T1											.61	.59	.40	.50	.57	.59	.41	.40
12.	LK_T2												.61	.36	.69	.63	.67	.60	.39
13.	PA_T2													.42	.76	.60	.67	.54	.50
14.	Vocabulary_T2														.33	.35	.46	.24	.32
15.	Word reading_T2															.40	.56	.56	.43
16.	Math concepts_T2																.58	.55	.46
17.	Counting_T2																	.44	.47
18.	Reading fluency_T3																		.47
19.	Math fluency_T3																		

Note: Correlations below .22 are non-significant. Correlations between .22 and .28 are significant at the $p < .05$ level and correlations higher than .28 are significant at the $p < .01$ level. PAT = Pre-kindergarten Attendance; PLT = Parent Literacy Teaching; PNT = Parent Numeracy Teaching; LK = Letter Knowledge; PA = Phonological Awareness; T1 = Time 1, T2 = Time 2; T3 = Time 3. $N = 82$.

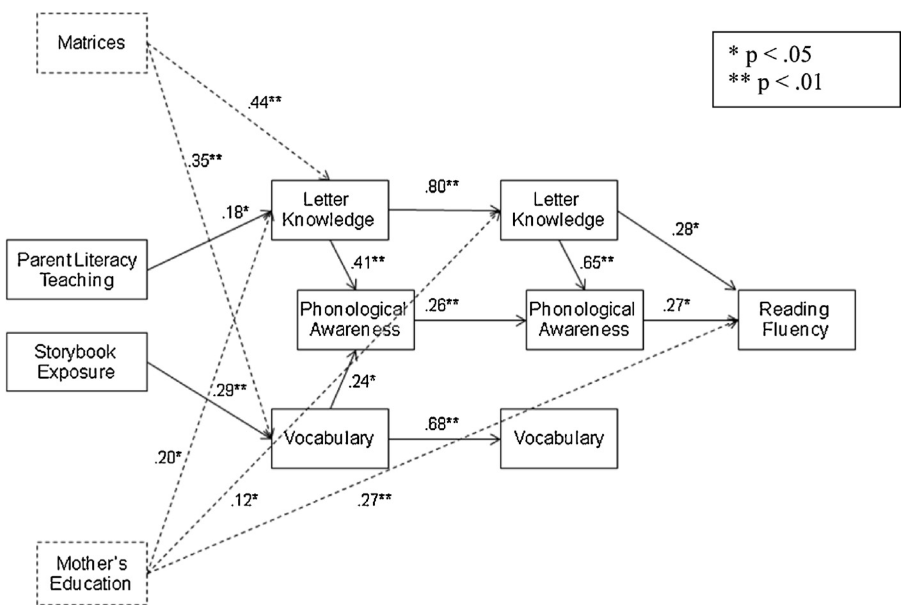

Fig. 1. The home literacy model with the significant predictors of reading fluency in grade 1.

3.5. *Predicting math ability*

In the next model, we examined the predictors of math ability in grade 1 (see Fig. 2). The model fit the data very well and accounted for 26% of the variance (see Table 4 for the fit indexes).

Table 4
Summary of fit indexes for the path analyses models.

Model	x^2	x^2/df	CFI	GFI	RMSEA
HLE → RF_G1 (df = 38)	47.34 (p = 142)	1.24	.97	.97	.05
HLE → RRF_G1(df = 40)	48.76 (p = .161)	1.22	.97	.96	.05
HNE → MF_G1 (df = 17)	20.56 (p = .246)	1.21	.98	.97	.05
HNE → RMF_G1(df = 18)	17.53 (p = .487)	.93	1.00	1.00	.00
HLE → MF_G1(df = 24)	24.44 (p = .436)	1.01	.99	.99	.01

Note: HLE = home literacy environment; HNE = home numeracy environment; RF = reading fluency; RRF = residualized reading fluency; MF = math fluency; RMF = residualized math fluency.

Parent numeracy teaching predicted only counting at the beginning of kindergarten. Both math concepts and counting were stable across time, and predicted each other's further growth, and math fluency in grade 1. Mother's education did not predict any skills in the math model.

We then examined the model in Fig. 2, after partialling out the effects of word-reading accuracy on math fluency in grade 1. The residualized math fluency scores were used in the place of math fluency factor scores. The model fit was excellent and accounted for 10% of the variance (see Table 4 for the fit indexes). The math concepts remained a significant predictor of the residualized math fluency scores in grade 1.

