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The Development of Mathematical Performance From Kindergarten to Grade 1: The Role of Children's Mathematical Liking and Parents' Beliefs and Activities

Gintautas Silinskas[1,2] | Taeko Bourque[3] | María Inés Susperreguy[4] | Jo-Anne LeFevre[3,5] | Saulė Raižienė[6]

[1]Turku Research Institute for Learning Analytics (TRILA), University of Turku, Turku, Finland | [2]Department of Psychology, University of Jyväskylä, Jyväskylä, Finland | [3]Department of Cognitive Science, Carleton University, Ottawa, Ontario, Canada | [4]Faculty of Education, Pontificia Universidad Católica de, Santiago, Chile | [5]Department of Psychology, Carleton University, Ottawa, Ontario, Canada | [6]Institute of Psychology, Vilnius University, Vilnius, Lithuania

Correspondence: Gintautas Silinskas (gintautas.silinskas@jyu.fi)

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ABSTRACT

The transition from kindergarten to formal schooling is an important period for examining children's developing mathematical performance. We studied reciprocal associations among children's mathematical performance, parent factors (i.e., numeracy activities, beliefs about children's mathematical skills), and child factors (i.e., mathematics liking). Lithuanian children ($N=341$; 180 girls) and their parents participated at three time points: end of kindergarten (T1; $M_{age}=6.87$ years), beginning of Grade 1 (T2), and end of Grade 1 (T3). Reciprocal cross-lagged associations between parent- and child-related factors showed that children's mathematical performance positively predicted parental beliefs [$\beta_{T1-T2}=0.247$, $\beta_{T2-T3}=0.280$] and negatively predicted numeracy activities [$\beta_{T1-T2}=-0.227$, $\beta_{T2-T3}=-0.110$] during the transition from kindergarten to Grade 1, and during Grade 1. Children's mathematical performance positively predicted their mathematics liking at the end of Grade 1 ($\beta_{T2-T3}=0.138$). The results emphasise the role of children's mathematical performance in shaping parents' involvement and beliefs about children's mathematical learning and their children's mathematics liking.

1 | Introduction

Children's numeracy skills prior to formal education are related to their mathematical performance once they start school (Jordan et al. 2009) and continue to predict performance in later grades (Davis-Kean et al. 2021; Duncan et al. 2007). The transition from kindergarten to Grade 1 (i.e., before and after the start of formal schooling) provides an opportunity to examine the effects of parents' involvement on children's developing mathematical performance during a period when major developmental changes take place (Entwisle and Alexander 1998). Children are moving from less formal learning in kindergarten (when stronger, positive associations between parental involvement and children's mathematics outcomes may occur) to the systematic formal schooling in Grade 1 (when parental involvement may be adjusted to children's mathematical performance). Different models have been proposed to explain parents' roles in their children's mathematical development; these models generally are focused on parent factors (i.e., expectations, beliefs, home numeracy activities), describe their associations with mathematical performance, and include work in a limited number of countries (Hornburg et al. 2021).

Summary

- We examined patterns of relations among children's mathematics and parents' involvement in their learning during the transition from kindergarten to formal education.
- Reciprocal cross-lagged associations between parent- and child-related factors showed that children's mathematical performance predicted parent-related factors during this transition period.
- Results emphasize the role of children's mathematical performance in shaping parents' involvement and beliefs about children's mathematical learning and liking.

More recently, calls have been made (Eason et al. 2022; Elliott and Bachman 2018; Hornburg et al. 2021) for a conceptual framework that broadens the definition of family engagement and children's mathematics, conceptualising children's mathematics broadly to include children's attitudes and interests in mathematics. Researchers, however, have mainly studied parents' factors among children prior to Grade 1 (Daucourt et al. 2021) whereas children's motivation and attitudes are usually assessed after children have started formal schooling (Gunderson et al. 2018; Song et al. 2021). In the present study, we explored the roles of parents' involvement and children's motivation on mathematical performance in the transition to formal schooling (i.e., Grade 1).

Parents' beliefs and expectations about children's performance may play a role in children's motivation to engage in related activities; parents communicate their beliefs to children, and these beliefs influence children's views of themselves as learners in that subject (Fredricks and Eccles 2002; Yamamoto and Holloway 2010). Children's performance and motivation (e.g., liking—or lack of liking) can also shape parents' beliefs about their child's mathematics skills (Carkoglu et al. 2023; Cheung et al. 2023, 2025; Silinskas et al. 2015). For example, children's poor mathematical performance across the transition from kindergarten to Grade 1 and later in primary school evokes more frequent teaching of mathematics from parents (Deng et al. 2015; Silinskas et al. 2010, 2020).

