

Home Numeracy Experiences and Children's Math Performance in the Early School Years

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Children's numerical competence in kindergarten is highly predictive of their acquisition of mathematics in Grade 1 and Grade 2, suggesting that experiences at home before schooling are important in understanding how numeracy develops. In this study, the mathematical skills of 146 children in Kindergarten, Grade 1, and Grade 2 were correlated with the frequency with which parents reported informal activities that have quantitative components such as board and card games, shopping, or cooking. Effect sizes were consistent with research relating home literacy experiences to children's vocabulary. The present research supports claims about the importance of home experiences in children's acquisition of mathematics.

Keywords: early numeracy, parent involvement, home experiences, preschoolers

Does early exposure to quantitative activities provide a foundation for children's acquisition of mathematics? Recent longitudinal studies show that children's numeracy skills in kindergarten, before they have had much formal instruction, are highly predictive of their performance at the end of Grades 1 and 2 (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Desoete & Grégoire, 2007; Jordan, Kaplan, Locuniak, & Ramineni, 2007). Such research strongly suggests that children's experiences at home or preschool form the foundation for mathematical learning in school. However,

few studies have examined the relations between parents' reports of specific home experiences and children's mathematical learning (cf. Blevins-Knabe, Berghout, Musun-Miller, Eddy, & Jones, 2000; Blevins-Knabe & Musun-Miller, 1996). The goal of the present research was to test whether the frequency of various home numeracy experiences, as reported by parents, is related to children's mathematical knowledge.

Decades of research on home literacy experiences and children's acquisition of literacy have resulted in strong recommendations for home practice (reviewed by Scarborough & Dobrich, 1994 and more recently by Fletcher & Reese, 2005). For example, research has shown that children's exposure to shared book reading is related to receptive vocabulary whereas word-focused instruction by parents correlates with the acquisition of decoding skills (Bus, van Ijzendoorn, & Pellegrini, 1995; Evans, Shaw, & Bell, 2000; Sénéchal, 2006; Sénéchal & LeFevre, 2001, 2002; Sénéchal, LeFevre, Thomas, & Daley, 1998). Sénéchal and LeFevre (2002) developed a model implicating the importance of both indirect experiences (i.e., storybook reading) and direct practices (i.e., teaching about word reading) on children's language and literacy development.

In comparison, the field of children's early numeracy and mathematics development is much less developed and documentation of the specific experiences through which mathematical knowledge is acquired outside of school is limited (Ginsburg, 1982; Song & Ginsburg, 1987). Only a few empirical studies have examined the relations between caregivers' reports of home numeracy experiences and children's math achievement in an approach similar to that in the early literacy domain; unfortunately, the results are not conclusive (Blevins-Knabe et al., 2000; Blevins-Knabe &

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Musun-Miller, 1996; Huntsinger, Jose, Larson, Balsink Krieg, & Shaligram, 2000; LeFevre, Clarke, & Stringer, 2002; Pan, Gauvain, Liu, & Cheng, 2006).

One reason for the lack of consensus across studies is that researchers have not distinguished amongst different types of home numeracy experiences. In accord with the research on early literacy, we propose that consideration of a variety of indirect and direct experiences is useful in understanding the relations between home experiences and numeracy development. On this view, direct activities are focused on numbers and typically are used by parents for the explicit purpose of developing quantitative skills (e.g., counting objects, practicing number names, printing numbers). In contrast, indirect activities are real-world tasks (e.g., playing card or board games that involve numbers, cooking, or carpentry) for which the acquisition of numeracy is likely to be incidental. The crucial distinction is that, although instruction in numeracy skills also occurs during indirect activities, this instruction is embedded in a real-world task.

The concept of numeracy as a life skill that needs to be connected to authentic activities is currently of considerable interest to educators of young children (National Mathematics Advisory Panel, 2008). As noted by Ginsburg, Lee, and Boyd (2008), children develop strong and deep knowledge of mathematics as part of their early development. The crucial task for educators is to connect that informal knowledge to the formal knowledge associated with schooling (Ginsburg et al., 2008). Broad exposure to a range of numeracy-related activities at home may be one way to facilitate those connections.

Blevins-Knabe and Musun-Miller (1996, Study 2) interviewed the parents of 49 kindergarten children on their home activities related to numeracy. Parents rated the frequency of 13 number-related activities that they observed their child doing alone (e.g., saying numbers, counting aloud), and 33 shared parent-child activities (e.g., parent teaching the child to count to 10, writing numbers, counting objects). Most of the activities involved specific number tasks, such as counting backward, discussing number values, or naming digits. The children completed a standardized test of their early numeracy knowledge. Blevins-Knabe and Musun-Miller (1996) reported eight significant correlations between home activities and the children's numeracy scores, however, four were negative (e.g., showing the child how to count more frequently was negatively correlated with the children's numeracy scores) and four were positive (e.g., the frequency of the child mentioning number facts was positively correlated with numeracy scores). All eight activities that were correlated with numeracy performance involved direct number instruction. These results suggest that there are some relations between home numeracy activities and children's early numeracy skills; however, most of the activities that parents were asked about were direct activities that were focused on number (e.g., naming numbers, counting), and thus did not address the possibility that a wider set of numeracy-related activities might relate to the children's developing quantitative skills.

In a later study, Blevins-Knabe et al. (2000, Study 3) found no significant correlations between parents' reports of home numeracy activities and children's numeracy skills. Furthermore, parents and home daycare providers reported that home numeracy activities occurred less frequently than literacy activities. Overall, the authors concluded that the frequency of home numeracy ac-

tivities was low for the children in their research and that both parents and daycare providers believed that literacy activities were more important than numeracy activities. Blevins-Knabe et al. concluded that children were exposed to very little problem-solving activity involving quantity in their home or daycare environments. One question in the present research, therefore, was whether parents report different levels of involvement in literacy versus numeracy activities (e.g., writing letters vs. writing numbers).