Finally, we examined the fit of the HNE model after replacing the parent numeracy teaching with the two HLE components (see Fig. 3). The model fit the data very well and accounted for 27% of the variance (see Table 4 for the fit indexes). Parent literacy teaching predicted counting at the beginning of kindergarten. Notably, the

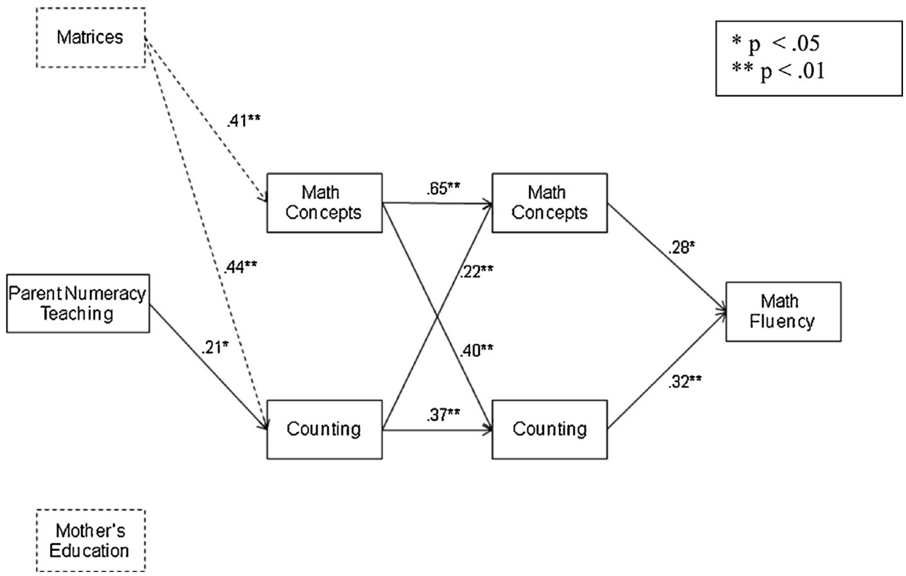

Fig. 2. The home numeracy model with the significant predictors of math fluency in grade 1.

effect of parent literacy teaching on early counting was similar to that observed for parent numeracy teaching in the HNE model (see Fig. 2).

3.6. Mediation analysis

To examine if the mediated paths between HLE/HNE and reading/mathematics in grade 1 were statistically significant, we used the bootstrap procedure that allows us to obtain confidence intervals (CI: 95%) for the mediated effects (Warner, 2012). If the confidence interval for an indirect path does not span zero, then we can conclude that there is statistically significant mediation. For the purpose of this study, we requested 2000 bootstrap samples. The results indicated first that both mediated paths from HLE to reading fluency were statistically significant. The lower and upper limits of the 95% CI for the path from formal HLE to reading fluency were .052 and .173 ($p = .03$). The corresponding limits for the informal HLE were .002 to .024 ($p = .05$). Second, the mediated path from HNE to math fluency was statistically significant (95% CI: .012–.079; $p = .01$).

4. Discussion

The purpose of the present longitudinal study was to trace the effects of HLE and formal HNE activities on reading and math achievement. In line with the findings of previous studies (Burgess et al., 2002; Frijters et al., 2000; Hood et al., 2008; Kirby & Hogan, 2008; Sénéchal, 2006; Sénéchal & LeFevre, 2002; Stephenson et al., 2008; Whitehurst & Lonigan, 1998), we found that HLE consisted of two distinct facets and that each facet predicted reading indirectly through partly distinct routes. Formal HLE activities predicted reading fluency in grade 1 through the effects of letter knowledge and phonological awareness (Hypothesis 1). In turn, the informal HLE activities predicted reading fluency in grade 1 through the effects of vocabulary on phonological awareness (Hypothesis 2).

Vocabulary did not directly predict reading fluency in grade 1, despite the fact that the correlations with reading fluency were

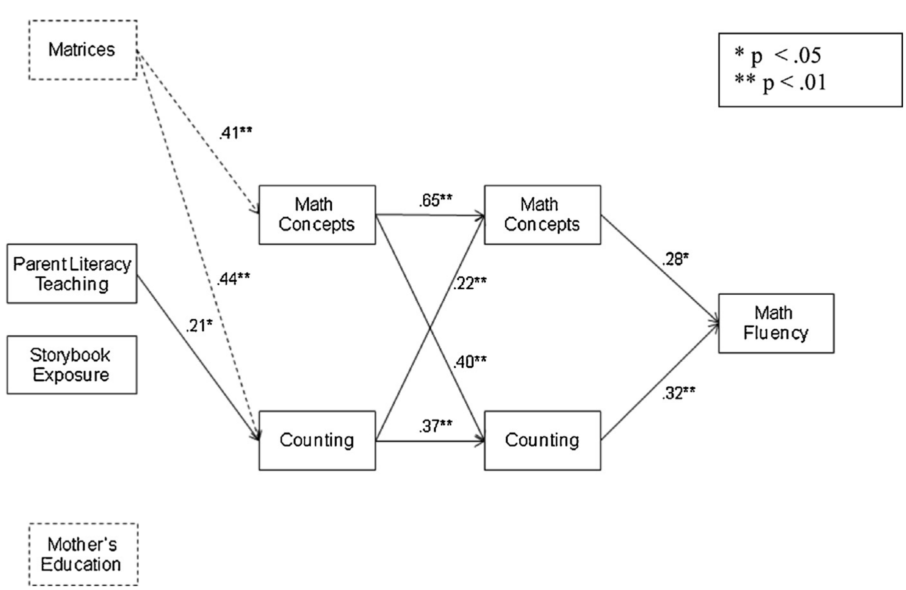

Fig. 3. The home numeracy model with the HLE components as predictors of math fluency in grade 1.

significant ($rs = .32$ and .24). This suggests that the predictive value of vocabulary on reading fluency is overlapping with that of phonological awareness. This finding calls for a revision of the proposed HLE connections to reading acquisition in order to account for the type of reading outcome. Previous studies have shown that vocabulary has a direct effect on reading comprehension (Roth et al., 2002; Sénéchal, 2006) and that shared book reading interventions have a significant impact on children's vocabulary (Chow & McBride-Chang, 2003; Jordan, Snow, & Porche, 2000). Therefore, we may argue that informal HLE activities predict reading through the effects of vocabulary when the outcome variable is reading comprehension, and through the effects of vocabulary on phonological awareness when the outcome variable is reading accuracy or fluency.