Many studies have linked formal home numeracy activities (e.g., teaching numbers and calculations) with children's symbolic number knowledge (Daucourt et al. 2021; Mutaf-Yıldız et al. 2020). Fewer researchers, however, have explored whether formal home numeracy activities relate to children's mathematics liking. Cheung et al. (2018) found that 4-year-old Filipino children's numeracy interest was linked to their parents' practices and attitudes. Similarly, Cheung et al. (2023) found that the frequency of home numeracy activities was related to 4- and 5-year-old Chinese children's numeracy abilities through their numeracy interest. Among older children, the focus has been on mathematical anxiety (Carkoglu et al. 2023; Song et al. 2021).

According to the expectancy–value theory (Eccles et al. 1983; Eccles 2005; Wigfield and Eccles 2000), children's motivation in learning is related to the value they place on the tasks and their expectancies of the subject. Interest-enjoyment value is one of the key components of task value (Eccles et al. 1983; Eccles and Wigfield 2020; Wigfield and Eccles 2000) and refers to the learner's intrinsic motivation to perform a task for its own sake, enjoyment, and interest. In the early years of schooling, children are generally very optimistic about academic subjects (Aunola et al. 2013; Song et al. 2021). We hypothesised that, in kindergarten, mathematics liking would be related to parental involvement around math, whereas in Grade 1, where there is a focus on mathematics instruction, mathematics liking may become more strongly associated with mathematical performance. We expected this differential pattern because mathematics liking promotes mathematical performance; children who like mathematics may engage in mathematics-related activities more frequently, improving their mathematical performance. Children's mathematics liking may also depend on how well they perform in mathematics.

2 | The Present Study

In this study, we re-analysed a longitudinal data set (Silinskas et al. 2020) to disentangle the complexity of mathematical development from kindergarten to Grade 1. We included factors (i.e., children's mathematics liking and parents' beliefs about their children's mathematical skills) that were not previously considered. Our objective was to examine the evolving patterns of longitudinal interrelations among children's mathematics liking and performance and parents' beliefs and activities during this key transition period to formal education.

3 | Method

This study is a part of a longitudinal study ("Get involved! Transition to grade 1"; Silinskas and Raiziene 2019), which followed Lithuanian children and their parents during the transition from kindergarten to the end of Grade 1. Our objective was to understand how children's learning environments contribute to their learning and how children's characteristics and agency evoke responses from their learning environments. Given that Lithuania is a relatively new cultural environment in this research area, the country's cultural and educational characteristics are important to note.

3.1 | Lithuania's Educational System

Since 2016, 1 year of kindergarten education before Grade 1 is compulsory in Lithuania (LR Ministry of Education, Science, and Sports 2014). This compulsory kindergarten year—officially labelled as *pre-primary education* in Lithuania (ISCED 0)—is not yet school in a traditional sense but rather a transition stage between early childhood education and formal schooling starting in Grade 1. Children begin kindergarten on September 1st of the calendar year when they turn six. The purpose of kindergarten is to prepare children for elementary school by developing their social, emotional, and basic cognitive skills. Mathematics guidelines for kindergarten include familiarising children with measuring, comparing and grouping objects, teaching children to count forwards to 20 and backwards from 10, and to recognise some numbers and mathematical signs (LR Ministry of Education, Science, and Sports 2014). However, there is no formal mathematics instruction and no explicit expectations for mathematical knowledge.

Primary education (ISCED 1) covers Grades 1–4. In Grade 1, children are exposed to the explicit and systematic learning of numbers and simple calculations (e.g., addition and subtraction up to 10). Teachers encourage children's learning about mathematics by providing tasks at multiple levels of difficulty and by encouraging motivation for mathematics (e.g., liking). The tasks of the present study were designed to reflect the country's kindergarten and Grade 1 curriculum. Although both kindergarten and Grade 1 education are compulsory and thus can be labelled as 'formal education', 'formal schooling' starts only when children enter Grade 1. The division between kindergarten and Grade 1 is clear both in the official curricular goals and in population, who traditionally celebrate September 1 of Grade 1 as the first day of the new developmental stage—formal schooling.

