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# Formal and informal home learning activities in relation to children's early numeracy and literacy skills: The development of a home numeracy model



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### ABSTRACT

The purpose of this study was to propose and test a model of children's home numeracy experience based on Sénéchal and LeFevre's home literacy model (*Child Development*, 73 (2002) 445–460). Parents of 183 children starting kindergarten in the fall (median child age = 58 months) completed an early home learning experiences questionnaire. Most of the children whose parents completed the questionnaire were recruited for numeracy and literacy testing 1 year later (along with 32 children from the inner city). Confirmatory factor analyses were used to reduce survey items, and hierarchical regression analyses were used to predict the relation among parents' attitudes, academic expectations for their children, reports of formal and informal numeracy, and literacy home practices on children's test scores. Parental reports of formal home numeracy practices (e.g., practicing simple sums) predicted children's symbolic number system knowledge, whereas reports of informal exposure to games with numerical content (measured indirectly through parents' knowledge of children's games) predicted children's non-symbolic arithmetic, as did numeracy attitudes (e.g., parents' enjoyment of numeracy). The home literacy results replicated past findings; parental reports of formal literacy practices (e.g., helping their children to read words) predicted children's word reading, whereas reports of informal experiences (i.e., frequency of shared reading measured indirectly through parents' storybook knowledge) predicted children's vocabulary.

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These findings support a multifaceted model of children's early numeracy environment, with different types of early home experiences (formal and informal) predicting different numeracy outcomes.

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## Introduction

Large-scale longitudinal studies have shown that children's early literacy and numeracy skills are strong predictors of academic success (Aunio & Niemivirta, 2010; Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Claessens, Duncan, & Engel, 2009; Duncan et al., 2007; LeFevre, Fast, et al., 2010; Melhuish et al., 2008). Children who start school with poor knowledge and skills in literacy (Hooper, Roberts, Sideris, Burchinal, & Zeisel, 2010) and numeracy (Jordan, Kaplan, Locuniak, & Ramineni, 2007) are unlikely to catch up to their peers. Individual differences in literacy and numeracy skills are evident at school entry—prior to formal instruction—suggesting that children acquire fundamental skills at home or in child care. Thus, in the current study, we examined children's home experiences as predictors of academic outcomes. Our goal was to adapt the home literacy model proposed by Sénéchal and LeFevre (2002) to describe children's home numeracy experiences and link those experiences to early numeracy outcomes.

### *Home learning activities and children's academic outcomes*

Researchers have found relations between the general quality of the home environment and children's social and academic outcomes (cf. Bakermans-Kranenburg, van IJzendoorn, & Bradley, 2005; Melhuish et al., 2008). Although the specific home experiences that predict early literacy have been explored in great depth (e.g., Evans, Shaw, & Bell, 2000; Scarborough & Dobrich, 1994; Sénéchal & LeFevre, 2002), fewer studies are available on the early experiences relevant for numeracy acquisition (cf. Blevins-Knabe, 2008).

### *Home activities and children's literacy outcomes*

In the home literacy model proposed by Sénéchal and LeFevre (2002; see also Sénéchal, 2006; Sénéchal & LeFevre, 2001; Sénéchal, LeFevre, Hudson, & Lawson, 1996; Sénéchal, LeFevre, Thomas, & Daley, 1998), two distinct pathways link children's experiences to their acquisition of early literacy skills. In one pathway, children's exposure to shared reading with parents, known as informal experiences, correlates with vocabulary knowledge (Sénéchal, 2006; Sénéchal & LeFevre, 2002) and are indirectly associated (via a mediating association with vocabulary) with reading ability in Grade 2 (Hood, Conlon, & Andrews, 2008), Grade 3 (Sénéchal & LeFevre, 2002), and Grade 4 (Sénéchal, 2006). In the second pathway, direct or formal literacy experiences, as indexed by parents' reports of teaching-specific early literacy skills (e.g., letter recognition, word reading), predicted kindergarten children's alphabet knowledge (Sénéchal, 2006) and word reading in all early school grades (Hood et al., 2008; Sénéchal, 2006; Sénéchal & LeFevre, 2002). Critically, these pathways are uncorrelated (Sénéchal, 2006; Sénéchal & LeFevre, 2002). The home literacy model has been supported by many studies (e.g., Evans & Shaw, 2008; Reynolds, Wheldall, & Madeline, 2011; Rodriguez & Tamis-LaMonda, 2011; Slavin, Lake, Davis, & Madden, 2011). In the current study, the home literacy model was adopted as the framework for a home numeracy model. We assessed both formal and informal home numeracy activities and examined whether these two types of practices differentially predicted children's early numeracy outcomes.

### *Home activities and children's numeracy outcomes*

In comparison with research on home literacy, evidence linking children's early numeracy learning to home experiences is more recent and less thorough—and, as a result, is less conclusive. Inconsistent results may indicate that researchers have not developed a clear distinction between informal and formal activities (also known as indirect and direct; LeFevre et al., 2009) that are related to numeracy (see

also [LeFevre, Polyzoi, Skwarchuk, Fast, & Sowinski, 2010](#)). Based on existing work on both literacy and numeracy environments, we define formal numeracy activities as shared experiences in which parents directly and intentionally teach their children about numbers, quantity, or arithmetic to enhance numeracy knowledge. In contrast, informal numeracy activities are those shared activities for which teaching about numbers, quantity, or arithmetic is not the purpose of the activity but may occur incidentally (e.g., playing number board games; measurement activities required in cooking, carpentry, or crafts; quantity comparisons; spatial processing).

*Formal numeracy activities.* Some researchers have found associations between formal home numeracy activities and children's early math skills. In a 4-year longitudinal study, [Huntsinger and colleagues \(Huntsinger, Jose, & Larson, 1998; Huntsinger, Jose, Larson, Balsink Krieg, & Shaligram, 2000\)](#) found that Chinese American parents reported greater frequencies of formal numeracy activities than European American parents and that Chinese American children outperformed European American children on mathematics achievement measures. Notably, however, parents' reports of formal numeracy practices predicted children's math scores in both the Chinese American and European American groups. [Huntsinger, Jose, Liaw, and Ching \(1997\)](#) found that the link between culture and children's math achievement scores was mediated by formal home numeracy practices. Taken together, these findings identify formal home numeracy practices as an important predictor of early math outcomes. [Huntsinger and colleagues distinguished between formal and informal numeracy practices, but they rated all of the practices on a continuum and calculated a mean "formality" score rather than examining formal and informal practices separately.](#)

In contrast to the findings of [Huntsinger and colleagues](#), some studies have failed to find relations between parents' reports of formal home numeracy practices and young children's mathematical knowledge ([Blevins-Knabe, Berghout Austin, Musun, Eddy, & Jones, 2000; LeFevre et al., 2009](#)). The lack of any explicit model may have been a limitation for these studies in terms of guiding survey question selection or the choice of suitable outcome measures to assess formal experiences. Consistent with this view, using a refined survey instrument, [LeFevre, Polyzoi, and colleagues \(2010\)](#) found that higher frequencies of formal home numeracy practices (e.g., teaching simple sums) uniquely predicted symbolic number knowledge (e.g., digit recognition) in both Canadian and Greek 5-year-old children. [Kleemans, Peeters, Segers, and Verhoeven \(2012\)](#) found that parents' reports of practicing a variety of numeracy skills at home were related to children's numeracy skills in kindergarten. [LeFevre, Clarke, and Stringer \(2002\)](#) also found that parents' reports of formal teaching of numeracy predicted children's digit naming and counting abilities. In sum, although some researchers have failed to find links between formal numeracy practices and children's early numeracy performance, there is also evidence to support this link.

*Informal numeracy activities.* Informal home numeracy activities (e.g., number game play, cooking) are situations in which a child may learn about number or quantity. In these activities, parents may present activities that are within the child's zone of proximal development, thereby allowing the child to engage in more sophisticated numerical activities than he or she could alone (e.g., [Anderson, 1997; Bjorklund, Hubertz, & Reubens, 2004; Saxe, Guberman, & Gearhart, 1987; Vandermaas-Peeler, Boomgarden, Finn, & Pittard, 2012](#)). During these interactions, various discussions about numbers, quantity, and concepts may arise (e.g., counting, talking about quantity, naming shapes; [Anderson, 1997; Bjorklund et al., 2004; Skwarchuk, 2009; Vandermaas-Peeler et al., 2012](#)). However, the informal home numeracy studies mentioned above tended to focus on the type of math content and the quality of the interactions rather than focusing on the frequency of activities or on which informal numeracy activities predicted numeracy outcomes.