In line with Sénéchal's (2006) findings, neither the formal nor the informal HLE activities predicted phonological awareness directly. The formal HLE activities predicted phonological awareness through the effects of letter knowledge and the informal HLE activities predicted phonological awareness through the effects of vocabulary. Letter knowledge helps Kindergarten children to understand that individual words are formed by individual sounds (Manolitsis & Tafa, 2011). In turn, vocabulary contributes to the development of accurate representations of the phonological structure of words (Torppa et al., 2007; Walley, Metsala, & Garlock, 2003).

The correlations between the two facets of HLE and phonological awareness in our study were non-significant. This finding merits some discussion because in our earlier work (Manolitsis et al., 2011) we found a negative correlation between HLE and phonological awareness. We interpreted the negative correlation as an indication that parents engage in direct teaching only when they notice that something is going wrong with their child's literacy development (thus they would teach more when the child was experiencing some difficulties). More direct teaching was also significantly associated with lower parental expectations for their children's future reading achievement (Manolitsis et al., 2011). This interpretation is also in line with the findings of previous studies reporting that the frequency of parents' teaching at home increased as their children's achievement decreased (see Georgiou, 1999; Silinskas, Leppanen et al., 2010). There may be two explanations why we did not find a similar negative correlation in this study. First, we assessed HLE at the beginning of kindergarten before the parents had a chance to discuss with teachers their child's progress in literacy and consequently modify their teaching at home. If 'timing' is a critical factor of the features of the environment that influence proximal processes (Bronfenbrenner, 1999), then it could be assumed that teacher's feedback to parents did not exert yet an influence on the HLE practices. In line with this interpretation Silinskas, Parrila et al. (2010) showed that children with better reading skills were exposed more to literacy activities by their parents than children with less developed reading skills at the beginning of kindergarten. Second, in our previous study (Manolitsis et al., 2011), we used Blending and Elision as measures of phonological awareness in Kindergarten and both resulted in relatively low performances that were further affected by a restriction of range. In this study, we used more time-sensitive measures of phonological awareness and we obtained better distributions of scores.

An important contribution of this study was the inclusion of a reading accuracy measure at the end of kindergarten to control for early reading ability. A significant number of children in this study were already readers by the end of kindergarten (13.4% of them could read all 10 words accurately). Partialling out the effects of early reading ability resulted in a non-significant contribution of letter knowledge and phonological awareness on reading fluency. Thus, early reading ability should be integrated into the existing HLE models (Sénéchal, 2006; Weigel, Martin, & Bennett, 2006).

Similar to the indirect relationship between HLE and reading fluency, we found that parent numeracy teaching predicted math fluency in grade 1 primarily through the effects of counting. The formal HNE activities correlated significantly only with counting at the beginning of kindergarten ($r = .28$). Weak correlations between formal HNE and early math abilities were reported in LeFevre et al. (2009) work as well. Viewed in conjunction with the weak correlation between formal HLE and letter knowledge at the beginning of kindergarten ($r = .23$), this finding may suggest that the direct effects of parent teaching are rather time-limited and specific. As soon as the children get exposed to literacy and numeracy instruction (even when this is done in the form of games), any individual differences that may have been brought about by differences in their home environment fade out (Manolitsis et al., 2011; Silinskas, Lerkkanen, Tolvanen, Niemi, Poikkeus, & Nurmi, 2012). However, our study revealed not only a direct link from formal HNE to counting, but also an indirect link to basic math concepts (e.g., read numbers, numbers comparisons) through counting ability. Both early numeracy skills directly predicted math fluency in grade 1, a finding that is in line with those of previous studies (Passolunghi & Lanfranchi, 2012; Stock et al., 2009).

Importantly, parent literacy teaching predicted early math acquisition as strongly as parent numeracy teaching. This finding is consistent with those of previous studies (Anders et al., 2012; LeFevre et al., 2009; Melhuish et al., 2008). The strong correlation between parent numeracy teaching and parent literacy teaching, but not storybook exposure suggests that, before systematic teaching begins, parents adopt a comprehensive direct teaching style, which contributes similarly to both academic skills. Moreover, the intercorrelations observed, on the one hand, between HLE and formal HNE and, on the other hand, between the early literacy and early math skills possibly indicate that, early on in children's development, the home-learning environment provides an advantage to a global set of academic skills. In line with this interpretation, Stylianides and Stylianides (2011) reported an isomorphic effect of parent–child interactions on children's academic skills (e.g., reading and mathematics) at the beginning of kindergarten. Besides, the development of reading and mathematics during the preschool years appears to go hand in hand (Betts, Pickart, & Heistad, 2009; Kleemans, Segers, & Verhoeven, 2011; Purpura et al., 2011).