4 | Participants and Procedure

This longitudinal study was approved by the Ethical Committee of the University of Jyväskylä, Finland (3 May 2017). All six principals that were approached gave us permission to conduct our study in their schools. Three of the schools were in rural parts of the country (33.5% of our participants), and three schools were in the capital, Vilnius (66.5% of the participants). Before the study, parents provided written consent for participation in the study for themselves and for their children. In all six schools, kindergarten classes (compulsory 1 year before Grade 1) took place in the same building as the future primary school. Lithuanian was the language of instruction in all schools. Most of the children used only Lithuanian at home (89.6%), a mixture of Lithuanian, Russian or Polish (7.4%), only Russian (2.0%), or only Polish (0.5%). This distribution represents the general population relatively well, as the major languages of a minority are Russian (5%) and Polish (6%). The sample was also highly homogeneous in ethnic and cultural background, which is typical in Lithuania. Parents listed their education level as university degree (71.7%), college diploma from specialised secondary schools/colleges but not a full university degree or polytechnics (19.4%), or high school diploma or lower (8.9%).

4.1 | Children

Children were tested three times, at the end of kindergarten (T1; April–May 2017; $n = 229$; 116 girls; $M_{age} = 6.79$ years, SD = 0.47, range 6.08–7.33), the beginning of Grade 1 (T2; October–November 2017; $n = 337$; 178 girls; $M_{age} = 7.30$, SD = 0.38, range 6.17–8.00), and the end of Grade 1 (T3; April–May; $n = 341$; 180 girls; $M_{age} = 7.77$, SD = 0.46, range 7.08–8.5). At each measurement point, children were individually tested by the school psychologists that were employed at the participating schools. Before each measurement point, school psychologists were trained on how to test children with our test battery. School psychologists administered tests in their rooms during school hours, and they had 1–2 months to complete testing of all children.

We had some variation in the number of participating children; across T1 and T2, 38 students changed schools (and withdrew from our study), and 146 new children entered Grade 1 in our participating schools (and joined the study). Missing data were analysed by dichotomising each variable (0 = missing, 1 = not missing) and comparing the means of all other variables using *t*-tests. No significant differences were found between children who dropped out, joined, or remained in the study, indicating that attrition did not bias the results. We did not recruit new participants across T2 and T3. However, reports of four more children became available at T3, as these children were absent from school at T2. These four children did not differ from the rest in any of the variables used in the present study.

4.2 | Parents

A total of 245 parents filled in questionnaires in the spring of kindergarten (T1), 349 at the beginning of Grade 1 (T2), and 318 at the end of Grade 1 (T3). Questionnaires were mostly completed by mothers (92.2,%); the other 7.8% included fathers, mothers and fathers answering questions together, and other guardians. Parents' ages ranged from 23 to 60 years ($M = 35.38$, SD = 5.46). Most of the children came from families with two parents (79.6,%); others came from families where the mother or father was living with a new spouse (4.5%), families comprised of a single mother (11.0%), and other (4.9%; e.g., grandparents, foster care professionals). Most participants had one sibling (56.7%), whereas 25.7% of children were singletons, 13.9% had two siblings, 2.9% had three siblings, and 0.8% had four siblings.

Due to children changing schools during the transition between kindergarten and Grade 1, 60 parents dropped out of the study and 164 parents joined the study in Grade 1. New families were not recruited between T2 and T3, although 31 parents dropped out of the study during this time. Parents who dropped out, remained in the study, or joined the study did not differ on any of the study variables. Across T1 and T2, there was a tendency for less-educated parents and parents of children who were not performing well in mathematics to drop out of the study. However, the difference between parents who dropped out and remained in the study was not significant ($p > 0.10$).

5 | Measures

Descriptive statistics and psychometric properties of all study variables are presented in Table 1 (all based on the current sample).

5.1 | Parents' Measures

5.1.1 | Parents' Beliefs About Their Children's Mathematical Skills (T1, T2, and T3)

Parents' beliefs concerning their children's mathematics skills were assessed by two statements, reflecting parents' beliefs about children's math skills now and in the future: (1) 'How well is your child doing in math?' and (2) 'How well will your child do in math next year?' These statements were developed by Aunola

TABLE 1 | Descriptive statistics.