Some research has examined the frequency of informal numeracy activities as predictors of children's outcomes. [LeFevre and colleagues \(2009\)](#) examined parents' reports of the frequency of informal home numeracy practices in relation to children's math outcomes and found that frequency of shared game play was predictive of children's math knowledge and arithmetic fluency for children in kindergarten, Grade 1, or Grade 2. In contrast, [LeFevre, Polyzoi, and colleagues \(2010\)](#) found no relations between parents' reports of informal home numeracy practices and kindergarten children's

symbolic numeracy knowledge for either Greek or Canadian children. In the latter study, however, calculation fluency was not assessed.

Some evidence for links between informal numeracy activities and numerical outcomes comes from intervention research. In [Peters \(1998\)](#), 5-year-olds played number games in small groups with parents (not their own). Compared with the control group, children who played number games showed greater improvement in counting, enumeration, and making collections. In [Young-Loveridge \(2004\)](#), 23 5-year-olds participated in a 7-week intervention. Pairs of children were read number storybooks and then played number games for 30 min each day; these children performed significantly better on counting, digit recognition, and addition with objects in comparison with children who engaged in other activities. Although these differences diminished during the 15 months post-intervention, the groups remained significantly different.

Other intervention work has involved the use of board games. [Siegler and Ramani \(2008, 2009\)](#); see also [Ramani, Siegler, & Hitti, 2012](#)) conducted intervention studies in which disadvantaged American children played a linear number board game. Experience with the number board game led to higher scores on various mathematical tasks (magnitude comparison, counting, number recognition, and number-to-position line task) compared with controls who played a color board game (see also [Whyte & Bull, 2008](#)). Evidence from these game intervention studies suggests that playing number games may provide children with experiences that enhance numeracy ability. Note, however, that although the context of the game playing was informal, the intent was to model and support children's numeracy skills. Thus, the studies might not be directly comparable to the informal activities taking place in homes where there might not be any intentions on the part of caregivers to enhance numeracy knowledge.

#### *Parent characteristics*

In the current study, we also assessed parent attitudes toward mathematics and literacy and their academic expectations as potential predictors of the frequencies of home practices (informal vs. formal) in these domains. Previous work has shown that, on average, parents personally report higher levels of enjoyment for literacy versus mathematics activities ([Skwarchuk, 2009](#)), which may account for their preference to establish literacy over numeracy goals with their children ([Blevins-Knabe & Musun-Miller, 1998](#)); however, the reasons for this bias are not well documented or clearly understood. Parents who have higher expectations for their children's academic skills before starting Grade 1 usually report more frequent formal literacy and numeracy practices ([LeFevre et al., 2002](#); [LeFevre, Polyzoi, et al., 2010](#); [Martini & Sénéchal, 2012](#); cf. [Kleemans et al., 2012](#)). [Martini and Sénéchal \(2012\)](#) reported that parents' academic expectations and children's interests in letters were directly related to children's emergent reading and letter knowledge even after controlling for formal literacy practices. [LeFevre, Polyzoi, and colleagues \(2010\)](#) found a similar pattern for early numeracy outcomes, whereas [LeFevre and colleagues \(2002\)](#) found that formal numeracy practices mediated the link between expectations and outcomes. Thus, inclusion of parents' academic expectations may be relevant for understanding the general home literacy and numeracy context. We hypothesized that parents with positive attitudes and higher academic expectations would engage in more home literacy and numeracy activities.

#### *The current research*

To summarize, researchers have linked formal numeracy activities and children's mathematics outcomes, and there is some evidence that informal activities (e.g., games) contribute to children's numeracy development, but no attempts have been made to examine the two pathways simultaneously. In fact, some researchers have purposely or inadvertently combined formal and informal practices in the same measure, which may be problematic if the two types of numeracy practices are distinguishable and differentially predictive of math outcomes. Thus, we assessed both informal and formal home numeracy experiences and examined them as predictors of two numeracy outcomes: non-symbolic arithmetic and symbolic number knowledge. We also assessed the frequencies of informal and formal home literacy activities as predictors of children's vocabulary and early reading skills. Parent factors related to home learning practices (i.e., academic expectations and attitudes)

were also measured. This parallel design allowed us to examine independent effects in addition to any potential relations among (a) parents' literacy and numeracy attitudes, (b) frequencies of home literacy and numeracy activities, and (c) parents' attitudes and academic expectations as predictors of their practices and of children's outcomes. The design ultimately enabled us to test a proposed home numeracy model with informal and formal home numeracy pathways as predictors of non-symbolic arithmetic and symbolic number knowledge. We simultaneously tested the home literacy model so as to provide a direct comparison.

Two control measures were used in the research. Visual spatial working memory (VSWM) skills (i.e., the ability to track, hold, and recall a visual pattern) were assessed and used as a control measure in the numeracy analyses. Phonological awareness abilities (i.e., the ability to detect sounds in spoken words) were included as a control measure in the literacy analyses. Both of these variables have been shown in previous work to be precursors of skills development in their respective domains (VSWM and number skills: [LeFevre, Fast, et al., 2010](#); [Rasmussen & Bisanz, 2005](#); [Rasmussen, Ho, & Bisanz, 2003](#); phonological awareness and literacy skills: [Hatcher & Hulme, 1999](#); [Høien, Lundberg, Stanovich, & Bjaalid, 1995](#); [Rohl & Pratt, 1995](#)); by controlling them, we hoped to understand the impact of home environment independent of these variables.

Consistent with previous research, parents were hypothesized to have more positive attitudes (in terms of personal enjoyment and experience) toward literacy activities than toward numeracy activities ([Skwarchuk, 2009](#)). Parents were also expected to report more literacy than numeracy activities given the societal emphasis on home literacy and comparative lack of emphasis on home numeracy ([Blevins-Knabe, 2008](#)). These variables were included so that we could test the hypothesis that parents' attitudes and academic expectations would predict home learning practices. We assumed that parent practices would have a direct effect on children's learning, whereas their attitudes and expectations would have an indirect effect. Hence, we expected relations between parents' attitudes and expectations and children's literacy and numeracy outcomes to be mediated by parents' practices (i.e., even if a parent thinks a skill is important, the child is not expected to learn it unless the parent reports teaching it to him or her). Specifically, informal literacy practices were expected to uniquely predict children's vocabulary but not their letter knowledge. Formal literacy practices were expected to uniquely predict children's letter knowledge but not their vocabulary. These predictions are based on findings from past research.

In [Sénéchal and LeFevre's \(2002\)](#) model, parents' knowledge of storybook titles (performance on a checklist with real and fake titles) was the measure of informal home literacy practices. Parents' storybook title knowledge is assumed to be an indirect measure of shared reading that avoids the social desirability biases inherent in simply asking parents how often they read to their children. It is also assumed to tap informal literacy experiences because parents are assumed to read to children for many purposes (e.g., it is pleasurable, it is a quiet bedtime activity, it provides an environment that invites discussion of many topics) and literacy instruction is not a central feature of the activity for most parents. To provide a comparable assessment for informal numeracy experiences, we developed a number game title checklist (see [Appendix A](#)) as our informal home numeracy practices measure; parents' number game knowledge is assumed to be an index of shared number game play. Experience with number games may help children to gain understanding of counting and quantity manipulation without requiring explicit knowledge of the symbolic number system. For example, children must count objects (e.g., squares on the game board, game pieces, dots on dice) to play games such as Snakes and Ladders, Hi-Ho Cherry O, and Trouble, but most of the games involve little or no knowledge of the symbolic system. Thus, we hypothesized that shared number game play (i.e., informal home numeracy experience) would uniquely predict children's abilities to represent and manipulate quantities (measured with a non-symbolic arithmetic task) but not their symbolic number knowledge. Finally, consistent with the informal literacy assessment (i.e., storybook knowledge), parents presumably choose to play games with their children for many reasons, but numeracy practice is probably not the main one.

As a measure of formal home literacy experiences, [Sénéchal and LeFevre \(2002\)](#) asked parents how frequently they taught their children to read and print words. Analogously, we asked parents about the frequencies of parent-initiated activities involving numbers and quantities as a measure of formal numeracy experiences. We hypothesized that formal numeracy practices would uniquely predict

children's knowledge of the number system but not their non-symbolic arithmetic performance. Thus, an important difference between formal and informal activities is that for formal activities parents' goal is assumed, at least in part, to ensure that children learn early academic skills. For informal activities, parents' primary goal in choosing the activity is enjoyment or entertainment rather than skill development.

## Method

### *Participants*

#### *Recruitment*

During the spring and summer of 2008, parents of children ( $N = 183$ ) starting kindergarten in the fall completed a questionnaire; recruitment was done through child care facilities, preschools, playgroups, early learning home visit programs, and a citywide wellness fair. The families recruited represented all but the central geographic region of a moderately large city located in the prairie region of Canada. A prize draw was an incentive for participation.

One year later, parents were contacted again and consent was obtained to complete literacy and numeracy assessments on their children. To improve the geographic representation of the study, an additional sample of 32 families was invited from the urban core (an area known to be affected by poverty) at the same time that follow-up testing was conducted with the initial group. Parents of the newly recruited children completed the home questionnaire within weeks of their children's academic skills being assessed.