In contrast to the work by Blevins-Knabe and colleagues, other studies in which parents have been asked about direct instruction of number-related activities have found reliable relations between parent reports and children's skills. LeFevre et al. (2002) found that the frequency with which parents reported directly teaching their preschoolers early literacy and numeracy skills (i.e., counting, simple addition, word reading) predicted counting and number naming. Figueredo, LeFevre, and Sénéchal (2001) similarly demonstrated that parents' reported frequency of teaching simple sums predicted the numeracy skills of Kindergarten children. Huntsinger et al. (2000) found that parents' deliberate efforts to teach math in early childhood correlated with later math achievement. The results of these studies suggest parents' reports of how frequently they provided direct numeracy instruction is related to their child's math performance. However, these results say little about what other experiences or characteristics of the home numeracy environment might relate to children's quantitative skills.

In summary, existing research showing a relation between home numeracy experiences and children's acquisition of numeracy skills has been focused on activities that are specifically related to learning the basics of the number system (e.g., the count words to 10) and on parents' deliberate attempts to teach specific number knowledge (e.g., how to read and write Arabic digits). In research on home literacy, however, one of the most compelling links between home activities and reading-related outcomes is between the frequency with which parents read storybooks and their children's vocabulary development (Sénéchal & LeFevre, 2002). Storybook reading does not foster the mechanical aspects of reading directly (unless instruction in word decoding is included as a component of the shared reading activity), but it appears to be a crucial component of how children develop the language skills that help them to become good comprehenders once they have mastered decoding (Sénéchal, 2006; Sénéchal & LeFevre, 2002) and may also encourage children to enjoy and value reading as an activity (Sénéchal, 2006).

Given these considerations, in the present research we sought to explore not only activities related to specific number skills but also to assess the frequency of a variety of situations that might involve children in quantitative activities, but where the focus is not necessarily on direct learning of number skills. In this regard, we drew a parallel between storybook reading as an indirect facilitator of literacy (through its relation to vocabulary development and motivation to read) and home numeracy activities that might indirectly facilitate acquisition of numeracy knowledge through a broad exposure to numeracy content and integration of numeracy practice in real-world tasks. Examples of such indirect math activities include board or card games that involve counting, arithmetic, or number recognition; and measurement and calculation in contexts such as cooking or carpentry.

To investigate the relation between home activities and children's math performance, parents in the present study completed a self-report questionnaire on the frequency with which their child participated in a variety of activities. The list of activities chosen was based on items used in other research (Anderson, 1998; Blevins-Knabe et al., 2000; Huntsinger et al., 2000) and on observations of activities occurring in Canadian homes. We asked both about direct instruction in numeracy skills (such as counting or writing numbers) and about numeracy-related activities (such as card games and cooking).

Parental responses were analyzed in relation to their children's mathematical performance on two different types of school-related outcomes: knowledge and fluency. Knowledge refers to children's ability to, for example, recognize Arabic digits, to count, to compare quantities and so on. In contrast, fluency indexes children's ability to execute mathematical procedures or to access mathematical information quickly and efficiently (Geary, 1994; Royer, Tronsky, Chan, Jackson, & Marchant, 1999; Walczyk & Griffiths-Ross, 2006). Most standardized measures that are administered individually tap children's knowledge (in our terminology) because accuracy and not speed is the determinant of performance. Knowledge of mathematical concepts and procedures develops through both instruction and practice, whereas fluency develops mainly through practice. Thus, we hypothesized that children who have had a greater degree of exposure to mathematics in a variety of contexts will have more opportunities to practice their skills, thus improving their fluency.

Questions about home literacy activities were also included on the questionnaire, as a comparison to an existing and established body of literature. We hypothesized that parents' reports of literacy activities would not be related to children's mathematical performance. However, if parents' reports of activities reflect an orientation toward school-relevant tasks in general or to the degree of parent involvement (not specifically with math), then the frequency of letter- and number-related activities might be correlated and jointly predict math outcomes. On this view, we would identify home experiences that facilitate academic performance, more generally, but are not specific to children's developing numeracy.

Method

The data presented were collected during the first year of a longitudinal project on early numeracy development. The assessments included language skills (e.g., vocabulary), cognitive skills (e.g., spatial memory), and mathematics measures (e.g., counting, addition). The present analyses are focused on a subset of participants whose parents completed a questionnaire in the first year of the project. These data were analyzed in relation to children's knowledge about numeracy and their fluency on simple addition combinations. Vocabulary and spatial memory were included as control variables in the analyses because together they approximate IQ and thus control for children's aptitudes for learning.

Participants

A total of 258 children from two Canadian cities (City A and City B) participated. These participants included the majority (typically over 90%) of children in the classrooms that were recruited for the study. After the children's participation was

complete, a questionnaire was sent to parents. One-hundred and forty-six parents returned the questionnaires (56% participation). This participation rate for parents is very similar to that in other studies (Blevins-Knabe & Musun-Miller, 1996; Sénéchal et al., 1998). The advantage of the present research, however, is that we had information on the children regardless of whether the parents agreed to complete the questionnaire, and thus could test whether parents' participation was related to their child's skills. Comparing children whose parents returned questionnaires and those who did not indicated no differences between groups of children in age, vocabulary, spatial memory span, or math achievement. One difference was apparent, however. The rate of parental response was higher from City A than from City B (74% vs. 40%), $\chi^2(1, N = 258) = 30.5, p < .01$. Furthermore, parents reported higher levels of education in City A than City B (which corresponded to other indices of the socioeconomic conditions of the schools in the two cities); therefore, city was included as a control variable for socioeconomic status.

Respondents included 122 mothers, 12 fathers, eight parents (unspecified), two families where parents responded together, and two respondents who did not indicate their relationship to the child. The children (55% girls) were distributed across Kindergarten (47), Grade 1 (54), and Grade 2 (45). Mean age was 5:11 (years: months) for Kindergarten, 6:9 for Grade 1, and 7:9 for Grade 2.