	N	*M*	SD	Cronbach's *α*	Range		Skewness	Kurtosis
					Potential	Actual		
Parent variables								
Home numeracy activities (T1)	244	2.75	1.06	0.867	1–5	1–5	0.36	−0.75
Home numeracy activities (T2)	346	2.50	1.19	0.866	1–5	1–5	0.54	−0.82
Home numeracy activities (T3)	323	2.11	1.07	0.872	1–5	1–5	1.13	0.52
Beliefs about children's mathematical skills (T1)	245	4.29	0.75	0.805	1–5	1–5	−1.69	3.80
Beliefs about children's mathematical skills (T2)	343	4.29	0.69	0.678	1–5	1.5–5	−1.00	0.99
Beliefs about children's mathematical skills (T3)	322	4.21	0.71	0.772	1–5	1–5	−1.18	2.51
Child variables								
Mathematical performance (T1)	229	8.43	4.82	0.927	0–18	0–18	0.10	−0.84
Mathematical performance (T2)	337	12.86	6.73	0.940	0–40	0–35	0.98	1.13
Mathematical performance (T3)	341	19.91	8.62	0.961	0–46	0–42	0.27	−0.28
Mathematics liking (T1)	229	4.32	0.74	0.622	1–5	1.67–5	−1.07	0.45
Mathematics liking (T2)	336	4.33	0.81	0.689	1–5	1–5	−1.56	2.60
Mathematics liking (T3)	342	4.63	0.75	0.720	1–5	1–5	−2.51	6.95
Control variable								
Highest education in the family[a]	367	4.60	0.72		1–5	1–5	−1.97	3.71

Note: T1, end of kindergarten; T2, beginning of Grade 1 and T3, end of Grade 1.
[a]1 = 0–8 years of education, 2 = 9–10 years of education, 3 = 11–12 years of education, 4 = college or polytechnics, 5 = university education.

et al. (2002) based on Parsons et al. (1982) and Frome and Eccles (1998) questionnaires. The statements were evaluated on a five-point scale, from 1 (*poorly*) to 5 (*excellent*). Scoring was the average score of both statements. Cronbach's alphas were 0.805 (T1), 0.678 (T2), and 0.772 (T3).

5.1.2 | Home Numeracy Activities (T1, T2, and T3)

Four questions were developed to assess the frequency of parents' formal home numeracy activities. The items were developed based on the work of LeFevre et al. (2009) and Skwarchuk et al. (2014) and following the guidelines of the Lithuanian national curriculum for kindergarten and primary school (LR Ministry of Education, Science and Sports 2014, 2019). At each measurement point, identical items were used (i.e., *How often do you teach your child … to recognise numbers, to write numbers, to compare quantities, and to conduct simple calculations*). Parents were asked about the current and retrospective frequency of home numeracy activities, with the time frame adjusted according to when the survey was completed (e.g., *during this school year [from September]* for T2; *since Christmas* for T1 and T3). A six-point scale was used (0 = *not anymore because my child has mastered the skill*, 1 = *never*, 2 = *rarely*, 3 = *sometimes*, 4 = *often*, 5 = *very often*). Categories 0 and 1 were merged into one category, thus making the scale range from 1 to 5. This decision was warranted by previous analyses of this data (Silinskas et al. 2020), suggesting that merging both categories or coding either category as missing would not affect the results. Cronbach's alphas were 0.867 (T1), 0.866 (T2), and 0.872 (T3).

5.2 | Children's Measures

5.2.1 | Mathematics Liking (T1, T2, and T3)

Children's mathematics liking was evaluated by three statements from Aunola et al. (2006) based on Eccles et al. (1983) to measure task motivation: (1) 'How much do you like mathematics?',

(2) 'How much do you like doing math-related tasks at school?' and (3) 'How much do you like doing math-related tasks at home?' The statements were evaluated on a five-point scale; the child was presented with pictures of faces that reflect his/her mathematics liking (ranging from 1 or a sad face = 'I do not like it at all' to 5 or a smiley face = 'I like it a lot'). The child was asked to point to the picture that best corresponds to their mathematics liking. The average of the three statements was calculated to obtain the final score for the child's mathematics liking. Cronbach's alphas were 0.622 (T1), 0.689 (T2), and 0.720 (T3).