The parents in our study reported engaging more frequently in formal HNE activities than in formal HLE activities. This is in contrast to the findings of previous studies (Anders et al., 2012; LeFevre et al., 2009; Skwarchuk, 2009). Greek parents may have reported engaging more frequently in formal HNE than HLE activities, because math acquisition raises more concerns to them than reading acquisition. Because learning to read in Greek is a relatively easy task that is achieved within the first three months of formal reading instruction (Papadopoulos, 2001; Papadopoulos et al., 2009), Greek parents may be reluctant to teach reading-related skills to their children (Manolitsis, Georgiou, Stephenson, & Parrila, 2009). In contrast, because math acquisition is not something that orthographic transparency can booster, parents may try to compensate by providing more frequent instruction. Interestingly, the reported frequency of numeracy teaching in Greek kindergartners is similar to that of literacy teaching among English-speaking children (Kirby & Hogan, 2008; Stephenson et al., 2008). The discrepancy with Anders et al.'s (2012) findings may be attributed to the age of the participants. Anders and colleagues measured the frequency of HLE and HNE activities when their subjects were very young (three years old). Previous studies indicated that numeracy activities such as sorting or counting objects and making simple calculations are rare in 3-year-old children (Tudge & Doucet, 2004).

Finally, mother's education – representing the environmental context – was not associated with parents' numeracy teaching or early numeracy skills. Previous studies have reported rather specific effects of mother's education on early numeracy skills. For example, Anders et al. (2012) found a significant effect of mother's education on numeracy skills at the age of three, but not on later numeracy growth until the age of five. Likewise, there were effects of mother's education on math knowledge skills, but not on math fluency skills (LeFevre et al., 2009), or minimal effects on early numeracy skills (Melhuish et al., 2008). Considering that our outcome measure was math fluency and that formal HNE was assessed at the age of five (beginning of kindergarten), our findings seem to be consistent with what has been found before. In addition, we did not find a significant association between mother's education and parents' numeracy teaching. Taken together with the non-significant correlation between mother's education and HLE, the present findings appear to support Hartas' (2011) argument that home-learning environment is provided by all parents irrespective of their socioeconomic status. Moreover, mother's education had a significant direct effect on letter knowledge and reading fluency. This also supports Hartas' (2011) argument that the socio-economic gap in literacy acquisition is independent of the intensity of home learning.

In contrast to the findings of previous studies (Dickinson, McCabe, Anastasopoulos, Peisner-Freinberg, & Poe, 2003; Hoff, 2003; Sylva et al., 2010), mother's education did not correlate significantly with children's vocabulary. This may be attributed to the type of vocabulary measure we used in our study. Previous studies have shown that mother's education is more strongly related to expressive than to receptive vocabulary (Snow, 1999; Umek et al., 2005).

4.1. Limitations of the study

Some limitations of the present study are worth reporting. First, information on HLE and formal HNE was collected by sending out a self-report questionnaire to the parents and not by directly observing them in their natural environment. This may have resulted in inflated values due to social-desirability bias. Future studies should consider assessing HLE and HNE with direct observations of the parent–child interactions during literacy or numeracy activities. Second, we assessed only formal HNE activities, because Greek parents reported very low involvement in informal HNE practices during a pilot study. Future studies should develop items for informal HNE activities that will be more sensitive. A diary of what mothers are doing at home with their children on a regular basis would perhaps be the first step in this direction. Third, we did not assess a specific context of shared book reading (e.g., dialogic reading), but a general index of storybook exposure. Considering that previous intervention studies showed that dialogic reading is more effective than typical shared reading on increasing oral language skills (Hargrave & Sénéchal, 2000; Mol, Bus, de Jong, & Smeets, 2008), future studies could focus on this specific type of shared reading. Finally, our sample size was relatively small. Future studies should try to replicate our findings with a larger sample size.

5. Conclusion

The findings of the present study add to a growing body of research examining the role of home literacy and numeracy activities on reading and math acquisition. Both forms of HLE and formal HNE predicted reading and math fluency indirectly through the effects of emergent literacy and numeracy skills. Given the strong correlation between parent numeracy and literacy teaching as well as the association between the parent literacy teaching and early numeracy skills, it is reasonable to argue that the home-learning environment contributes equally to children's reading and math acquisition.

Our findings have important educational implications. First, we should encourage parents to foster their children's early literacy and early math skills in order to help them build a strong foundational level that will boost future growth in reading and math. Second, given the distinct paths from the HLE activities to reading, parents have the opportunity to choose the kind of activities they want to engage in. For example, if the goal is to enhance the children's reading accuracy or fluency, parents should really focus on direct teaching activities (i.e., teach letters and words). On the other hand, if the goal is to enhance the children's reading comprehension, then shared book reading is also necessary (Mol & Bus, 2011; Sénéchal, 2006).