Materials and Procedure

Parent Questionnaire

Parents completed a questionnaire that included demographic questions, questions about the frequency of involvement in home activities, and questions assessing parents' academic expectations and math attitudes (see Appendix). Preliminary analyses relating parents' math attitudes and expectations to other variables did not reveal any noteworthy findings; for brevity reasons, they are not reported. The list of home activities included 40 items compiled from a variety of sources. Parents were asked to indicate the frequency with which their child participated in the various activities using a 5-point scale (0 to 4, as shown in Table 1). The category "not applicable" was recoded as 0 before data analysis. The items included 20 numeracy-related activities, ranging from direct instruction of specific skills (e.g., printing numbers), to indirect activities involving quantitative content (e.g., playing board games with dice, measuring ingredients while cooking). The other 20 items included: direct literacy activities (e.g., identifying names and sounds of letters, $n = 3$); fine-motor skills (e.g., picking up objects, $n = 10$); and general activities unrelated to mathematics or literacy (e.g., watching TV, $n = 7$).

Child Measures

Children completed all tasks in one (40–50 min) session or two (15–30 min) sessions.

Numeracy measures. Mathematical knowledge was indexed by several measures, including three subtests of the KeyMath Test—Revised, Form B (Connolly, 2000). The KeyMath is an individually administered diagnostic math assessment that can be used with children as young as 4.5 years. The Numeration subtest assesses concepts and number system knowledge, including quan-

Table 1
Mean Reported Frequencies of Numeracy and Literacy Activities

Description	Factor loading	<i>M</i>	<i>SD</i>	<i>Mdn</i>
Letter activities				
• Printing letters	.84	3.3	1.1	4
• Identifying sounds of alphabet letters	.83	2.7	1.3	3
• Identifying names of written alphabet letters	.68	2.4	1.4	3
Numeracy activities				
(1) Number skills				
• Counting objects	.80	2.8	1.2	3
• Sort things by size, color or shape	.80	1.8	1.4	2
• Counted down (10, 9, 8, 7 . . .)	.71	1.8	1.2	2
• Printing numbers	.64	2.7	1.2	3
• Identifying names of written numbers	.63	2.1	1.4	3
(2) Number books				
• "Connect-the-dot" activities	.82	1.9	1.2	2
• Using number activity books	.70	1.7	1.3	2
• Reading number storybooks	.61	1.7	1.3	2
(3) Games				
• Playing card games	.76	2.1	1.1	2
• Making collections	.71	1.8	1.2	2
• Playing board games with die or spinner	.63	2.0	1.1	2
• Being timed	.62	1.7	1.4	1
(4) Applications				
• Having your child wear a watch	.66	1.2	1.4	1
• Measuring ingredients when cooking	.62	1.8	1.1	2
• Using calendars and dates	.60	3.0	1.1	3
• Talking about money when shopping (e.g., "which costs more?")	.60	2.4	1.1	3
• Playing with calculators	.60	1.4	1.2	1

Note. Instructions given to parents: "In the past month, how often did you and your child engage in the following activities? Circle 0 if the activity did not occur, 1 if it occurred less than once a week, but a few times a month (1–3 times), 2 if it occurred about once a week, 3 if it occurred a few times a week (2–4 times), 4 if it occurred almost daily, and NA if the activity is not applicable to your child." Not applicable responses were re-coded as 0 for the purposes of the analyses. For all items, the reported range of responses was from 0 to 4.

tity, digit recognition, place value, and order. The Addition, and Subtraction subtests start with pictures and progress to symbolic arithmetic (e.g., $2 + 1$, $4 - 2$). Reported alternate form reliability coefficients for these subtests are: Numeration, .75, Addition, .65, and Subtraction, .69 (Connolly, 2000). The KeyMath Test was chosen because administration is uncomplicated and quick (about 10 min per child), there is a relatively large range of test questions within each of the three subtests, and it has a Canadian version and Canadian norms.

The fluency measure was a test of single-digit addition. Children viewed 18 single-digit addition problems shown as Arabic digits (e.g., $2 + 1$) where the maximum sum of the problems was 12. The child sat in front of a laptop computer and pressed the spacebar to initiate each trial. Once the child spoke a response, the experimenter pressed a key on an auxiliary keyboard to stop the timer, and entered the child's response. The computer automatically terminated the task after the child made five consecutive errors. Performance was measured in terms of accuracy (i.e., number correct) and median latency on correct responses for each student.

Cognitive measures. The Peabody Picture Vocabulary Test, 3rd Edition (PPVT-III) was included as an index of receptive vocabulary (Dunn & Dunn, 1997). Children chose one picture from a set of four pictures that corresponded with a target vocabulary word. The task was terminated when children made six errors within a block of eight words. Standardized scores were used in the analyses. This measure was used as an index of verbal ability. Reported reliability coefficients for this test are greater than .90 for standardized scores for children in this age range.

Children completed a computerized measure of spatial memory span modeled after the Corsi blocks task (Berch, Krikorian, & Huha, 1998). In this task, they viewed a frog jumping in sequence from one lily pad to another (Klein & Bisanz, 2000). After watching the frog, the children indicated the sequence by pointing. The experimenter clicked on each location after the child pointed. Sequences started with two locations and increased to six locations, with two trials at each length. If a child missed both sequences of a given length, the task was terminated. The score consisted of the total number of correct sequences, with a maximum possible score of 10. This measure is an index of spatial (working) memory ability (LeFevre, DeStefano, Coleman, & Shanahan, 2005) and was used in the present research to control for children's nonverbal abilities.