5.2.2 | Mathematical Performance (T1, T2, and T3)

Children's mathematical performance was measured by an arithmetic fluency test, which included two subtests: (1) addition and (2) subtraction. Similar tasks were used in other studies (e.g., Aunola and Räsänen 2007). First, to measure addition skills, children responded orally to written addition questions. The sum score of correct responses in 1 min was used as an indicator. To avoid a ceiling effect, the number of items increased from nine questions at T1, to 20 questions at T2, and 23 questions at T3. The questions were ordered in increasing difficulty. For instance, at T3, eight of the questions were single-digit addition, 12 questions included addition of one two-digit number and one single-digit number, and three questions included addition of two two-digit numbers. Second, to assess subtraction skills, children responded orally to written subtraction questions. The sum score of correct responses in 1 min was used as an indicator. To avoid a ceiling effect, the number of items increased from nine questions at T1, to 20 questions at T2, and 23 questions at T3. The questions were ordered in increasing difficulty. For instance, at T3, six questions included subtracting a single digit from a two-digit number, 15 questions included subtracting a single digit number from a two-digit number, and two questions included subtracting a two-digit number from a two-digit number. Correct answers of both tests (addition and subtraction) were added to compute the total sum score of mathematical performance. Cronbach's alpha was 0.927 (T1), 0.940 (T2), and 0.961 (T3).

6 | Data Analysis

The SEM analyses were performed using M*plus* (Version 8.8; Muthén and Muthén 1998). For missing data analysis, we employed Little's (1988) Missing Completely at Random (*MCAR*) test. Non-significant Little's MCAR test results, χ^2 (1698) = 1762.46, $p = 0.135$, suggested data to be MCAR. The models were estimated using full information maximum likelihood (FIML), which uses all available information to estimate the model. We used estimator MLR (maximum likelihood estimation with robust standard errors), which is robust to non-normality and non-independence of observations. Our data were hierarchical, that is, each child was nested within a certain classroom. Intra-class correlations (ICCs) of all variables in our sample confirmed this effect (ranging from 0.018 to 0.233). To account for nestedness in our data, we used the COMPLEX function of Mplus for all our analyses. The clustering variable was teacher/classroom ID in Grade 1. This TYPE = COMPLEX function of Mplus estimates the coefficients at the individual level but takes the hierarchical nature of data into account by adjusting standard errors and chi-square statistics for clustering. Model fit was evaluated by four indices: The Tucker–Lewis index (TLI), the comparative fit index (CFI), root mean square error of approximation (RMSEA), and standardised root mean square residual (SRMR). A CFI and TLI values above 0.95, RMSEA value below 0.06, and SRMR value below 0.08 indicate a good model fit. A CFI and TLI value above 0.90, and RMSEA and SRMR values below 0.10 indicate acceptable fit (Kline 2015).

The purpose of this longitudinal study was to investigate the extent to which parents' mathematics involvement (beliefs and activities) reciprocally relates to children's mathematical outcomes (liking and performance in mathematics) across the transition from kindergarten to Grade 1 and further in Grade 1. Thus, we constructed a cross-lagged panel model (CLPM). The model included autoregressive paths of each construct and cross-lagged longitudinal paths between all constructs (both variables of parents' mathematics involvement and children's mathematical outcomes) across each subsequent time point. At each measurement point, concurrent associations among all variables were estimated. For the final path model, we added the highest education in the family as a control variable by specifying it to predict all other study variables. In addition, we estimated all indirect paths from T1 variables to all T3 variables.

7 | Results

7.1 | Descriptive Analyses

Descriptive analyses of all study variables are presented in Table 1, and correlations are presented in Table 2. On average, parents held high and positive beliefs for their children's mathematical skills (4.21–4.29 across time; scale 1–5) and, as is typical among young children, children reported high levels of mathematics liking (4.32–4.63 on a scale 1–5). The reported frequency of home numeracy activities ranged, on average, from 'rarely' to 'sometimes' (means of 2.11–2.75 on a scale from 1 to 5), and mathematical performance (i.e., arithmetic fluency tests) showed an increase from 8.43 at the end of kindergarten (T1) to 19.91 at the end of Grade 1 (T3).

We compared the means for each construct across time using repeated measures. The results revealed that parents' beliefs about children's mathematical skills did not significantly change across time, $F(2, 346) = 0.466$, $p = 0.169$, $\eta^2 = 0.010$. The frequency of home numeracy activities decreased over time, $F(2, 36) = 4.056$, $p = 0.026$, $\eta^2 = 0.184$, with a significant difference between T1 and T3 (LSD test comparison of estimated marginal means, $\Delta M = 1.000$, SE = 0.367, $p = 0.014$). Furthermore, children's mathematics liking increased over time, $F(2, 98) = 5.383$, $p = 0.006$, $\eta^2 = 0.099$, with a significant increase between T2 and T3 ($\Delta M = -0.340$, SE = 0.102, $p = 0.002$).