Parents were told that the study would examine their academic expectations, their literacy and numeracy attitudes, and home practices before their children started school. With this design, reports of home activities by most parents, therefore, could reflect only their expectations and beliefs about appropriate early academic activities rather than occurring as a response to their children's school work or teachers' recommendations. Kindergarten-age children were selected because they had recently begun formal schooling; thus, the impact of home learning activities might be easier to detect than that in older children who had received more formal schooling. We also assumed that the effects of early experiences would start to be measurable with the academic assessments roughly a year after parents' reports and would continue into the school years, following the trajectories outlined in other research (e.g., [Huntsinger et al., 1998](#); [LeFevre et al., 2009](#); [Sénéchal, 2006](#)).

Of the total participating parent–child dyads ( $N = 132$ ), 11 were excluded from analyses because 5 parents and 4 children had incomplete data and 2 parent questionnaires were completed by people other than parents (grandmother and foster guardian), leading to a final sample of 121. Children were offered a prize at the end of the assessment, and parents received a \$10 honorarium.

#### *Final sample*

Children (54.5% males) were tested between March and June 2009. When tested, children ranged in age from 5:3 (years:months) to 6:5 ( $Mdn = 5:10$ ). Responding parents (104 mothers and 17 fathers) ranged in age from 22 to 52 years ( $M = 35.5$  years,  $SD = 5.7$ ). English was spoken in 96% of homes. Filipino/Tagalog was spoken in one home, German was spoken in one other home, and 2 parents did not respond to this question. In addition, 2% of parents reported high school education, 98% reported college certificate, college diploma, or university education, and 1 parent did respond to this question. Finally, 22 parents (18%) reported qualifying for subsidized child care, and 12% of parents did not respond to this question.

### *Measures*

#### *Parent questionnaire*

Parents completed a seven-page survey in paper or electronic format (via the Web survey tool SurveyMonkey). This questionnaire asked parents about their academic expectations, literacy and numeracy attitudes, and formal and informal literacy and numeracy practices (see details below).

**Academic expectations.** To assess parents' academic expectations for their children's early literacy and numeracy performance, parents indicated the importance (1 = *unimportant* to 5 = *extremely important*) that children achieve 13 literacy and numeracy benchmarks before they start Grade 1 (e.g., "read a few words," "count to 100"; see [Appendix B](#)). Some items were extremely advanced for children of this age (e.g., "read chapter books," "count to 1000") to minimize response biases (e.g., selecting extremely important ratings for all benchmarks).

**Literacy and numeracy attitudes.** Parents rated their agreement/disagreement (1 = *strongly disagree* to 5 = *strongly agree*) with two statements ("I find math/writing enjoyable" and "I avoid situations involving math/writing"); these statements were designed to tap their overall feelings or attitudes toward literacy and numeracy.

**Formal home literacy and numeracy practices.** We developed a list of 28 home learning activities that were appropriate for the age group and the home context. Four activities lacking specific literacy or numeracy content were included in this measure to reduce its academic focus; these activities were not included in analyses (i.e., "My child plays computer games that involve numbers/letters," "I encourage my child to pretend while playing," "I ask my child to answer a question very quickly," and "We time how fast an activity can be completed"). Parents indicated how frequently they engaged in each literacy and numeracy activity (for specific items, see [Tables 1 and 2](#)); these items were taken as measures of parents' formal home literacy and numeracy practices (see details below).

**Informal home literacy practices (storybook exposure).** As was done in past research, parents were asked to indicate their familiarity with children's storybook titles as measure of informal home literacy practices ([Sénéchal & LeFevre, 2002, 1996, 1998](#)). For this study, a list of 18 storybook titles and 6 plausible but nonexistent titles were selected from a longer list of 40 titles and 20 foils used by [Sénéchal, Pagan, Lever, and Ouellette \(2008\)](#). A shorter list was developed to minimize the amount of time that parents would need to complete the various assessments and so that the length of the title checklist would be similar to that of the games checklist (see details below). Because parents rarely check foils, the relative proportion of foils to real titles does not influence the scores (M. Sénéchal, personal communication, December 2012). These 18 items were chosen because they had the highest correlations with the expressive vocabulary measure in [Sénéchal and colleagues \(2008\)](#). English-speaking parents'

**Table 1**

Descriptive statistics and rotated factor loadings for home numeracy practices.

| Item   | Mean | SD  | PCA 1 component loadings |     | PCA 2 component loadings |     |
|--|------|-----|--------------------------|-----|--------------------------|-----|
|  |      |     | 1                        | 2   | 1                        | 2   |
| I help my child learn simple sums (e.g., 2 + 2)                  | 2.1  | 1.3 | .82                      | .05 | .82                      | .05 |
| I encourage my child to do math in his/her head                  | 1.7  | 1.5 | .77                      | .21 | .78                      | .22 |
| We talk about time with clocks and calendars                     | 2.3  | 1.2 | .68                      | .13 | .69                      | .09 |
| I help my child weigh, measure, and compare quantities           | 1.1  | 1.0 | .59                      | .30 | .63                      | .30 |
| We play games that involve counting, adding, or subtracting      | 2.2  | 1.1 | .58                      | .57 |                          |     |
| I teach my child to recognize printed numbers                    | 2.9  | 1.1 | .50                      | .59 |                          |     |
| We sort and classify by color, shape, and size                   | 2.3  | 1.3 | .46                      | .62 |                          |     |
| I ask about quantities (e.g., How many spoons?)                  | 2.6  | 1.3 | .45                      | .60 |                          |     |
| We play board games or cards                                     | 2.2  | 1.0 | .28                      | .65 | .30                      | .66 |
| I encourage collecting (e.g. cards, stamps, rocks)               | 1.7  | 1.5 | .22                      | .64 | .27                      | .66 |
| I help my child to recite numbers in order                       | 2.8  | 1.0 | .13                      | .67 | .16                      | .69 |
| We sing counting songs (e.g., Five Little Monkeys)               | 2.2  | 1.3 | -.08                     | .80 | -.06                     | .81 |
| I encourage the use of fingers to indicate how many <sup>a</sup> | 2.6  | 1.3 |                          |     |                          |     |

Note. PCA, principal component analysis (1 = advanced formal numeracy; 2 = basic formal numeracy). Parents were asked, "How often do you do the following activities with your child?" Response options were *rarely or never* (0), *monthly* (1), *weekly* (2), *several days per week* (3), and *most days per week* (4). The range of responses on all items was 0 to 4.

<sup>a</sup> This item was not included in the PCA or the numeracy activity mean.

**Table 2**  
Descriptive statistics and rotated factor loadings for home literacy practices.

| Item  | Mean | SD  | PCA 1 component loadings   |     | PCA 2 component loadings |     |
|---|------|-----|----------------------------|-----|--------------------------|-----|
|   |      |     | 1                          | 2   | 1                        | 2   |
|   |      |     | I help my child read words | 2.6 | 1.3                      | .89 |
| I ask my child to point to words/letters when we read   | 2.3  | 1.3 | .84                        | .14 | .89                      | .21 |
| I teach my child to recognize printed letters           | 2.9  | 1.1 | .59                        | .57 |                          |     |
| I help my child to print words                          | 2.6  | 1.3 | .55                        | .49 |                          |     |
| We identify words on signs(e.g., Stop, Exit)            | 2.6  | 1.2 | .56                        | .51 |                          |     |
| I teach my child the sounds of letters                  | 2.8  | 1.0 | .46                        | .68 |                          |     |
| I introduce new words and their definitions to my child | 2.7  | 1.2 | .23                        | .74 | .24                      | .72 |
| I help my child to sing/recite the alphabet             | 2.6  | 1.2 | .14                        | .65 | .15                      | .73 |
| We make up rhymes in songs(e.g., Down by the Bay)       | 2.3  | 1.2 | .10                        | .73 | .11                      | .78 |
| I ask questions when we read together <sup>a</sup>      | 3.1  | 1.0 |                            |     |                          |     |
| We visit the library for children's books <sup>a</sup>  | 0.9  | 0.8 |                            |     |                          |     |

Note. PCA, principal components analysis (1 = advanced formal literacy; 2 = basic formal literacy). Parents were asked, "How often do you do the following activities with your child?" Response options were *rarely or never* (0), *monthly* (1), *weekly* (2), *several days per week* (3), and *most days per week* (4). The range of responses on all items was from 0 to 4.

<sup>a</sup> These items were not included in the PCAs.