Results

Parent Questionnaire

Reported Frequencies of Numeracy and Literacy Activities

Parents provided ratings of how frequently their children participated in 40 activities. The seven general activities (e.g., watching TV, playing with action figures) had been included to provide a range of options (i.e., not just activities that were related to numeracy and literacy) and so these were not analyzed further. The 10 fine-motor activities (e.g., picking up objects, buttoning buttons) showed little variability in this group of children and also were not considered further. These fine-motor activities may be relevant for younger children or for comparing typically developing children to those with specific disabilities due to the importance of fingers in early counting and addition (e.g., Barnes, Smith-Chant, & Landry, 2005; Butterworth, 2005). The remaining 23 activities pertained to numeracy or literacy, either directly (e.g., counting, printing numbers, printing letters) or indirectly (e.g., cooking, wearing a watch, playing card games). Rated frequencies were examined to determine those activities that were infrequent or not applicable in this sample. On two items, "using number or arithmetic flash cards" and "playing with number fridge magnets," most parents indicated that their children never participated in these activities (i.e., 62% and 73%, respectively) so these activities were omitted from further analysis. On another item, "learning simple sums," the rating scale was printed incorrectly, so it was excluded from the analyses, as the responses were ambiguous. The mean frequencies with which parents reported the 17 remaining numeracy activities and three literacy-related activities are shown in Table 1.

Parents reported letter-related activities, on average, one or more times per week. Similar number-related activities were re-

ported as occurring less frequently than letter activities. Parents reported printing letters with their children more frequently than printing numbers (3.3 vs. 2.7), $t(143) = -6.80$, $p < .001$, and naming letters more frequently than naming numbers (2.4 vs. 2.1), $t(143) = -2.34$, $p = .016$. Thus, consistent with Blevins-Knabe et al. (2000), number-related activities may occur less frequently than similar letter-related activities.

Only four of the 20 activities listed in Table 1 varied in reported frequencies across grade. Parents reported a lower frequency of identifying letter names and sounds, and of counting objects as grade increased, $F_s(2,142) > 5$, $ps < .01$. They also reported less frequent reading of number storybooks in Grade 2 than in Grade 1 or Kindergarten, $F(2, 142) = 4.87$, $p < .01$. In general, however, children experienced the activities equally across this age range, as reflected in the lack of variability with age.

There was considerable variability in the frequency with which parents reported numeracy activities, ranging from a low of 1.2 for having the child wear a watch (i.e., a few times a month) to 3.0 for using calendars and dates (i.e., a few times per week). None of the sampled activities approached the frequency of shared storybook reading, which similar groups of parents report doing, on average, every day (Sénéchal, 2006; Sénéchal et al., 1998). Parents reported playing board and card games about once a week, but some parents reported that they never participated in these activities. Therefore, the early numeracy experiences of children are likely to be quite diverse across different households.

Data Reduction

To reduce the frequency of letter-related activities to a single variable, parents' reports of the frequency of engaging in the three letter-related activities (i.e., identifying letter names and sounds, printing alphabet letters) were analyzed using a principal components analysis. A single factor, Letter Skills, was extracted that accounted for 62% of the variability (see factor loadings in Table 1). The factor score was used in subsequent analyses. Cronbach's alpha for the summed measure was .69.

The 17 numeracy-related activities were analyzed in a principal components analysis with varimax rotation to reduce the number of variables and to determine whether certain activities grouped together. Four factors were extracted, accounting for 59% of the variability. The items that loaded on each factor are shown in Table 1. The numeracy factors were labeled as follows: (a) number skills, (b) games, (c) applications, and (d) number books. Items loaded at .6 or higher on these factors, indicating that the four-factor solution was a good description of the data. Cronbach's alpha for summed scales based on these factors were acceptable, ranging from .71 for the applications factor to .84 for the number-skills factor. The first important finding is that, as we expected, the frequency with which parents reported directly teaching number skills versus involving their child indirectly in numeracy-related activities were separable in parents' responses. The number skills and number books factors are interpreted to reflect parents' direct efforts to expose children to specific numeracy skills. These factors may also reflect parents' orientation toward engaging children in school-like tasks. In contrast, the games and applications factors appear to reflect indirect experiences, in that quantitative activities often take place during these activities (e.g., counting during board games) but instruction is presumably incidental and embedded in

a larger context of the activity (Bjorklund, Hubertz, & Reubens, 2004). Therefore, the factor analysis suggested a structure in home experiences reflecting variation in direct instruction of number skills versus indirect activities where there was a numeracy component.

Parents' estimates of the number of children's books in the home varied widely, from 12 to 2,000 books. The modal estimate was 100 books. These estimates were recoded: a value of 1 was assigned to estimates of up to 49 books, 2 for 50 to 99 books, 3 for 100 to 149 books, and so on, with a maximum score of 7 (representing 300 or more books). The resulting distribution was positively skewed, with the modal interval of 100–149 books and a mean of 3.9, or close to 200 books per home. The number of children's books was used as an index of children's exposure to storybook reading (Sénéchal et al., 1998).

Child Measures

These children showed above-average vocabulary performance ($M = 111.6$, $SD = 10.6$), as is usual in samples of mostly middle-class, typically achieving children. The standardized numeracy scores were also somewhat above average, with the mean scaled scores of 12.0, 11.3, and 11.3 for KeyMath numeration, addition, and subtraction, respectively (where a scaled score of 10 represents the 50th percentile).

On the single-digit addition problems, children's accuracy improved with grade (45%, 78%, and 87%, respectively), $F(2, 134) = 36.92$, $MSE = 538$. Across grades, children responded in an average of 4.0 s ($SD = 1.6$ s) on the single-digit addition problems, but response latencies decreased with grade, $F(2, 134) = 14.90$, $MSE = 2,272,981$. Kindergarten and Grade 1 children responded in an average of 4.5 s, whereas the Grade 2 children responded in an average of 3.0 s. Note that because the Kindergarten children were less accurate than older children, their latencies are based on fewer (and easier) problems than those of the older children. All children were able to correctly identify the single-digit Arabic numbers 1, 3, and 9 shown on the computer screen, so variations in addition performance probably do not reflect knowledge of digits, per se.