However, the effects of HLE and formal HNE in our study appear to be time-limited. This likely suggests that the instruction children receive in kindergarten is so powerful that considerably decreases any advantages children from rich home literacy and numeracy environments carry with at school. Consequently, home-based intervention programs are likely to be more effective, if they are implemented before children enter kindergarten (Jordan et al., 2000; Lonigan & Whitehurst, 1998; van Otterloo, van der Leij, & Henrichs, 2008).

References

Al Otaiba, S., Puranik, C. S., Rouby, A., Greulich, L., Sidler, J. F., & Lee, J. (2010). Predicting kindergarteners' end-of-year spelling ability based on their reading, alphabetic, vocabulary, and phonological awareness skills as well as prior literacy experiences. *Learning Disability Quarterly*, *33*, 171–183.

Anders, Y., Rossbach, H.-G., Weinert, S., Ebert, S., Kuger, S., Lehr, S., et al. (2012). Home and preschool learning environments and their relations to the development of early numeracy skills. *Early Childhood Research Quarterly*, *27*, 231–244.

Aram, D., & Levin, I. (2002). Mother–child joint writing and storybook reading: Relations with literacy among low SES Kindergartners. *Merrill-Palmer Quarterly*, *48*, 202–224.

Aunola, K., Leskinen, E., Lerkkanen, M. K., & Nurmi, J. E. (2004). Developmental dynamics of mathematical performance from preschool to Grade 2. *Journal of Educational Psychology*, *96*, 699–713.

Aunola, K., & Räsänen, P. (2007). *The 3-minutes basic arithmetic test*. Jyväskylä, Finland: University of Jyväskylä (Unpublished Test).

Betts, J., Pickart, M., & Heistad, D. (2009). Construct and predictive validity evidence for curriculum-based measures of early literacy and numeracy skills in Kindergarten. *Journal of Psychoeducational Assessment*, *27*, 83–95.

Bronfenbrenner, U. (1995). Developmental ecology through space and time: A future perspective. In P. Moen, G. H. Elder, & K. Luscher (Eds.), *Examining lives in context: Perspectives on the ecology of human development* (pp. 619–647). Washington, DC: American Psychological Association.

Bronfenbrenner, U. (1999). Environment in developmental perspective: Theoretical and operational models. In S. L. Friedman, & T. D. Wachs (Eds.), *Measuring environment across the life span: Emerging methods and concepts* (pp. 3–28). Washington, DC: American Psychological Association.

Browne, M. W., & Cudeck, R. (1993). Alternative ways in assessing model fit. In K. Bollen, & J. S. Long (Eds.), *Testing structural equation models* (pp. 136–162). Newbury Park, CA: Sage.

Buchs, E. S., Welch, G., Burt, J., & Knoche, L. (2011). Family engagement in literacy activities: Revised factor structure for The Familia – An instrument examining family support for early literacy development. *Early Child Development and Care*, *181*, 989–1006.

Burgess, S. R., Hecht, S. A., & Lonigan, C. J. (2002). Relations of home literacy environment (HLE) to the development of reading-related abilities: A one-year longitudinal study. *Reading Research Quarterly*, *37*, 408–426.

Chow, B. W.-Y., & McBride-Chang, C. (2003). Promoting language and literacy development through parent–child reading in Hong Kong preschoolers. *Early Education and Development*, *14*, 233–248.

Dickinson, D. K., McCabe, A., Anastasopoulos, L., Peisner-Freinberg, E. S., & Poe, M. D. (2003). The comprehensive language approach to early literacy: The interrelationships among vocabulary, phonological sensitivity and print knowledge among preschool-aged children. *Journal of Educational Psychology*, *95*, 465–481.

Duncan, G. J., Dowsett, C., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., et al. (2007). School readiness and later achievement. *Developmental Psychology*, *43*, 1428–1446.

Evans, M. A., Shaw, D., & Bell, M. (2000). Home literacy activities and their influence on early literacy skills. *Canadian Journal of Experimental Psychology*, *54*, 65–75.

Foster, M. A., Lambert, R., Abbott-Shim, M., McCarty, F., & Franze, S. (2005). A model of home learning environment in relation to children's emergent literacy and social outcomes. *Early Childhood Research Quarterly*, *20*, 13–36.

Foy, J. G., & Mann, V. (2003). Home literacy environment and phonological sensitivity in preschool children: Differential effects for rhyme and phoneme awareness. *Applied Psycholinguistics*, *24*, 59–88.

Frijters, J. C., Barron, R. W., & Brunello, M. (2000). Direct and mediated influences of home literacy and literacy interest on prereaders' oral vocabulary and early written language skill. *Journal of Educational Psychology*, *92*, 466–477.

Fuchs, L. S., Geary, D. C., Compton, D. L., Fuchs, D., Hamlett, C. L., Seethaler, M., et al. (2010). Do different types of school mathematics development depend on different constellations of numerical versus general cognitive abilities? *Developmental Psychology*, *46*, 1731–1746.

Galindo, C., & Sheldon, S. B. (2012). School and home connections and children's achievement gains: The mediating role of family involvement. *Early Childhood Research Quarterly*, *27*, 90–103.

Geary, D. C., Bailey, D. H., & Hoard, M. K. (2009). Predicting mathematical achievement and mathematical disability with a simple screening tool: The number sets test. *Journal of Psychoeducational Assessment*, *27*, 265–279.