( $n = 84$ ) performance on the 18-title version was correlated with children's (4-year-olds) expressive vocabulary scores at .27 ( $p < .05$ ) (Sénéchal et al., 2008). Titles appeared alphabetically, and parents were told that some were popular storybook titles and others were made up. Parents were asked to check the boxes beside titles that they recognized without guessing or verifying responses with books in their home. To correct the checklist performance for guessing, the number of foils selected was subtracted from the number of storybook titles selected, divided by the total number of actual books (18), and then multiplied by 100 (e.g., if 9 titles and 1 foil were checked, the score would be  $[(9 - 1)/18] \times 100 = 44\%$ ). The foils were selected infrequently (the median was 0), suggesting that few parents guessed when filling out this checklist. The observed split-half reliability was .93. Scores were standardized and saved as z-scores for use in further analyses.

*Informal home numeracy practices (number game exposure).* A number game checklist was developed as a measure of informal home numeracy practices. To develop the game checklist, the second author visited local department stores (e.g., Zellers, Walmart) to gather information about commercially available games suitable for children between 3 and 6 years of age. Games were categorized according to whether or not they included numerical components (counting, adding, and recognizing numbers). The game list consisted of 25 game titles: 10 numerical games, 10 non-numerical games, and 5 plausible but nonexistent games (see Appendix A). Game titles were presented alphabetically; parents were informed that some titles were popular children's games and others were made up. Parents were asked to check the boxes beside the games titles that they recognized without guessing or verifying their responses with games in their home. To calculate a number game score, the total of correctly checked number games was corrected for guessing in the same way that the storybook title checklist was corrected (e.g., If 6 number games and 1 foil were checked, this was scored as  $[(6 - 1)/10] \times 100 = 50\%$ ). The median number of foils selected was 0, suggesting that parents did not guess when filling out this checklist. The observed split-half reliability was .88. Standardized scores (z-scores) were created for further analyses. Two extreme scores ( $>|3|$ ) were made less extreme by reducing them to 3.

#### Median income

Median family income was estimated by postal code using the 2006 Canadian census data; estimated incomes ranged from \$28,135 to \$145,472, with a median income of \$69,282 (Statistics Canada, n.d.). In this study, special effort was made to obtain children from all geographic areas of the city representing diverse home situations. Consequently, the range of income was diverse but



not uncharacteristic of other North American city populations. In past research, correlations have been found between household income and children's learning outcomes (Bradley, Corwyn, Burchinal, McAdoo, & Coll, 2001); thus, we included this variable as a control in the current study.<sup>1</sup>

### *Child assessments*

Children completed the assessment in their home, in a child care center, or at a university. According to their preference, parents either stayed with their children or left the room. Children completed the assessments in the following order: (a) vocabulary, (b) symbolic number knowledge, (c) non-symbolic arithmetic, (d) finger recognition, (e) letter word reading, (f) rapid automatized naming of letters and quantities, (g) phonological awareness, (h) nonverbal reasoning, (i) visual–spatial working memory, and (j) processing speed. The measures of finger recognition, rapid automatized naming, nonverbal reasoning, and processing speed are not included in the current study and are not further discussed. The entire assessment length ranged from 45 to 60 min, and breaks were encouraged in between tests when children seemed fatigued. Due to the young age of the children, the time length for the standardized tests was short because children often reached the criterion for stopping the test quickly.

*Control measures.* Two measures were collected as control and validation variables. Phonological awareness is a well-known correlate of early literacy skill, so it should account for variance in letter recognition and reduce individual differences (Alloway et al., 2005; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997; Whitehurst & Lonigan, 1998). Phonological awareness is not usually correlated with home literacy experiences, however, so it should not mediate the relations between home literacy experiences and literacy outcomes (e.g., Sénéchal & LeFevre, 2002). The visual–spatial span task, in contrast, is consistently associated with early numeracy skill (Bull, Espy, & Wiebe, 2008; LeFevre, Fast, et al., 2010; Rasmussen & Bisanz, 2005). Thus, it should correlate with the numeracy outcomes. The home numeracy experiences that we assessed, however, should not affect visual–spatial span performance, and so it was not expected to mediate the relation between home experiences and numeracy outcomes. Finally, phonological awareness was not expected to predict numeracy outcomes, nor was visual–spatial span expected to correlate with literacy outcomes.

Phonological awareness was assessed with the Sound Matching subtest of the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999). In this task, children were given a target word (the word was spoken and a picture was shown) and asked to choose a picture from a set of three pictures that either started with the same sound (Items 1–10) or ended with the same sound (Items 11–20). Feedback was given for the first three trials of each type (starting and ending sounds); testing ceased once children were incorrect on 4 of 7 items. The reported internal consistency for this subtest is  $\geq .90$ .

For the visual–spatial working memory task, children viewed a computer screen with nine “lily pads” (i.e., green circles) and watched “Hoppy” the frog jump from one lily pad to the next in a pseudo-random order. Children were then asked to copy Hoppy's path using a pointer. There was one demonstration trial, followed by two trials each of sequences of two, three, four, five, and six locations. Children continued the task until they finished all trials or made errors on both trials of the same sequence length. Performance is the number of sequences correctly reproduced (maximum = 12). Mean performance was substituted for one case with missing data. The observed split-half reliability for this measure was .74.

*Numeracy outcomes.* The non-symbolic arithmetic measure was adapted from Huttenlocher, Jordan, and Levine (1994; Levine, Jordan, & Huttenlocher, 1992; see also LeFevre, Fast, et al., 2010). Children

<sup>1</sup> We also considered using maternal education as a proxy measure of socioeconomic status in the analyses because it is a common control variable. However, we were concerned that our measure of maternal education was not valid because many parents indicated that they had graduate degrees. Many families were recruited from the inner city, and so we were concerned that not all parents fully understood the question and/or the response options. Furthermore, although education was correlated with some outcomes, including it in the regressions did not significantly change the pattern of results, nor did it uniquely predict variability in any of the outcomes. Given these patterns, median income was retained as the measure of socioeconomic status.

were familiarized with a toy barn and toy animals. The experimenter and children each had their own sets of animals and mats to place animals on while responding or demonstrating. During two practice trials, children were asked to match what the experimenter did by setting out the same number of animals; feedback was given to ensure comprehension. For addition trials, the experimenter moved some animals into the barn and then added some more; for subtraction trials, the experimenter placed animals in the barn and then removed some. The barn obstructed children's view of the animals inside. Once the experimenter had finished moving animals, children were asked to show how many animals were in the barn. There were two matching trials (2 and 5; not scored), four addition trials (1 + 2, 3 + 1, 2 + 3, and 4 + 2), and four subtraction trials (3 - 1, 4 - 3, 5 - 2, and 6 - 4) in total, completed in the same order for all children. Subtraction trials were omitted if the child was unsuccessful on all addition trials. Performance is total correct. The observed split-half reliability for this measure was .89.

Symbolic number knowledge was assessed by the Numeration subtest of KeyMath-Revised (Connolly, 2000). For kindergarten children, the test includes questions involving counting, ordinal numbers, number identification, and magnitude. Testing was terminated once a child produced three consecutive errors. Performance is total correct. In the test manual, split-half reliabilities are reported as .70 for kindergarten children during the spring period.

*Literacy outcomes.* To assess receptive vocabulary, children completed a modified administration of the Peabody Picture Vocabulary Test—Third Edition (PPVT-III; Dunn & Dunn, 1997). The PPVT is a frequently used standardized measure with a reported internal reliability of .94. For each trial, a word is presented verbally, the child sees four pictures, and the child is asked to identify the target word. Children started the test on Item 61 (no basal established) and continued to Item 120 or until they made eight or more errors per set. This revised administration reduced testing time to less than 10 min per child. Number correct was used as the index of performance.

The Letter Word subtest of the Woodcock-Johnson Tests of Achievement-Revised (WJ-R; Woodcock & Johnson, 1989) was used as a measure of letter and word reading performance. Children first attempted to identify single letters followed by single words. Testing was terminated when a child made six consecutive errors.

## Results

### *Data reduction*

#### *Academic expectations*

Of the 13 academic expectations items, 7 had almost no variability and, thus, were removed from analyses ("count to 10," "know some alphabet letters," "know all 26 alphabet letters," and "print name" were rated as extremely important to know by Grade 1; "read chapter books," "count to 1000," and "know multiplying" were rated as unimportant). Means, standard deviations, and ranges for these items are shown in Appendix B. The observed internal reliability (Cronbach's  $\alpha$ ) was .89 for the remaining 6 items; the academic expectations mean is calculated using these items (see Table 3). A principal component analysis (PCA) extracted one factor accounting for 65% of the variance in academic expectations.