We derived two measures of mathematical performance (i.e., math knowledge and math fluency). First, raw scores on the Numeration, Addition, and Subtraction subtests of the KeyMath Test were used to calculate z-scores within each grade for the whole sample of 258 children and each child's three z-scores were averaged for the final math knowledge measure. Z-scores based on the raw scores were used instead of normative measures (e.g., scaled or grade equivalent scores) because many children reached ceiling performance levels with these norms. Because the z-scores were calculated within each grade, the resulting values are independent of grade. Cronbach's alpha for this summed measure was .80. This measure is assumed to reflect math knowledge because it includes numeration knowledge and arithmetic accuracy—children's conceptual and procedure skills measured independently of how quickly they can respond.

Median latencies on correct trials in the addition task were used as the measure of math fluency. (Analyses of counting fluency showed similar results, but for brevity only the analysis of addition fluency is presented.) Children who had at least three trials correct were included in this measure. Nine kindergarten children did not meet this criterion for performance. Z-scores were calculated

within grades (based on the whole sample of children). The resulting measure is therefore uncorrelated with grade and represents the child's rank within the sample of children of the same grade. For ease of discussion, the latency z-scores were reverse coded (multiplied by -1) so that a high fluency score corresponded to a high knowledge score; a child with a high fluency score responded quickly to the addition problems.

Correlations

Correlations amongst the various predictors (i.e., frequencies of home numeracy and letter activities, estimates of books), control measures (i.e., grade, sex, city, vocabulary, spatial memory), and the two outcome measures (i.e., math knowledge and math fluency) are shown in Table 2. Because factor scores were used to represent the categories of home numeracy activities, the four specific math-experience factors are uncorrelated with one another.

Examination of the correlation between the letter-skill and the number-skill factors ($r = .50$) suggests that the same parents tended to report teaching both letter and number skills. The frequency of teaching letter skills was also correlated with the number books factor ($r = .38$), further supporting the view that these factors index parents' direct attempts to foster specific academic skills. In contrast, the games factor was uncorrelated with the letter-skills factor and the applications factor was only weakly related to letter skills ($r = .18$). Overall, the analyses of the parents' responses provides support for the view that a distinction can be made between activities that directly relate to parents' attempts to enhance academic skills versus activities that may provide quantitative experiences incidentally. Further, the correlations between the letter-skills factor and both the number skills and number books factors suggest that some parents have an orientation toward activities promoting school preparation.

Math knowledge and math fluency were moderately correlated. Children with more knowledge of the number system and of arithmetic procedures also tended to respond quickly to the addition

questions. The relation is moderate, however, because a child who solved simple addition problems such as $3 + 4$, for example, by counting with his or her fingers, would respond much more slowly than a child who produced the answer from memory, but both would be credited with knowing how to add. Knowledge and fluency of mathematics are, to some extent, independent in young children.

Of interest were the correlations between these two math outcomes and the home numeracy factors. For math knowledge, only the frequency of participation in games correlated with performance. However, for math fluency, three of the four activity factors correlated with performance. Correlations for the math games and applications factors were positive indicating that more frequent participation was related to greater fluency. In contrast, a higher rate of participation in number books activities was negatively correlated with fluency. Similarly, frequency of practicing letter skills was negatively correlated with fluency. Thus, children who spent more time on letter activities and number books activities had slower latencies on the addition task. One possibility is that these negative correlations may indicate that parents are helping their children with these school-related skills because the children need some extra assistance. Accordingly, parents reported less frequent involvement in activities involving letter and number skills as grade increased (presumably because these skills were being mastered with schooling). Blevins-Knabe and Musun-Miller (1996) also found negative correlations between certain shared activities (e.g., parent teaching the child to recite numbers, showing the child how to count, child reciting numbers) and early numeracy skills, possibly because children who had not mastered these simple skills needed help at home.

Vocabulary, math fluency, and math knowledge were uncorrelated with grade as all were standardized within grade. Spatial memory span increased with grade. There were three correlations involving sex: Boys had higher vocabulary and math knowledge scores than girls, and boys responded more quickly to addition problems than girls. Because there were some relations between grade and sex, and the predictors, these variables were included as controls in the regression analyses.

Table 2

Correlations Among Home Experience Measures, Control Variables, and Children's Mathematical Performance

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Number skills	.84												
2. Number books	.00	.78											
3. Games	.00	.00	.72										
4. Applications	.00	.00	.00	.71									
5. Letter skills	.50*	.38*	-.07	.18*	.69								
6. Children's books	-.07	-.15	-.12	.18*	-.11	—							
7. Sex ³	.05	-.14	.16	-.07	-.03	-.03	—						
8. Grade	-.25*	-.10	.04	.16*	-.30*	.01	-.00	—					
9. City	-.03	-.08	-.01	-.10	-.04	.05	.06	-.16	—				
10. Vocabulary	-.08	-.22*	.06	.10	-.23*	.18*	.25*	.02	-.02	—			
11. Spatial span	-.07	.01	.20*	.03	-.12	-.07	.10	.24*	.02	.21*	.78 ¹		
12. Math knowledge	-.06	-.14	.27*	.02	-.21*	.05	.24*	-.02	.25*	.38*	.35*	.80 ²	
13. Math fluency	.07	-.19*	.26*	.16	-.18*	.18*	.25*	.00	.14	.00	.13*	.29*	—

Note. The number of individuals in each correlation ranges from 144 to 146 for all the variables, except math fluency, where $N = 137$. Where available, reliability coefficients are shown on the diagonal. For the factor scores, these are Cronbach's alpha values based on summed item means. Where available, reliability coefficients are shown on the diagonal, in italics.

¹ Split-half reliability for a sample of 435 children in Kindergarten through Grade 3. ² Cronbach's alpha for the summed Numeration, Addition, and Subtraction subtests of the KeyMath-Revised. ³ Coded as 1 for girls, 2 for boys.