Georgiou, G. K., Parrila, R., & Papadopoulos, T. C. (2008). Predictors of word decoding and reading fluency in English and Greek: A cross-linguistic comparison. *Journal of Educational Psychology*, *100*, 566–580.

Georgiou, S. N. (1999). Parental attributions as predictors of involvement and influences on child achievement. *British Journal of Educational Psychology*, *69*, 409–429.

Gest, S. D., Freeman, N. R., Domitrovich, C. E., & Welsh, J. A. (2004). Shared book reading and children's language comprehension skills: The moderating role of parental discipline practices. *Early Childhood Research Quarterly*, *19*, 319–336.

Ginsburg, P. H., & Baroody, A. J. (2003). *Test of early mathematics ability. Examiner's manual* (3rd ed.). Austin, TX: Pro-Ed.

Hargrave, A. C., & Sénéchal, M. (2000). A book reading intervention with preschool children who have limited vocabularies: The benefits of regular reading and dialogic reading. *Early Childhood Research Quarterly*, *15*, 75–90.

Hartas, D. (2011). Families' social background matter: Socio-economic factors, home learning and young children's language literacy and social outcomes. *British Educational Research Journal*, *37*, 893–914.

Haveman, R., Wolfe, B., & Spaulding, J. (1991). Childhood events and circumstances influencing high school completion. *Demography*, *28*, 123–157.

Hoff, E. (2003). The specificity of environmental influence: Socioeconomic status affects early vocabulary development via maternal speech. *Child Development*, *74*, 1368–1378.

Hood, M., Conlon, E., & Andrews, G. (2008). Preschool home literacy practices and children's literacy development: A longitudinal analysis. *Journal of Educational Psychology*, *100*, 252–271.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indices in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*, 1–55.

Jordan, G. E., Snow, C. E., & Porche, M. V. (2000). Project EASE: The effect of a family literacy project on kindergarten students' early literacy skills. *Reading Research Quarterly*, *35*, 524–546.

Kim, Y.-S. (2009). The relationship between home literacy practices and developmental trajectories of emergent literacy and conventional literacy skills for Korean children. *Reading and Writing*, *22*, 57–84.

Kirby, J., & Hogan, B. (2008). Family literacy environment and early literacy development. *Exceptional Education Children*, *18*, 112–130.

Kleemans, T., Segers, E., & Verhoeven, L. (2011). Cognitive and linguistic precursors to numeracy in kindergarten: Evidence from first and second language learners. *Learning and Individual Differences*, *21*, 555–561.

Krajewski, K., & Schneider, W. (2009). Early development of quantity to number-word linkage as a precursor of mathematical school achievement and mathematical difficulties: Findings from a four-year longitudinal study. *Learning and Instruction*, *19*, 513–526.

Kyttälä, M., & Lehto, J. E. (2008). Some factors underlying mathematical performance: The role of visuospatial working memory and non-verbal intelligence. *European Journal of Psychology of Education*, *23*, 77–94.

LeFevre, J., Clarke, T., & Stringer, A. P. (2002). Influences of language and parental involvement on the development of counting skills: Comparisons of French- and English-speaking Canadian children. *Early Child Development and Care*, *172*, 283–300.

LeFevre, J., Polyzoi, E., Skwarchuk, S., Fast, L., & Sowinski, C. (2010). Do home numeracy and literacy practices of Greek and Canadian parents predict the numeracy skills of kindergarten children? *International Journal of Early Years Education*, *18*, 55–70.

LeFevre, J., Skwarchuk, S., Smith-Chant, B., Fast, L., Kamawar, D., & Bisanz, J. (2009). Home numeracy experiences and children's math performance in the early school years. *Canadian Journal of Behavioural Science*, *41*, 55–66.

Liberman, I. Y., Shankweiler, D., Fisher, F. W., & Carter, B. (1974). Explicit syllable and phoneme segmentation in the young child. *Journal of Experimental Child Psychology*, *18*, 201–212.

Loehlin, J. C. (2003). *Latent variable models: An introduction to factor, path, and structural equation analysis*. Mahwah, NJ: Erlbaum.

Lonigan, C., & Whitehurst, G. J. (1998). Relative efficacy of parent and teacher involvement in a shared-reading intervention for preschool children from low-income backgrounds. *Early Childhood Research Quarterly*, *13*, 263–290.

Manolitsis, G. (2000). (*Measurement and evaluation of 5–6 years old children's metalinguistic abilities*) *Metrisi ke aksiologisi metaglosikon ikanotiton pedion ilikias 5–6 eton*. Athens, Greece: Grigoris.

Manolitsis, G., Georgiou, G. K., & Parrila, R. (2011). Revisiting the home literacy model of reading development in an orthographically consistent language. *Learning and Instruction*, *21*, 496–505.

Manolitsis, G., Georgiou, G., Stephenson, K., & Parrila, R. (2009). Beginning to read across languages varying in orthographic consistency: Comparing the effects of non-cognitive and cognitive predictors. *Learning and Instruction*, *19*, 466–480.

Manolitsis, G., & Tafa, E. (2011). Letter-name letter-sound and phonological awareness: Evidence from Greek-speaking kindergarten children. *Reading and Writing: An Interdisciplinary Journal*, *24*, 27–53.