#### *Literacy and numeracy attitudes*

Parents tended to *neither agree nor disagree* (0) to *agree* (1) that they found writing ( $M = 0.52$ ,  $SD = 1.10$ ) and math ( $M = 0.63$ ,  $SD = 1.21$ ) to be enjoyable; they also tended to *disagree* (1) to *neither agree nor disagree* (0) that they avoided situations involving writing ( $M = 0.92$ ,  $SD = 0.96$ ) and math ( $M = 0.67$ ,  $SD = 1.25$ ). As a means of dimension reduction, two PCAs were conducted: one for literacy attitudes and one for numeracy attitudes. In each case, one component was extracted, accounting for 62% of the variance in literacy attitudes (component loadings were .81) and 65% of the variance in numeracy attitudes (component loadings were .79). The mean score for literacy and numeracy attitudes was used in one case with missing data.

**Table 3**  
Correlations among the predictor and outcome measures.

|                                      | 1      | 2                | 3     | 4    | 5                | 6                | 7                | 8                | 9                 | 10                | 11   | 12   | 13   | 14   | 15   | 16   | 17   | 18  |  |
|--------------------------------------|--------|------------------|-------|------|------------------|------------------|------------------|------------------|-------------------|-------------------|------|------|------|------|------|------|------|-----|--|
| 1 Median income                      |        |                  |       |      |                  |                  |                  |                  |                   |                   |      |      |      |      |      |      |      |     |  |
| 2 Child age                          | -.14   |                  |       |      |                  |                  |                  |                  |                   |                   |      |      |      |      |      |      |      |     |  |
| 3 Child gender                       | .13    | -.13             |       |      |                  |                  |                  |                  |                   |                   |      |      |      |      |      |      |      |     |  |
| 4 Phonological awareness             | .29*   | .24*             | .21*  |      |                  |                  |                  |                  |                   |                   |      |      |      |      |      |      |      |     |  |
| 5 Visual-spatial working memory      | -.02   | .12              | .03   | .28* |                  |                  |                  |                  |                   |                   |      |      |      |      |      |      |      |     |  |
| 6 Academic expectations              | .04    | .13              | .04   | .20* | .16 <sup>†</sup> |                  |                  |                  |                   |                   |      |      |      |      |      |      |      |     |  |
| 7 Literacy attitudes                 | .14    | -.12             | .00   | -.03 | -.07             | .03              |                  |                  |                   |                   |      |      |      |      |      |      |      |     |  |
| 8 Numeracy attitudes                 | .20*   | .15              | -.08  | .22* | .19*             | .04              | -.09             |                  |                   |                   |      |      |      |      |      |      |      |     |  |
| 9 Informal literacy (book exposure)  | .34*   | .04              | .06   | .20* | -.06             | -.08             | .20*             | .11              |                   |                   |      |      |      |      |      |      |      |     |  |
| 10 Informal numeracy (game exposure) | .23*   | -.04             | -.10  | .05  | .23*             | .12              | .06              | .04              | .46*              |                   |      |      |      |      |      |      |      |     |  |
| 11 Basic formal literacy             | .20*   | .05              | .08   | .22* | .03              | .11              | .21*             | -.04             | .04               | .05               |      |      |      |      |      |      |      |     |  |
| 12 Advanced formal literacy          | -.13   | .23*             | .08   | .09  | .08              | .38*             | -.01             | -.06             | .04               | -.14              | .00  |      |      |      |      |      |      |     |  |
| 13 Basic formal numeracy             | .10    | .04              | .10   | .10  | .13              | .21*             | .12              | .04              | .02               | .10               | .66* | .14  |      |      |      |      |      |     |  |
| 14 Advanced formal numeracy          | .06    | .21*             | .02   | .21* | .00              | .36*             | -.19*            | .09              | .01               | -.03              | .23* | .42* | .00  |      |      |      |      |     |  |
| 15 Vocabulary                        | .40*   | .21*             | -.07  | .46* | .04              | .05              | .01              | .20*             | .33*              | .13               | .11  | .12  | -.07 | .25* |      |      |      |     |  |
| 16 Letter word reading               | .18*   | .17 <sup>†</sup> | .06   | .57* | .07              | .17 <sup>†</sup> | -.11             | .27*             | .17 <sup>†</sup>  | .01               | -.01 | .27* | -.06 | .31* | .52* |      |      |     |  |
| 17 Non-symbolic arithmetic           | .30*   | .16 <sup>†</sup> | -.04  | .46* | .31*             | .07              | -.04             | .30*             | .29*              | .30*              | .00  | .07  | -.03 | .14  | .42* | .51* |      |     |  |
| 18 Symbolic number knowledge         | .20*   | .25*             | -.22* | .40* | .20*             | .12              | -.12             | .32*             | .01               | .12               | .01  | .04  | -.08 | .27* | .39* | .51* | .54* |     |  |
| Mean                                 | 70 256 | 70               | 1.4   | 11.3 | 3.9              | 3.6 <sup>a</sup> | .72 <sup>a</sup> | .65 <sup>a</sup> | 37.9 <sup>a</sup> | 62.1 <sup>a</sup> | 0    | 0    | 0    | 0    | 92.1 | 18.0 | 6.5  | 6.2 |  |
| SD                                   | 20 887 | 3.3              | .5    | 5.4  | 1.8              | .9 <sup>a</sup>  | .80 <sup>a</sup> | 1.0 <sup>a</sup> | 27.2 <sup>a</sup> | 19.7 <sup>a</sup> | 1    | 1    | 1    | 1    | 12.3 | 6.6  | 3.0  | 1.9 |  |

Note.  $N = 121$  for all correlations except for those including non-symbolic arithmetic, where  $N = 120$ . Correlations with an asterisk (\*) were significant at  $p < .05$ ; correlations with a dagger (†) were significant at  $p \leq .08$ . Child age is in months. Median income is in Canadian dollars. Child gender: 1 = female; 2 = male.

<sup>a</sup> Descriptive statistics are the raw scores before standardized and component scores were computed.

### Home learning activities

Descriptive statistics for home numeracy and literacy activities are presented in Tables 1 and 2. Two extremely skewed items were removed (“We visit the library for children’s books” occurred infrequently; “I ask questions when we read together” occurred very frequently). The list of home learning experiences was designed to include a range of formal and informal literacy and numeracy activities; therefore, PCAs were conducted to reduce data and examine whether items grouped together as expected.

*Formal home numeracy practices.* An initial PCA with an orthogonal rotation (varimax) resulted in two components accounting for 56% of the variance in numeracy practices (see Table 1 for rotated factor loadings). Unfortunately, 4 of the 12 items had substantial loadings on both components. These 4 items were removed, and a second PCA was conducted with an orthogonal rotation (varimax), resulting in two components that accounted for 56% of the variance in numeracy practices. Component 1 was named *advanced formal numeracy* because the more advanced formal activities, such as directly teaching children numeracy arithmetic, loaded highly on this component. Component 2 was named *basic formal numeracy* because the items loading on this component included simple numerical activities such as counting and reciting numbers. Regression factor scores were saved to create two uncorrelated variables (i.e., advanced and basic formal numeracy practices).

*Formal home literacy practices.* A PCA with an orthogonal rotation (varimax) produced two components accounting for 62% of the variance in literacy practices (see Table 2 for rotated factor loadings). Unfortunately, 4 of the 9 items had substantial loadings on both components; therefore, the PCA was conducted again with these items removed. The second PCA (varimax rotation) resulted in two components accounting for 69% of the variance in literacy practices. Component 1 was named *advanced formal literacy* because more advanced formal activities, such as teaching children to read words, loaded highly on this component. Component 2 was named *basic formal literacy* because the items loading highly on this component were the simpler literacy activities such as making up rhymes and reciting the alphabet. Regression factor scores were saved, creating two uncorrelated variables (i.e., advanced and basic formal literacy practices) as potential predictors of literacy outcomes.

### Comparisons across literacy and numeracy attitudes and practices

Parents’ literacy attitudes were slightly more positive ( $M = 0.72$ ,  $SD = 0.80$ ) than their numeracy attitudes ( $M = 0.65$ ,  $SD = 1.00$ ), but this difference was not significant,  $t(120) = 0.64$ ; thus, our hypothesis that parents would have more positive attitudes toward literacy than toward numeracy was not supported. Mean frequencies were calculated for literacy and numeracy practices using the same items included in the final PCAs (see Tables 1 and 2 for items). The hypothesis that parents would report more frequent engagement in literacy practices ( $M = 2.50$ ,  $SD = 0.89$ ) than in numeracy practices ( $M = 2.00$ ,  $SD = 0.77$ ) was supported,  $t(119) = 8.97$ ,  $p < .001$ .

### Correlations

Table 3 contains the correlations, raw means, and standard deviations among all variables and composite scores. Consistent with past research (Bradley et al., 2001; Melhuish et al., 2008), median income was correlated with literacy and numeracy variables such as phonological awareness, vocabulary, symbolic number knowledge, non-symbolic arithmetic, informal literacy practices (storybook exposure), and informal numeracy practices (number game exposure). Parents’ academic expectations were correlated with advanced formal literacy and numeracy practices but not with basic formal literacy and numeracy practices. Thus, parents with higher expectations were more likely to engage in advanced formal learning practices; this finding is consistent with past results (LeFevre et al., 2002; LeFevre, Polyzoi, et al., 2010; Martini & Sénéchal, 2012). Parents’ academic expectations were weakly correlated with word reading but not with other outcomes.