* $p < .05$.

In summary, parents' reports of the frequency with which their children engage in math-related activities were correlated with their children's math performance. The correlations are modest, but similar in size to those for the relations between home literacy activities and literacy outcomes (Sénéchal et al., 1998). Regression analyses, as described below, allow stringent evaluation of the relations between home numeracy activities and outcomes, allowing us to control for related factors.

Regression Analyses

Hierarchical regression analyses were used to relate parents' reports of home activity experiences to math knowledge and math fluency, controlling for other factors that may account for these relations. Variables were added in three blocks. In the first block, grade, city, and sex were entered to account for these potential sources of variability. Vocabulary was entered to control for general verbal aptitude. Spatial span was entered to control for non-verbal aptitude. In the second block, home literacy factors were entered (i.e., storybook exposure and reported frequency of letter skills), to test whether parental involvement more generally could account for the relation between home numeracy experiences and outcomes. In the third block, the four home numeracy factors were entered. If these numeracy factors account for significant variability in math outcomes after all the other variables have been entered, then we can conclude that the correlations are likely to reflect relations between home numeracy experiences and math outcomes that go beyond other related factors.

Math Knowledge

As shown in Table 3, the control variables (block 1) accounted for 29% of the variability in math knowledge, with city, vocabulary, and spatial span contributing uniquely to the final model.

Math knowledge is greater for children whose parents had higher levels of education, for children with better verbal abilities, and for children with greater spatial memory spans. As expected, literacy-related home activities (block 2) did not account for variability in math knowledge, indicating that the relation between math outcomes and children's experiences did not just reflect parents' involvement in academic activities at home. The home numeracy experiences (block 3) accounted for an additional 4% of the variability in math scores, as a group. Of this variability, most was associated with the games factor, which accounted for 3% unique variability in the final model. Thus, the modest relation between children's experience of math-related games at home and their math knowledge was independent of other predictors, providing support for the hypothesis that there is a relation between children's skills and parents' reports of the frequency with which their children are involved in math-related activities. These results suggest that the knowledge assessment provided through the use of the standardized tests are closely tied to factors such as verbal ability and socioeconomic status (Ginsburg et al., 2008; Jordan, Huttenlocher, & Levine, 1992). The contribution of the home experience variable is thus independent of these traditional predictors.

Math Fluency

Analyses of addition latencies are shown in Table 4. The control variables, as a group, accounted for 10% of the variability (block 1). In the final model, boys responded more quickly than girls, as did children with better verbal skills. Fluency was unrelated to parents' education, however, or to spatial span. The letter skills factor (block 2) was negatively related to fluency, such that children who participated in more letter-related activities had slower latencies. Children who had greater exposure to books, however, showed faster latencies.

Table 3
Hierarchical Regression Analysis of Mathematics Knowledge (KeyMath Composite Score Including Numeration, Addition, and Subtraction Z-Scores)

Block	Predictors	R^2 change (block)	Final model statistics			
			Beta coefficients	t	p	Semipartial r
1	Control variables	.29**				
	Grade		-.043	-.55	.583	-.039
	Sex ¹		.115	1.54	.125	.108
	City		.225	3.11**	.002	.218
	Vocabulary		.252	3.20**	.002	.224
2	Spatial span	.02	.236	3.21**	.002	.224
	Literacy activities					
	Letter skills		-.154	-1.57	.118	-.110
3	Story books	.04	.010	.13	.897	.009
	Numeracy activities					
	Number skills		.033	.39	.696	.027
	Number books		.001	.01	.989	.001
	Games		.181	2.49*	.014	.174
Total R^2	Applications	.34**	.059	.76	.446	.054

Note. For final model, $F(11, 134) = 6.34$, $MSE = .50$, $p < .001$.

¹ Coded as 1 for girls, 2 for boys.

* $p < .05$. ** $p < .01$.

Finally, the number experience factors accounted for an additional 13% of the variability in addition latencies (block 3). These results suggest that faster responses to single-digit addition problems were related to the frequency of home numeracy activities, specifically, number skills, participation in numeracy-related games, and a greater frequency of experience with number-related artifacts. These children may have had more opportunities for practicing arithmetic skills in a variety of contexts. In contrast to the knowledge measures, fluency is less closely tied to factors such as socioeconomic status.

Discussion

Do children who experience more numeracy-related activities at home show greater proficiency at school-based mathematical tasks? Parents were asked to complete a questionnaire in which they indicated the frequency with which their children experienced a variety of numeracy experiences. Parents' reports of home numeracy activities were correlated with their child's math performance. Factor analysis supported our hypothesis that numeracy activities fall into two broad categories: direct activities that relate to acquisition of specific skills, such as counting or recognizing digits, and indirect activities that have quantitative components (such as playing board games with dice, or measuring while cooking) but are not specifically geared to teaching numeracy skills. Regression analysis provided support for the hypothesis that these indirect numeracy-related activities are related to children's developing fluency with basic numerical skills, such as addition or number-line knowledge (Bjorklund et al., 2004; Ramani & Siegler, 2008; Siegler & Ramani, in press; Young-Loveridge, 2004). The present research is the first to show a robust relation between the frequency with which children participate in indirect numeracy activities at home and mathematical proficiency.

Parents, teachers, and policy makers appear to believe that early experiences are important to numeracy development (Anderson,

1998; Charlesworth & Lind, 1999; Ginsburg, Klein, & Starkey, 1998). Accordingly, a plethora of materials is available describing activities for developing math skills (e.g., Ashlock, 1990; Balfanz, Ginsburg, & Greenes, 2003; Caldwell, 1998; Mirra, 2005; National Association for the Education of Young Children, 2006; National Council of Teachers of Mathematics, 2000; Rich, 1995) and governments are encouraging a focus on mathematics by offering early numeracy grants as incentives to schools (Manitoba Ministry of Education, Citizenship, & Youth, 2003). The present results provide support for the view that participation in mathematical activities at home is related to children's acquisition of mathematics in school and suggest that such activities are valuable when they occur in a variety of contexts.