Melhuish, E. C., Phan, M. B., Sylva, K., Sammons, P., Siraj-Blatchford, I., & Taggart, B. (2008). Effects of the home learning environment and preschool center experience upon literacy and numeracy development in early primary school. *Journal of Social Issues*, *64*, 95–114.

Mol, S. E., & Bus, A. G. (2011). To read or not to read: A meta-analysis of print exposure from infancy to early adulthood. *Psychological Bulletin*, *137*, 267–296.

Mol, S. E., Bus, A. G., de Jong, M. T., & Smeets, D. J. H. (2008). Added value of dialogic reading parent–child book readings: A meta-analysis. *Early Education & Development*, *19*, 7–26.

Morrison, F. J. (2009). Parenting and academic development. *Merill-Palmer Quarterly*, *55*, 361–372.

Naglieri, J. A., & Das, J. P. (1997). *Das-Naglieri Cognitive Assessment System*. Itasca, IL: Riverside.

National Statistical Service of Greece. (2007). . *Population and housing census* (Vol. III, Part B) Pireas, Greece: National Statistical Service of Greece.

Neuman, S. B., & Celano, D. (2001). Access to print in low-income and middle-income communities: An ecological study of four neighborhoods. *Reading Research Quarterly*, *36*, 8–26.

Nicolson, R., & Fawcett, A. (2004). *Dyslexia Early Screening Test (DEST)*. London, UK: Psychological Corporation.

Papadopoulos, T. C. (2001). Phonological and cognitive correlates of word reading acquisition under two different instructional approaches. *European Journal of Psychology of Education*, *16*, 549–567.

Papadopoulos, T. C., Georgiou, G. K., & Kendeou, P. (2009). Investigating the double-deficit hypothesis in Greek: Findings from a longitudinal study. *Journal of Learning Disabilities*, *42*, 528–547.

Papadopoulos, T. C., Georgiou, G. K., & Kendeou, P. (2008). *Dyslexia early screening test-second edition (DEST-2): Standardization in Greek*. Department of Psychology, University of Cyprus (Original work published 2004).

Papadopoulos, T. C., Georgiou, G. K., Kendeou, P., & Spanoudis, G. (2008). *Das-naglieri cognitive assessment system: Standardization in Greek*. Department of Psychology, University of Cyprus (Original work published 1997).

Passolunghi, M. C., & Lanfranchi, S. (2012). Domain-specific and domain-general precursors of mathematical achievement: A longitudinal study from kindergarten to first grade. *British Journal of Educational Psychology*, *82*, 42–63.

Phillips, B. M., & Lonigan, C. J. (2009). Variations in the home literacy environment of preschool children: A cluster analytic approach. *Scientific Studies of Reading*, *13*, 146–174.

Pomerantz, E. M., Moorman, E. A., & Litwack, S. D. (2007). The how, whom and why of parents' involvement in children's academic lives: More is not always better. *Review of Educational Research*, *77*, 373–410.

Protopapas, A., & Vlachou, E. (2009). A comparative quantitative analysis of Greek orthographic transparency. *Behavior Research Methods*, *41*, 991–1008.

Purpura, D. J., Hume, L. E., Sims, D. M., & Lonigan, C. J. (2011). Early literacy and early numeracy: The value of including early literacy skills in the prediction of numeracy development. *Journal of Experimental Child Psychology*, *110*, 647–658.

Roberts, J., Jurgens, J., & Burchinal, M. (2005). The role of home literacy practices in preschool children's language and emergent literacy skills. *Journal of Speech, Language and Hearing Research*, *48*, 345–359.

Rodriguez, E. T., & Tamis-LeMonda, C. S. (2011). Trajectories of the home learning environment across the first 5 years: Associations with children's vocabulary and literacy skills at prekindergarten. *Child Development*, *82*, 1058–1075.

Roth, F. P., Speece, D., & Cooper, D. H. (2002). A longitudinal analysis of the connection between oral language and early reading. *Journal of Educational Research*, *95*, 259–272.

Saracho, O. N. (1997). Perspectives on family literacy. *Early Child Development and Care*, *127–128*, 3–11.

Schmitt, S. A., Simpson, A. M., & Friend, M. (2011). A longitudinal assessment of the home literacy environment and early language. *Infant and Child Development*, *20*, 409–431.

Sénéchal, M. (2006). Testing the home literacy model: Parent involvement in kindergarten is differentially related to Grade 4 reading comprehension, fluency, spelling and reading for pleasure. *Scientific Studies of Reading*, *10*, 59–87.

Sénéchal, M., & LeFevre, J. (2002). Parental involvement in the development of children's reading skill: A five-year longitudinal study. *Child Development*, *73*, 445–460.

Sénéchal, M., LeFevre, J., Thomas, E. M., & Daley, K. E. (1998). Differential effects of home literacy experiences on the development of oral and written language. *Reading Research Quarterly*, *33*, 96–116.

Silinskas, G., Leppänen, U., Aunola, K., Parrila, R., & Nurmi, J.-E. (2010). Predictors of mothers' and fathers' teaching of reading and mathematics during kindergarten and grade 1. *Learning and Instruction*, *20*, 61–71.