Parents’ literacy attitudes were related to basic formal literacy practices and informal literacy practices. In contrast, parents’ numeracy attitudes were correlated with children’s numeracy outcomes but

not with their practices; this finding is consistent with research by LeFevre, Polyzoi, and colleagues (2010). Parents' basic formal literacy and numeracy practices were strongly correlated; advanced formal literacy and formal numeracy practices were moderately correlated.

Informal literacy practices were correlated with vocabulary but not word reading, whereas advanced formal literacy practices were correlated with word reading but not vocabulary (replicating Sénéchal & LeFevre, 2002). Informal numeracy practices were correlated with non-symbolic arithmetic but not symbolic number knowledge; informal numeracy practices also were correlated with vocabulary scores. In contrast, advanced formal numeracy practices were correlated with symbolic number knowledge (replicating LeFevre, Polyzoi, et al., 2010). The pattern of correlations supports the view that literacy and numeracy experiences have differential relations with outcomes despite high correlations among outcomes.

### Regression analyses

#### Home environment

Multiple regression analyses were conducted to test our hypotheses that parents' attitudes and academic expectations would predict their literacy and numeracy activities (while controlling for income and age) (see Table 4). As hypothesized, parents' academic expectations uniquely predicted basic and advanced formal numeracy; parents' expectations also predicted advanced formal literacy practices. In sum, as parents' expectations increased, so did frequencies of advanced formal home learning activities. As hypothesized, parents' literacy attitudes predicted informal and basic formal literacy practices. In contrast, numeracy attitudes did not predict any aspects of home numeracy practices. The significant pathways are summarized in Fig. 1.

#### Children's performance

Four hierarchical regressions were used to predict numeracy (non-symbolic arithmetic and symbolic number knowledge) and literacy (vocabulary and letter word reading) outcomes. Basic formal numeracy and literacy factors were uncorrelated with children's outcomes and, thus, were excluded from these analyses. Literacy-specific predictors were used to predict literacy outcomes, whereas numeracy-specific predictors were used to predict numeracy outcomes. Thus, phonological awareness was controlled for in regressions predicting literacy outcomes (Sénéchal & LeFevre, 2002), and visual-spatial attention was controlled for in numeracy outcome regressions (LeFevre, Fast, et al., 2010). Advanced formal literacy practices and informal literacy experiences (i.e., storybook exposure) were compared as predictors of literacy outcomes; advanced formal numeracy practices and informal numeracy experiences (i.e., number game exposure) were compared as predictors of numeracy outcomes.

**Table 4**

Standardized coefficients for the regression analyses of parent attitudes and practices.

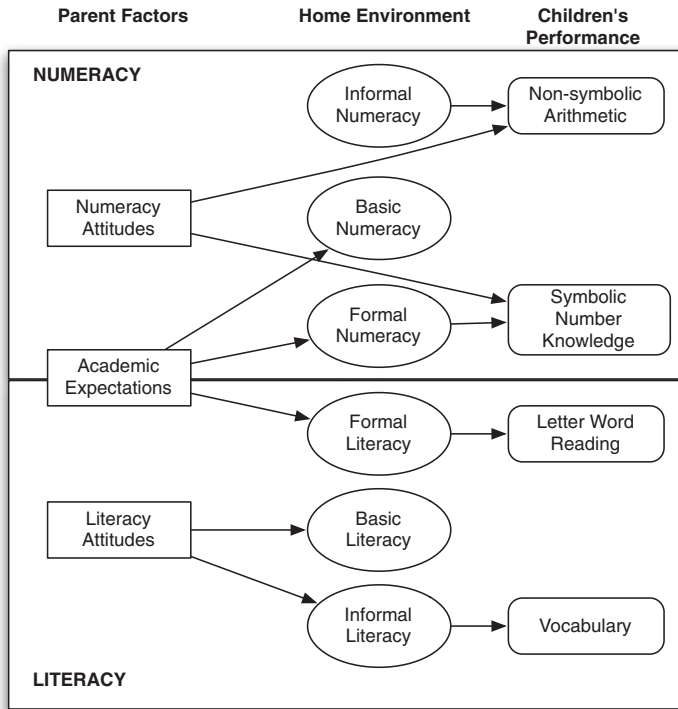
| Domain   | Outcome                                  | Predictors |           |           |                       | Model $R^2$ |
|----------|--|------------|-----------|-----------|-----------------------|-------------|
|          |  | Income     | Child age | Attitudes | Academic expectations |             |
| Numeracy | Basic formal numeracy                    | .09        | .03       | .01       | .20*                  | .05         |
|          | Advanced formal numeracy                 | .06        | .17*      | .04       | .34**                 | .17**       |
|          | Informal numeracy (number game exposure) | .22*       | -.02      | .00       | .12                   | .07         |
| Literacy | Basic formal literacy                    | .18*       | .09       | .19*      | .09                   | .09*        |
|          | Advanced formal literacy                 | -.13       | .17*      | .01       | .36**                 | .19**       |
|          | Informal literacy (storybook exposure)   | .34**      | .12       | .17†      | -.11                  | .17**       |

Note. The attitude composite variables are domain specific. The other predictor variables are the same across all analyses.  $N = 121$ .

\*\*  $p \leq .01$ .

\*  $p \leq .05$ .

†  $p = .06$ .



**Fig. 1.** Home numeracy and home literacy models summarizing relations among parents' attitudes and expectations, home environment variables, and numeracy and literacy outcomes in kindergarten. Note that the pathways shown are those significant in the regression analyses. Informal numeracy was measured with the number game checklist, and informal literacy was measured with the storybook checklist.

Predictor variables were entered in a similar order for each regression: control variables in Step 1, parents' academic expectations and attitudes in Step 2, and home learning experiences in Steps 3 and 4. For Steps 1 and 2, variables were included in the regression analysis only if they were significantly correlated with the outcome. However, the two home learning experiences were always entered as potential predictors of the associated (literacy or numeracy) outcomes so that their relative contributions could be assessed. In summary, the goal was to test whether advanced formal versus informal numeracy and literacy practices were differentially related to children's outcomes.

**Numeracy.** Table 5 shows results from regression analyses predicting non-symbolic arithmetic and symbolic number knowledge. The block of control variables that included median income, child age, and visual-spatial attention accounted for significant variance in non-symbolic arithmetic; median income and visual-spatial attention were significant unique predictors in the final model. In Step 2, parents' numeracy attitudes accounted for additional variance in non-symbolic arithmetic, predicting unique variability in the final model. As hypothesized, informal numeracy practices (i.e., number game exposure) predicted non-symbolic arithmetic, but advanced formal numeracy practices did not. The bottom of Table 5 contains results from the regression analysis predicting symbolic number knowledge. The block containing control variables accounted for significant variance; median income and child gender remained significant in the final model. Parents' numeracy attitudes predicted symbolic number skills in Step 2 and remained a significant predictor in the final model. As hypothesized, advanced formal numeracy practices predicted symbolic number knowledge, but informal practices did not (Steps 3 and 4). We hypothesized that parents' attitudes would predict parents' practices but not children's outcomes; this hypothesis was not fully supported because parents' numeracy

**Table 5**  
Hierarchical regression analysis of numeracy outcomes.

| Block                            | Predictor  | Hierarchical model |       |          |                     |
|----------------------------------|--|--------------------|-------|----------|---------------------|
|                                  |  | $\Delta R^2$       | $R^2$ | F change | Final model $\beta$ |
| <i>Non-symbolic arithmetic</i>   |  |                    |       |          |                     |
| Step 1                           | Median income                                      |                    |       |          | .23**               |
|                                  | Child age  |                    |       |          | .13                 |
|                                  | Spatial attention                                  |                    |       |          | .22*                |
|                                  | Control variables                                  | .22**              | .22** | 10.7**   |                     |
| Step 2                           | Numeracy attitudes                                 | .02†               | .24** | 3.7†     | .17*                |
| Step 3                           | Advanced formal numeracy practices                 | .00                | .25** | <1.0     | .07                 |
| Step 4                           | Informal numeracy practices (number game exposure) | .04*               | .28** | 5.8*     | .20*                |
| <i>Symbolic number knowledge</i> |  |                    |       |          |                     |
| Step 1                           | Median income                                      |                    |       |          | .19*                |
|                                  | Child gender                                       |                    |       |          | -.21†               |
|                                  | Child age  |                    |       |          | .16†                |
|                                  | Spatial attention                                  |                    |       |          | .14                 |
|                                  | Control variables                                  | .20**              | .20** | 7.1**    |                     |
| Step 2                           | Numeracy attitudes                                 | .04**              | .23*  | 5.3**    | .19*                |
| Step 3                           | Informal numeracy practices (number game exposure) | .00                | .23*  | <1.0     | .04                 |
| Step 4                           | Advanced formal numeracy practices                 | .04*               | .27** | 6.5**    | .21*                |