Boys outperformed girls in mathematical performance at the beginning of Grade 1 ($\Delta M = -2.211$, SE = 0.726, $t[335] = -3.044$, $p = 0.003$, $d = -0.332$), and at the end of Grade 1 ($\Delta M = -2.885$, SE = 0.925, $t[336] = -3.119$, $p = 0.002$, $d = -0.340$). There were no

TABLE 2 | Correlations among all study variables.

		Home numeracy activities			Parents' beliefs			Arithmetic performance			Child's mathematics liking		
		1	2	3	4	5	6	7	8	9	10	11	12
	Parent variables												
1	Home numeracy activities (T1)												
2	Home numeracy activities (T2)	0.329**											
3	Home numeracy activities (T3)	0.324**	0.496**										
4	Beliefs (T1)	0.017	−0.159*	−0.250**									
5	Beliefs (T2)	0.008	−0.247**	−0.222**	0.503**								
6	Beliefs (T3)	0.064	−0.153**	−0.256**	0.513**	0.530**							
	Child variables												
7	Performance (T1)	−0.023	−0.318**	−0.299**	0.433**	0.465**	0.442**						
8	Performance (T2)	−0.089	−0.285**	−0.272**	0.390**	0.358**	0.436**	0.768**					
9	Performance (T3)	−0.081	−0.257**	−0.233**	0.366**	0.365**	0.482**	0.740**	0.774**				
10	Liking (T1)	0.025	−0.014	−0.009	0.108	0.014	0.129*	0.077	0.125*	0.075			
11	Liking (T2)	0.156*	0.037	−0.009	0.050	0.094	0.105	0.065	0.083	0.137*	0.397**		
12	Liking (T3)	0.101	0.033	−0.036	0.197*	0.129*	0.150*	0.153*	0.121*	0.174*	0.264**	0.308**	
	Control variable												
13	Highest education	−0.259**	−0.216**	−0.191**	0.242**	0.246**	0.247**	0.325**	0.260**	0.296**	0.017	−0.014	−0.005

Note: T1, end of kindergarten; T2, beginning of Grade 1 and T3, end of Grade 1.
*$p < 0.05$.
**$p < 0.01$.

other gender differences. We controlled for parents' level of education because, as shown in Table 2, parents' level of education was correlated with all variables except for children's mathematics liking.

7.2 | Path Model of Cross-Lagged Relations Between Parents' Mathematics Involvement and Children's Mathematical Outcomes

The final path model (see Figure 1) had an acceptable model fit: χ^2 (16) = 38.662, p = 0.001, CFI = 0.976, TLI = 0.881, SRMR = 0.032, RMSEA = 0.067. First, we explored the extent to which parents' mathematics involvement predicted children's mathematical outcomes, both over the transition from kindergarten to Grade 1 and during Grade 1. The findings from kindergarten to Grade 1 (T1–T2) show that neither home numeracy activities nor parents' beliefs about children's mathematical skills predicted children's mathematical outcomes (albeit the prediction between parents' beliefs and mathematical performance during the transition from kindergarten to Grade 1 [T1–T2] was marginally significant, β = 0.067, p = 0.078). During Grade 1 (T2–T3), parents' beliefs about children's mathematical skills positively predicted both mathematical performance (β = 0.091, p = 0.044) and mathematics liking (β = 0.106, p = 0.036). That is, the more positive beliefs parents held about their children's mathematical skills at the beginning of Grade 1, the better mathematical outcomes were at the end of Grade 1.

Second, we explored the child–driven or evocative effects on parents' mathematics involvement. The results showed that children's mathematical performance positively predicted their parents' beliefs about children's mathematical skills across the transition from kindergarten to Grade 1 (T1–T2; β = 0.247, p < 0.001) and across Grade 1 (T2–T3; β = 0.280, p < 0.001). That is, the better children's mathematical performance was, the more positive the beliefs parents held concerning their children's mathematical skills. As shown in the prior analysis with these data (Silinskas et al. 2020), children's mathematical performance negatively predicted the frequency of home numeracy activities across the transition from kindergarten to Grade 1 (β = −0.227, p = 0.006) and across Grade 1 (β = −0.110, p = 0.022).

Furthermore, we estimated all other cross-lagged associations between each subsequent time point. Estimation of these paths was not the focus of our study but was tested to determine if the results would be more robust if additional paths were added. We found one such path that reached significance: Mathematical performance positively predicted children's mathematics liking across Grade 1 (β = 0.138, p = 0.019). That is, the better children's mathematical performance showed at the start of Grade 1, the more they reported liking mathematics at the end of Grade 1.