Silinskas, G., Lerkkanen, M. K., Tolvanen, A., Niemi, P., Poikkeus, A.-M., & Nurmi, J. E. (2012). The frequency of parents' reading – Related activities at home and children's reading skills during kindergarten and Grade 1. *Journal of Applied Developmental Psychology*, *33*, 302–310.

Silinskas, G., Parrila, R., Lerkkanen, M.-K., Poikkeus, A.-M., Niemi, P., & Nurmi, J.-E. (2010). Mothers' reading-related activities at home and learning to read during kindergarten. *European Journal of Psychology of Education*, *25*, 243–264.

Skwarchuk, S.-L. (2009). How do parents support preschoolers' numeracy learning experiences at home. *Early Childhood Educational Journal*, *37*, 189–197.

Snow, C. E. (1999). Social perspectives on the emergence of language. In B. MacWhinney (Ed.), *The emergence of language* (pp. 257–276). Mahwah, NJ: Erlbaum.

Stephenson, K., Parrila, R., Georgiou, G., & Kirby, J. (2008). Effects of home literacy parents' beliefs and children's task-focused behavior on emergent literacy and word reading skills. *Scientific Studies of Reading*, *12*, 24–50.

Stipek, D., Milburn, S., Clements, D., & Daniels, D. H. (1992). Parents' beliefs about appropriate education for young children. *Journal of Applied Developmental Psychology*, *13*, 293–310.

Stock, P., Desoete, A., & Roeyers, H. (2009). Predicting arithmetic abilities: The role of preparatory arithmetic markers and intelligence. *Journal of Psychoeducational Assessment*, *27*, 237–251.

Stylianides, A. J., & Stylianides, G. J. (2011). A type of parental involvement with an isomorphic effect on urban children's mathematics, reading science and social studies achievement at kindergarten entry. *Urban Education*, *46*, 408–425.

Sylva, K., Chan, L. L. S., Melhuish, E., Sammons, P., Siraj-Blatchford, I., & Taggart, B. (2010). Emergent literacy environments: Home and preschool influences on children's literacy development. In S. B. Neuman, & D. K. Dickinson (Eds.), *Handbook of early literacy research* (Vol. 3) (pp. 97–117). New York, NY: Guilford Press.

Sylva, K., & Roberts, F. (2010). Quality in early childhood education: Evidence for long term effects. In G. Pugh, & B. Duffy (Eds.), *Contemporary issues in the early years* (pp. 47–62). London, UK: Sage Publications.

Tafa, E. (2011). (*Reading and writing in preschool education*) *Anagnosi kai grafi stin prosxoliki ekpaidefsi*. Athens, Greece: Pedio.

Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (1999). *TOWRE: Test of word reading efficiency*. Austin, TX: PRO-ED.

Torppa, M., Poikkeus, A.-M., Laakso, M.-L., Tolvanen, A., Leskinen, E., Leppänen, P. H. T., et al. (2007). Modeling the early paths of phonological awareness and factors supporting its development in children with and without familial risk of dyslexia. *Scientific Studies of Reading*, *11*, 73–103.

Tracey, D. H., & Young, J. W. (2002). Mothers' helping behaviors during children's at-home oral-reading practice: Effects of children's reading ability, children's gender and mothers' educational level. *Journal of Educational Psychology*, *94*, 729–737.

Tudge, J. R. H., & Doucet, F. (2004). Early mathematical experiences: Observing young black and white children's everyday activities. *Early Childhood Research Quarterly*, *19*, 21–39.

Umek, L. M., Podlesek, A., & Fekonja, U. (2005). Assessing the home literacy environment: Relationship to child language comprehension and exression. *European Journal of Psychological Assessment*, *21*, 271–281.

van Otterloo, S. G., van der Leij, A., & Henrichs, L. F. (2008). Early home-based intervention in the Netherlands for children at familial risk of dyslexia. *Dyslexia*, *15*, 187–217.

Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1999). *Comprehensive test of phonological processing*. Austin, TX: PRO-ED.

Wallach, L., Wallach, M. A., Dozier, M. G., & Kaplan, N. E. (1977). Poor children learning to read do not have trouble with auditory discrimination but do have trouble with phoneme recognition. *Journal of Educational Psychology*, *69*, 36–39.

Walley, A. C., Metsala, J. L., & Garlock, V. M. (2003). Spoken vocabulary growth: Its role in the development of phoneme awareness and early reading ability. *Reading and Writing: An Interdisciplinary Journal*, *16*, 5–20.

Warner, R. M. (2012). *Applied statistics* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Weigel, D., Martin, S. S., & Bennett, K. K. (2006). Contributions of the home literacy environment to preschool-aged children's emerging literacy and language skills. *Early Child Development and Care*, *176*, 357–378.

Whitehurst, G. L., & Lonigan, C. J. (1998). Child development and emergent literacy. *Child Development*, *69*, 848–872.

Yeung, W. J., Linver, M. R., & Brooks-Gunn, J. (2002). How money matters for young children's development: Parental investment and family processes. *Child Development*, *73*, 1861–1879.