\*\*  $p \leq .01$ .\*  $p \leq .05$ .†  $p = .07$ .**Table 6**  
Hierarchical regression analysis of literacy outcomes.

| Block                      | Predictor  | Hierarchical model |       |          |                     |
|----------------------------|--|--------------------|-------|----------|---------------------|
|                            |  | $\Delta R^2$       | $R^2$ | F change | Final model $\beta$ |
| <i>Letter word reading</i> |  |                    |       |          |                     |
| Step 1                     | Median income                                    |                    |       |          | .04                 |
|                            | Child age  |                    |       |          | .00                 |
|                            | Phonological awareness                           |                    |       |          | .53**               |
|                            | Control variables                                | .32**              | .32** | 18.5**   |                     |
| Step 2                     | Academic expectations                            | .00                | .32** | <1.0     | -.02                |
| Step 3                     | Informal literacy practices (storybook exposure) | .00                | .33** | <1.0     | .04                 |
| Step 4                     | Advanced formal literacy practices               | .04**              | .37** | 8.1**    | .24**               |
| <i>Vocabulary</i>          |  |                    |       |          |                     |
| Step 1                     | Median income                                    |                    |       |          | .29**               |
|                            | Child age  |                    |       |          | .15†                |
|                            | Phonological awareness                           |                    |       |          | .30**               |
|                            | Control variables                                | .32**              | .32** | 18.5**   |                     |
| Step 2                     | Advanced formal literacy practices               | .01                | .33** | <1.0     | .09                 |
| Step 3                     | Informal literacy practices (storybook exposure) | .02*               | .35** | 3.9*     | .16*                |

\*\*  $p \leq .01$ .\*  $p \leq .05$ .†  $p \leq .07$ .

attitudes directly predicted children's numerical outcomes. The home numeracy model is summarized in Fig. 1.

**Literacy.** Table 6 contains the results from regression analyses predicting literacy outcomes. As hypothesized, and consistent with the home literacy model (Sénéchal & LeFevre, 2002), advanced formal literacy practices predicted letter word reading, whereas informal experiences did not. Informal literacy practices uniquely predicted vocabulary, but advanced formal literacy practices did not, consistent with our hypothesis and with results presented by Sénéchal and colleagues.

## Discussion

### *Home numeracy model*

The most important goal of the current research was to extend the home literacy model to create a model of the relations between home numeracy experiences and children's early numeracy skills. Fig. 1 presents a proposed home numeracy model based on the observed relations among parent characteristics, home numeracy activities, and children's numerical outcomes. We found evidence for two home numeracy pathways; in each pathway, specific home numeracy practices predict specific numeracy outcomes. Formal home numeracy practices (e.g., teaching about arithmetic) accounted for unique variance in children's symbolic number knowledge but did not predict children's non-symbolic arithmetic performance. In contrast, informal home numeracy practices (i.e., children's exposure to numeracy-related content in games) accounted for unique variance in children's non-symbolic arithmetic performance but did not predict children's symbolic number system knowledge. This pattern of results is consistent with predictions and supports the proposed home numeracy model. We also hypothesized that parent characteristics (i.e., academic expectations and attitudes) would predict their numeracy practices but not children's outcomes. Parents' academic expectations predicted their formal numeracy practices, as hypothesized (LeFevre et al., 2002). However, parents' numeracy attitudes did not predict home numeracy practices but did uniquely predict children's numeracy outcomes (non-symbolic arithmetic and number system knowledge). These findings suggest that further work is necessary to understand the relations among parents' beliefs and attitudes toward numeracy, the nature of the home numeracy environment, and children's early numeracy skills.

Previous research (Blevins-Knabe & Musun-Miller, 1998; Huntsinger et al., 1998; Huntsinger et al., 2000; LeFevre et al., 2002, 2009; LeFevre, Polyzoï, et al., 2010; Kleemans et al., 2012) supported the link between children's home numeracy experiences and their numeracy performance. In the current study, parents' reports of directly teaching relatively advanced numeracy skills predicted children's symbolic number knowledge, replicating the findings reported by LeFevre, Polyzoï, and colleagues (2010) with separate groups of Canadian and Greek children. In contrast, LeFevre and colleagues (2009) found that basic numeracy activities (e.g., playing number-related games, sorting, collections) predicted symbolic number knowledge; however, in that study, parents were not asked about advanced numeracy activities, children were older (in kindergarten and Grades 1 and 2), and home numeracy accounts were retrospective. Both advanced and basic factors predicted children's arithmetic fluency in that study. Blevins-Knabe and colleagues' (2000) work also showed no relation between home practices and mathematical knowledge, but many children in the sample were under 5 years of age and may have been too young to acquire accurate symbolic number knowledge assessments. In sum, the current research supports the view that home numeracy practices are related to children's numeracy outcomes; the lack of evidence for this link in some other research may be attributable to the limitations of those studies. The current research provides a clear framework for future research by suggesting which kinds of home number experiences relate to specific numerical outcomes.

### *Home literacy model*

The bottom of Fig. 1 summarizes observed relations among parent characteristics, home literacy practices, and children's literacy outcomes. Sénéchal and LeFevre (2002) proposed a model of children's early literacy development in which different home experiences predicted different outcomes. Consistent with many other studies over the past 10 years, the results of the current study support the home literacy model (e.g., Evans & Shaw, 2008; Reynolds et al., 2011). The frequency of formal literacy practices predicted children's letter word reading even when controlling for phonological awareness and median income; the 4% of variance accounted for is the same as the 4% in Sénéchal and LeFevre's (2002) study with children at the end of kindergarten. In contrast, informal literacy practices—that is, shared storybook exposure—predicted children's vocabulary skills, although the effect size was smaller than those reported in other studies (2% vs. 9% in Sénéchal & LeFevre, 2002). In the current study, storybook exposure was examined as a unique predictor of vocabulary while controlling for median



income; the smaller effect size is in part attributable to the variance shared by storybook exposure and median income. In addition, the modification of the vocabulary test may have resulted in a less sensitive measure.

We also predicted that parents' attitudes toward literacy would influence home literacy experiences and, thus, would be indirectly linked to children's performance. As hypothesized, parent characteristics (attitudes toward literacy and academic expectations) predicted their literacy practices but did not directly predict children's outcomes. In contrast, [Martini and Sénéchal \(2012\)](#) found that parents' expectations were directly related to children's alphabet knowledge and emergent reading skill (i.e., reading single words). As for numeracy, further work is needed to examine the relations among parents' attitudes and beliefs, practices, and children's literacy performance.

### *Comparing home numeracy and literacy*

The inclusion of parallel variables allowed us to directly compare literacy and numeracy factors. Contrary to our expectations, parents did not report more positive attitudes toward literacy than toward numeracy. This finding is inconsistent with some past research. When asked to rate the importance of acquiring skills in preschool, parents rated reading skills as more important than numeracy skills ([Musun-Miller and Blevins-Knabe, 1998](#)). However, relative importance is a different index of attitudes than parents' own feelings and experiences regarding numeracy and literacy. In future work, it may be useful to address all of these facets of parents' attitudes. As such, future work will be important to determine why differences between parental attitudes toward literacy and numeracy exist and whether those attitudes are changing with the advent of new technology and encouraged involvement in science, technology, engineering, and mathematics (STEM) disciplines.

We did find support for our prediction that parents would report more home literacy than home numeracy practices. This finding is consistent with a societal bias in North America such that a higher importance is placed on literacy and shared reading than on numeracy and related activities ([Blevins-Knabe, 2008](#)). Given the small amount of research linking specific home numeracy practices to children's numerical outcomes, parents may receive little evidence-based information as to what constitutes appropriate home numeracy practices.

The similarities between the home literacy and home numeracy models are evident in [Fig. 1](#). Parents' academic expectations predicted both formal literacy and numeracy practices, suggesting that parents act in line with their beliefs. Parents who think that it is important for children to be able to count to 100, read printed numbers, print alphabet letters, and read a few words by Grade 1 reported more engagement in formal learning activities than parents who thought that these skills were less important. In contrast, parents' expectations did not predict informal practices. The expectation items are focused on academic abilities rather than on the importance of other skills (e.g., story comprehension, quantity concepts) that might relate more closely to informal activities. One difference between the models is that academic expectations predicted basic numeracy practices but did not predict parents' basic literacy practices. This differential pattern may have occurred because parents have a sense for the literacy practices that prepare their children for school-based literacy; in comparison, parents presumably know little about appropriate numeracy practices and, therefore, may provide both basic and advanced formal numeracy practices in relation to their concerns about children's early knowledge. The relations between parents' attitudes and other variables also differ in the two models. Parents' literacy attitudes predicted informal literacy (shared storybook exposure) and basic formal literacy practices but not children's outcomes; in contrast, parents' numeracy attitudes did not predict home numeracy practices but did predict children's outcomes. Why might this be? One possibility is that parents' numeracy attitudes may manifest in other kinds of numeracy-relevant experiences that support children's numeracy skills that were not tapped by the current assessments. Additional work characterizing home numeracy activities more broadly will help to address these issues.