Finally, we estimated all possible indirect effects from T1 to T3 (Table S1). We found one significant indirect effect that did not include stability paths of the same variables: Mathematical performance at T1 significantly predicted children's mathematics liking at T3 via parents' beliefs about children's mathematical skills at T2 (β = 0.026, p = 0.022). That is, the better children's mathematical performance was at the end of kindergarten, the higher the beliefs about children's mathematical skills parents held at the start of Grade 1, which resulted in children liking mathematics more at the end of Grade 1. Other indirect paths were not significant or included at least one stability/autoregressive path.

See Data S1 for additional analyses including (1) using an alternative approach to the main CLPM results and (2) testing the robustness of different scoring and scaling methods for the home numeracy instrument.

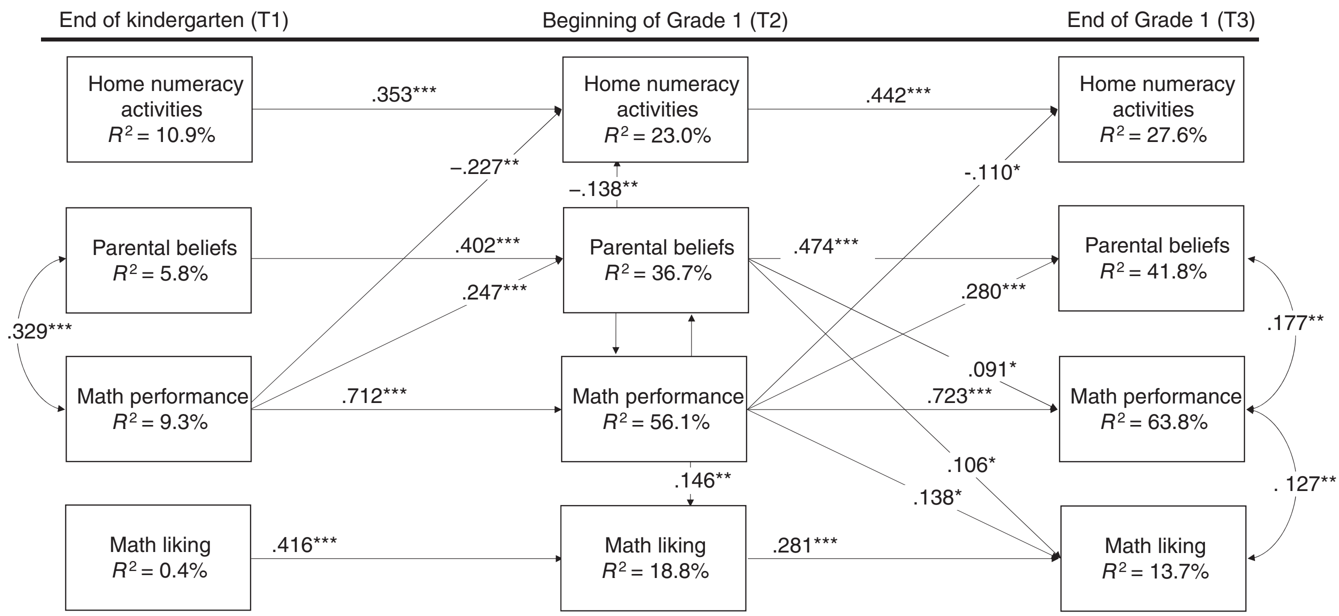

FIGURE 1 | Longitudinal associations between parental beliefs about children's mathematical skills, children's mathematical performance, children's mathematics liking, and home numeracy activities (N = 315). CLPM, cross-lagged panel model. Standardised solution, only significant associations at p < 0.05 are depicted. We controlled for parental education (not shown for parsimony). ***p < 0.001, **p < 0.01, *p < 0.05.

8 | Discussion

We investigated the longitudinal cross-lagged associations between parents' mathematics involvement and children's mathematical outcomes across the transition from kindergarten to Grade 1, and across Grade 1. Overall, our findings underscore the role of children's mathematical performance in driving parents' mathematics involvement in the transition from kindergarten to Grade 1 and during Grade 1, and in promoting children's mathematics liking during Grade 1.