The conceptual framework for this research was adapted from research on the relations between children's home experiences and literacy development (e.g., Evans et al., 2000; Sénéchal, 2006; Sénéchal & LeFevre, 2002). In contrast to previous work on children's home numeracy (e.g., Blevins-Knabe et al., 2000; LeFevre et al., 2002) we assessed a range of home numeracy activities and collected both accuracy and fluency performance. Effect sizes were modest but similar to those observed in research on home literacy experiences (Sénéchal, 2006; Sénéchal & LeFevre, 2002). In accord with Ginsburg and colleagues (cf. Ginsburg, 1982; Seo & Ginsburg, 2003), the most consistent relations occurred between activities that indirectly implicated quantitative skills and the fluency of developing addition. Notably, however, the low levels of reported numeracy activities suggest that exposure to numeracy activities occur incidentally and infrequently in Canadian homes (Blevins-Knabe et al., 2000).

Reports of home numeracy activities did not vary much with grade, with the exception of certain very specific numeracy skills such as identifying number names, where these activities were reported as more frequent for younger than for older children. The lack of differences across grade, for most of the activities, suggests

Table 4
Hierarchical Regression Analysis of Math Fluency

Block	Predictors	R^2 change (Block)	Final model statistics			
			Beta coefficients	t	p	Semipartial r
1	Control variables	.10*				
	Grade		-.088	-1.03	.304	-.077
	Sex		.248	3.13**	.002	.234
	City		.099	1.28	.202	.096
	Vocabulary		-.226	-2.70**	.008	-.201
2	Spatial span	.08**	.120	1.48	.141	.111
	Literacy activities					
	Letter skills		-.321	-3.05**	.003	-.228
3	Story books	.13**	.189	2.37*	.019	.177
	Numeracy activities					
	Number skills		.207	2.25*	.026	.168
	Number books		-.058	-0.66	.508	-.050
	Games		.207	2.64**	.009	.197
Applications			.241	2.93**	.004	.219
Total R^2		.31**				

Note. For final model, $F(11, 125) = 4.94$, $MSE = .75$, $p < .001$.

¹ Sex was coded 1 for girls, 2 for boys.

* $p < .05$. ** $p < .01$.

that parents reported the same general kinds of activities whether children were in kindergarten, Grade 1, or Grade 2. These findings suggest that home numeracy experiences (as indexed by parental reports) are stable over the early school years. Thus, for example, parents' decisions to play board and card games with their children presumably reflect their views about the value of playing games—the specific games may change but game playing itself may persist as a frequent activity in specific homes.

It was interesting to find that among the many activities included in the present study, involvement in games predicted unique variability of the addition fluency measure. This result is consistent with findings reported by Young-Loveridge (2004). Kindergarten children who participated in an intervention that involved numeracy activities in the form of board games and number storybooks showed substantial gains in early numeracy skills. Similarly, Siegler and Ramani (in press; Ramani & Siegler, 2008) reported that children from low-income families who participated in 1 hr of playing a very simple number board game showed substantial gains in their knowledge of number and magnitude. These intervention studies support the correlational conclusions from the present research: Children's indirect experiences with number, particularly in motivating contexts such as games, may be important contributors to their preparation for numeracy experiences in the early grades.

Little research has specifically addressed the role that parents might have in fostering numeracy during such interactions. Bjorklund et al. (2004) found that parents of kindergarten children competently modeled addition strategies and provided help appropriate to their child's abilities in both a game context (i.e., Chutes and Ladders) and a more traditional math problem context. In contrast, Hyde, Else-Quest, Alibali, Knuth, and Romberg (2006) found that on numerical equivalence problems, the quality of help provided by individual mothers of Grade 5 children varied with the mother's math abilities and confidence. In both of these studies, parents knew their behaviors were being monitored, so the patterns of performance may not reflect those occurring naturally at home. In summary, the role of parents in their children's home numeracy experiences will likely depend on a variety of factors.

Given the importance of children's early numeracy abilities to their acquisition of mathematics in school (e.g., Aunola et al., 2004; Jordan et al., 2007), it is surprising that research on children's home numeracy experiences is so limited. Several aspects of our research may account for the general lack of findings and provide a starting point for further work. Our study suggests that it is important to consider different mathematical outcomes in order to understand the role of home experiences in development. Another issue is that the construct of early numeracy itself is still being revised (Desoete & Grégoire, 2007). Howell and Kemp (2005) found that it was difficult to obtain agreement on a definition of numeracy amongst a group of mathematics researchers let alone amongst parents and educators. Similarly, definitions of "formal" and "informal" mathematics vary (e.g., compare Song & Ginsburg, 1987 with Anderson, 1998), making comparisons across studies difficult. Adding to the complexity of the problem, once definitions are clarified, it is difficult to know how directly involved and pedagogically focused parents must be to influence their children's knowledge acquisition (Aubrey, Bottle, & Godfrey, 2003). All of these issues need to receive some attention so that research on early

numeracy can be used to address the practical concerns of parents and teachers.

Despite the importance of our findings, the research has limitations. First, there are inherent social-desirability bias and instrument decay (vis-à-vis having to recall earlier experiences) in the use of parents' retrospective accounts of home activities. Nonetheless, parent reports have been used profitably in other research areas (e.g., home literacy and parenting practices). Furthermore, the reported frequencies of home numeracy activities were much lower than those reported for home literacy activities, suggesting that parents did not inflate their estimates dramatically. Parents may have received strong messages about the importance of shared reading but may not have heard much about numeracy. Thus, although replication using other kinds of methodologies will be useful, this study provides a foundation for further exploration of the interplay between home numeracy experiences and math learning.