### *Implications*

The current research suggests that there are specific activities reported by parents that are linked to children's numeracy knowledge, whereas other activities might not be related (at least initially) to

numeracy development. It is possible that across development, these pathways mediate or affect other mathematical developments (much as vocabulary mediated Grade 3 reading development in the home literacy model; Sénéchal, 2006; Sénéchal & LeFevre, 2002; see also LeFevre, Fast, et al., 2010). Activities with an intentional focus on number knowledge and mathematical computations afford children the opportunity to practice school-based mathematics that rely on knowledge of the symbolic number system, potentially providing a foundation for later school-based mathematical learning. Furthermore, LeFevre, Fast, and colleagues (2010) showed that for kindergarten children a quantitative composite variable that included the same non-symbolic arithmetic task used in the current study was predictive of calculation and number system knowledge 2 years later. Thus, both formal and informal home experiences are important in children's mathematical development. Activities involving applied aspects of mathematics (e.g., cooking, measuring, sorting) may become relevant to the development of number-related vocabulary knowledge, quantitative awareness abilities, and cognitive development in general.

It is noteworthy that the home literacy model that has emerged as the result of more than a decade of research can be extended in predicted ways to a similar model for home numeracy. More generally, the results of this study coincide with the large body of developmental research supporting early exposure and intervention in areas such as literacy to facilitate learning and development. Basic formal numeracy practices were more frequently reported than advanced formal practices and, thus, tend to be activities shared across families. We also observed that advanced (but not basic) formal numeracy practices accounted for individual differences in numeracy outcomes, but more research (particularly intervention research) is necessary before specific recommendations can be made. It is important to note that the ability of children to benefit from more advanced formal activities may depend on their mastery of the basic skills. For example, learning the number words, learning how to count small numbers of objects, and recognizing printed numbers are all requisite skills for arithmetic. Thus, we posit that both basic and advanced numeracy practices (as described in the current study) are relevant and necessary activities for children's early numeracy development.

We recommend that parents and educators consider children's numeracy development (especially before the onset of formalized schooling) and seek opportunities to introduce early numeracy concepts in intellectually stimulating and developmentally appropriate ways. In the past, a societal emphasis on early literacy skills has led to successful public awareness campaigns to increase home literacy practices and effective early literacy interventions. Our understanding of early numeracy development may benefit from similar public awareness campaigns and intervention research.

### *Limitations and future directions*

The current study has five limitations. First, it is important to use other methods of data collection to confirm and replicate the home numeracy model. Controlled intervention studies and observational methods would enhance the conclusions drawn from the current survey-based correlational approach. These latter methods are focused on the quantity of early numeracy exposure, and they might not capture the quality of the parent–child interactions in the home numeracy experience that are relevant to numeracy learning. Related to this limitation, it would be important to delineate the kinds and levels of broad involvement that are required to establish a learning foundation (in numeracy, literacy, music development, and otherwise). For example, from the existing research base, it is difficult to determine how often and how involved parents become in playing number board games with their children even though this measure did predict children's non-symbolic arithmetic performance. A third study limitation is that despite a concerted attempt to recruit both mothers and fathers in this project, findings include the input of only 17 fathers. Without larger samples of mothers and fathers who both complete the survey, it is impossible to determine the relative contribution of numeracy inputs by each parent in the home milieu. Future research is needed to expand on ways to enhance the participation of fathers in research projects. Fourth, this study was completed before portable media players and tablet computers became available in North America, and although our questionnaire included home practices involving screen time (use of video games accessed via television, computer, or the internet), the popularity of these devices may have changed the ways in which children and families access literacy and numeracy information at home and should be included in future research. Finally, although

we collected parents' reports of their beliefs and their home learning practices prior to collecting children's performance, this study is more cross-sectional than longitudinal. Extrapolating from the longitudinal research findings in literacy, a natural next step will involve determining how the home numeracy model applies beyond the start of school.

## Conclusion

In the current research, we extended the home literacy model (Sénéchal & LeFevre, 2002) to early numeracy. Parents' reports of informal numeracy exposure via shared game playing predicted non-symbolic numeracy abilities, whereas parental reports of advanced formalized numeracy exposure predicted symbolic numeracy skills that are common in standardized tests and Grade 1 curricula. These uncorrelated pathways suggest a distinction between parents' home activities—between the direct teachings of numeracy concepts and general enrichment activities that relate to different numeracy competencies in young children. We anticipate that this framework will help to clarify the differential reporting of early experiences described in previous work, provide clarification on the relevant home experiences affecting early learning, and enhance models for developing effective programs of intervention. Future work should continue to investigate the validity of this framework, using different methodological paradigms, to determine the longitudinal scope of the home numeracy model.

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## Appendix A

**Table 7**

Percentage of parents who checked each of the games on the games checklist (ordered alphabetically).

| Game                        | %  | Game   | %  |
|-----------------------------|----|--|----|
| <i>1 2 3 Parakeet</i>       | 3  | <b>Hi Ho Cherry-O</b>                            | 32 |
| <i>Adding Armadillos</i>    | 2  | <b>Hungry Hungry Hippos</b>                      | 85 |
| Bouncin' Tigger             | 9  | <b>Insey Winsey Spider</b>                       | 10 |
| Candy Land                  | 89 | Monkey Madness                                   | 17 |
| <b>Cariboo</b>              | 48 | <b>Monopoly Junior</b>                           | 81 |
| Crocodile Dentist           | 34 | Mr. Bucket                                       | 30 |
| <b>Dominoes</b>             | 81 | Operation  | 90 |
| Elefun                      | 45 | Perfection                                       | 67 |
| <i>Exasperation</i>         | 6  | <i>Picking Peppers</i>                           | 2  |
| <i>Forage in the Forest</i> | 2  | Scrabble Junior                                  | 80 |
| <b>Go Diego Go 123 Game</b> | 39 | <b>Snakes &amp; Ladders/Chutes &amp; Ladders</b> | 92 |
| <b>Go Fish Card Game</b>    | 92 | <b>Trouble</b>                                   | 85 |
| Guess Who                   | 62 |  |    |

*Note.* Number games are in bold; foils are in italics. Instructions were as follows: "Below you will see a list of games for preschoolers. Some of these are popular children's games, and some are made up. Please read the names and put a check next to those games that you know to be real games. Do not guess, but only check those you know. Please answer without stopping to verify any games in your home."

## Appendix B

**Table 8**

Academic expectations measure.

| Item  | N   | Range   |         | Mean | SD   |
|---|-----|---------|---------|------|------|
|   |     | Minimum | Maximum |      |      |
| <b>Numeracy</b>                             |     |         |         |      |      |
| Count to 10                                 | 120 | 3       | 5       | 4.73 | 0.59 |
| Count to 100 <sup>a</sup>                   | 121 | 1       | 5       | 3.58 | 1.11 |
| Read printed numbers up to 100 <sup>a</sup> | 121 | 1       | 5       | 3.20 | 1.14 |
| Know simple sums (e.g., 2 + 2) <sup>a</sup> | 121 | 1       | 5       | 3.56 | 1.23 |
| Count to 1000                               | 119 | 1       | 5       | 2.08 | 0.96 |
| Know multiplying (e.g., 2 × 6)              | 120 | 1       | 5       | 1.90 | 1.00 |
| <b>Literacy</b>                             |     |         |         |      |      |
| Know some alphabet letters                  | 121 | 3       | 5       | 4.66 | 0.65 |
| Print his/her name                          | 121 | 3       | 5       | 4.59 | 0.66 |
| Know all 26 alphabet letters                | 121 | 2       | 5       | 4.45 | 0.86 |
| Print all 26 alphabet letters <sup>a</sup>  | 121 | 2       | 5       | 4.08 | 1.01 |
| Read a few words <sup>a</sup>               | 121 | 1       | 5       | 3.61 | 1.13 |
| Read simple picture books <sup>a</sup>      | 121 | 1       | 5       | 3.54 | 1.22 |
| Read chapter books                          | 121 | 1       | 5       | 1.72 | 0.93 |

Note. Parents were asked, "How important is it for your child to achieve each of the following benchmarks before starting Grade 1?" Response options were as follows: *unimportant* (1), *neither important nor unimportant* (2), *important* (3), *very important* (4), and *extremely important* (5).

<sup>a</sup> These items were used in the factor score.

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