To what extent does parents' mathematical involvement predict children's math outcomes? Similar to research with Finnish Grade 1 students (for mathematical performance, Aunola et al. 2003; for mathematics liking, Aunola et al. 2006), we found that parents' beliefs about children's mathematical skills at the start of Grade 1 were positively associated with children's mathematical performance and mathematics liking at the end of Grade 1. When parents have positive beliefs about their child's mathematical skills, they may communicate higher expectations about their achievement, and children, in turn, internalise those expectations, motivating them to perform better (Fredricks and Eccles 2002; Kleemans et al. 2012; Yamamoto and Holloway 2010; Wei et al. 2020).

There are increased academic demands and evaluation outside of the home in Grade 1 compared to kindergarten that focuses on social and self-regulation skills, play-based learning, and foundational skills rather than on structured math instruction. This may explain the longitudinal association between parents' beliefs and mathematical performance found between the beginning and end of Grade 1, but not across the transition from kindergarten to Grade 1. In Grade 1, feedback is provided about children's mathematical progress, and children may become more sensitive to external influences (e.g., what parents think about their skills, or expect from them). This may lead parents to form more realistic beliefs about their children's mathematical skills, and children to become more aware of their own mathematical progress and their parents' beliefs about their abilities, which may help to explain the observed gains in mathematical performance and mathematics liking.

In contrast to some previous research (Mutaf-Yıldız et al. 2020), home numeracy activities were not longitudinally related to children's mathematical outcomes. However, children in our sample were transitioning to formal schooling and it is possible that parents' numeracy activities reflected remedial support as children get older.

To what extent did children's mathematical outcomes predict parents' mathematics involvement? We found that both during the transition to Grade 1 and across Grade 1 children's mathematical performance was negatively related to parents' home numeracy activities and positively related to parents' beliefs about children's mathematical skills. Similarly, Deng et al. (2015) found a negative association between math skills in Grade 1 and formal home numeracy activities in Grade 2 among Chinese participants.

In the present research, parents' mathematics involvement appeared to be driven by children's mathematical performance rather than by children's mathematics liking. Mathematical performance positively predicted children's mathematics liking. This pattern in which earlier performance influences later affective responses to mathematics has been reported in other studies with students in Grade 1 (Gunderson et al. 2018) and for students moving from Grade 2 to Grade 3 (Song et al. 2021). These findings suggest that children's mathematical performance is key in evoking parents' involvement in children's mathematics and supporting children's mathematics liking, at least once children are receiving formal instruction in mathematics.

9 | Limitations

The present study has some limitations. First, we are unable to make causal claims about the direction of influences; experimental and intervention studies are needed to confirm these associations. Although alternate-form reliability may be preferred, due to available data, we used Cronbach's alpha as a measure of internal consistency. Additionally, self-reports are sensitive to social desirability biases and to parents' interpretations of the questions (Elliott and Bachman 2018). Non-normality of the data (i.e., 'mathematics liking' variable) may affect the accuracy or reliability of our findings. It is also possible that families engaged in home numeracy activities that were not accurately captured by our measure. In the future, researchers should consider broader measures of parents' and children's math-related beliefs and home numeracy activities (Carkoglu et al. 2023; Cheung et al. 2023, 2025; Eason et al. 2022; Hornburg et al. 2021).

10 | Conclusion

This longitudinal study of the reciprocal associations between parents' involvement and children's mathematical outcomes during the transition from kindergarten to Grade 1 and during Grade 1 expands on the previous research on parents' mathematics involvement and children's mathematical development. Our findings highlight the role of mathematical performance in driving parents' beliefs and children's motivation, with practical implications for parents, early childhood educators, and educational programmes targeting children's mathematical improvement.

Author Contributions

Gintautas Silinskas: methodology, formal analysis, resources, writing – original draft, project administration, funding acquisition. **Taeko Bourque:** writing – original draft, writing – review and editing. **María Inés Susperreguy:** writing – review and editing. **Jo-Anne LeFevre:** writing – review and editing, supervision. **Saulė Raižienė:** formal analysis, investigation.

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Disclosure

The analyses presented in this study were not preregistered.

Ethics Statement

We complied with the ethical standards of *Infant and Child Development*.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data used in this study cannot be made publicly available due to the restrictions in the 'Purpose of use, handling and storage of research data' section of the participant consent form but are available from the corresponding author upon reasonable request and by respecting the original data use agreement. As per the original data use agreement: 'Digital data will be stored under the strict control of the scientists in charge at the University of Jyväskylä. [Data] use will be restricted as only the scientists in charge will be able to provide access to the data. The data will be used only for research and teaching purposes'. Analytic code, materials, and detailed instructions for data requests can be found on https://osf.io/jvm8q/.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** icd70071-sup-0001-Supinfo.docx.