In summary, the current study showed a relation between parents' reports of their children's participation in math-related activities and the children's mathematical outcomes. The activities grouped into those that involved direct instruction in number-specific skills (e.g., printing numbers, identifying number names, counting objects) versus activities that have some quantitative component but are only indirectly related to number (e.g., board games, card games, being timed, talking about money, measuring while cooking). We hypothesized that both types of activities are likely to be important in children's early numeracy experiences, in the same way that direct teaching of reading skills versus shared storybook activities are both related to children's literacy development (Sénéchal & LeFevre, 2002). There was substantial variability across parents in reports of the frequency of specific activities. Thus, identifying either the most important activities or the optimal mixture of activities will require further work, including observational and intervention studies. Most research on children's early activities at home, however, is of necessity correlational. Thus, the present research contributes valuable information about the nature of the activities that are related to numeracy development and supports recommendations from other sources that children will benefit from exposure to numerical activities in many contexts (e.g., Balfanz et al., 2003; Seo & Ginsburg, 2003; Ramani & Siegler, 2008; Siegler & Ramani, in press; Young-Loveridge, 2004).

Résumé

Chez les enfants de la maternelle, la compétence numérique est très prédictive dans le cadre de l'acquisition des habiletés mathématiques requises en 1re et 2e année du primaire. Ce phénomène suggère que les expériences vécues à la maison avant l'intégration en milieu scolaire sont importantes dans la compréhension du développement des acquis numériques. Dans la présente étude, les compétences mathématiques de 146 enfants de la maternelle, de la 1re et de la 2e année ont été mises en corrélation avec la fréquence avec laquelle les parents encouragent les activités informelles dotées de composantes quantitatives, comme pratiquer des jeux de société et de cartes, magasiner ou cuisiner. Les valeurs de l'effet obtenues correspondaient à la recherche comparant les expériences d'alphabetisation vécues à la maison au vocabulaire des enfants. L'étude appuie les affirmations concernant l'importance des ex-

périences au foyer vécues par les enfants en matière d'acquisition de compétences mathématiques.

Mots-clés : compétence numérique précoce, participation parentale, expériences au foyer, enfants d'âge préscolaire

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Appendix

Parent Questionnaire

Instructions: Please complete the following questionnaire, answering all questions. This questionnaire will take approximately 10 minutes to complete.

Relation to the child: _____

Literacy Questions

- Estimate the number of children's books in your household _____
- Estimate the number of adult's books in your household _____

Benchmarks

In your opinion, how important is it for children to reach the following benchmarks prior to entering kindergarten? (Circle 0 if not important and 4 if very important).

Note. A scale with the numbers from 0 to 4 was included for each item.

Count to 10; Count to 100; Identify/recognise written numbers; Simple sums; Rehearse the alphabet; Identify/recognise alphabet letters; Print name; Print alphabet letters.

Counting

- How high can your child count? _____
- Did you ask your child to count to answer the above question? _____

Frequency of Literacy and Numeracy Activities

In the past month, how often did you and your child engage in the following activities? Circle 0 if the activity did not occur, 1 if

it occurred less than once a week, but a few times a month (1-3 times), 2 if it occurred about once a week, 3 if it occurred a few times a week (2-4 times), 4 if it occurred almost daily, and NA if the activity is not applicable to your child.

Note. The scale was provided next to each question. Question numbers indicate the order in which the questions were presented, however, they have been grouped according to category in this list.

- Numeracy:
- Using number or arithmetic flashcards
 - Identifying names of written numbers
 - Playing with number fridge magnets
 - Counting objects
 - Sort things by size, colour or shape
 - Counted down (10, 9, 8, 7. . .)
 - Learning simple sums (i.e., $2 + 2 = 4$)
 - Printing numbers
 - Talking about money when shopping (e.g., "which Costs more?")
 - Measuring ingredients when cooking
 - Being timed
 - Playing with calculators
 - Making collections
 - "Connect-the-dot" activities
 - Using calendars and dates
 - Having your child wear a watch
 - Using number activity books
 - Reading number storybooks
 - Playing board games with die or spinner
 - Playing card games

(Appendix continues)

- Fine motor: 9. picking up sticks, objects, etc.
 10. Movement songs (i.e., Itsy Bitsy Spider)
 13. Playing musical instruments
 20. Putting pegs in a board or shapes into holes, playing with puzzles
 25. Threading beads
 30. Playing with "Playdoh" or clay
 32. Playing with blocks
 26. "Paint-by-number" activities
 29. Tying shoes
 32. Buttoning buttons
 General: 11. Playing "store"
 12. Colouring, painting, writing
 14. Playing "teacher"
 19. Doing crafts involving scissors and glue
 40. Watching educational TV shows
 27. Using educational software (eg. Reader Rabbit, Disney Preschool)
 27. Building Lego or construction set (Duplo, Megablocks, etc.)
 Letters: 17. Identifying names of written alphabet letters
 18. Identifying sounds of alphabet letters
 40. Printing letters

Caregiver's Attitudes Toward Mathematics

Please read the following statements. Using the following five-point scale, please indicate the degree to which you agree with the statement by circling the appropriate box.

- Strongly Disagree: Disagree: Neutral: Agree: Strongly Agree
1. When I was in school, I was good at mathematics.
 2. When I was in school, I enjoyed mathematics.
 3. The career path I have chosen is mathematics related.
 4. When I was in school, I was good at language arts activities such as reading.
 5. When I was in school, I enjoyed language arts activities such as reading.
 6. I find mathematics activities enjoyable.
 7. I find reading enjoyable.
 8. It is important for my child to be exposed to mathematical concepts every day.
 9. It is important for my child to be read to every day.

Additional Questions (only Given to Parents in City A)

How do you encourage mathematical learning in your home?
 Is it important for caregivers to focus on math skills in young children? Why/why not?

List three activities you think are important in developing mathematical knowledge.

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