EARLY EDUCATION AND DEVELOPMENT
2021, VOL. 32, NO. 5, 637–652
https://doi.org/10.1080/10409289.2020.1799617

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Early Sources of Children's Math Achievement in Chile: The Role of Parental Beliefs and Feelings about Math

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ABSTRACT

Research Findings: Two hundred and sixty-seven Chilean children from grades 1–3, their fathers and their mothers completed measures of implicit and explicit math-related beliefs (math–gender stereotypes, math self-concepts) and feelings (math anxiety), as well as tests of mathematical achievement. Children, fathers, and mothers exhibited stereotypes that link math with males. More specifically, mothers identified more with language than with math, while fathers and children identified more with math than with language. Path analyses models revealed that children's explicit math self-concepts significantly predicted their actual math achievement. Children's explicit self-concept was, in turn, explained marginally by the mathematical anxiety of their mothers. *Practice or Policy*: These results contribute to our understanding of the relation between parental and children's beliefs and children's math achievement during early elementary school years. In countries such as Chile, with a significant gender gap in math achievement, these findings may highlight relevant aspects to consider when designing interventions aimed at educational equity and providing equal mathematical learning opportunities to boys and girls.

Math skills are crucial not only for academic achievement during school (Lyons et al., 2014), but also for success in adult professional life (Liu & Fernandez, 2018). The math skills that children exhibit at the beginning of schooling form one important foundation for later math achievement (LeFevre et al., 2010) and also for achievement in other domains (Duncan et al., 2007). Despite the relevance of math skills for students' performance in school, Latin-American children, and Chilean students in particular, are not equipped with the math skills needed to face the technological and societal challenges of the 21st century (Organisation for Economic Co-operation and Development (OECD), 2019). Additionally, Chile has a substantial gender gap in math achievement that favors boys (OECD, 2016), which is one of the largest math gender gaps in all of Latin America. Such gender gaps in math have been implicated in contributing to fewer opportunities for women, both in terms of choosing higher education paths and when entering the labor market (Smeding, 2012).

Importantly, data from Chilean kindergarten children show that, as early as 5-years-old, children already have acquired gendered beliefs about math, which are associated to those of their parents (Del Río et al., 2019). Given the gender differences in math achievement, and the low math achievement of Chilean students in general, studying the early sources of these differences is important for improving early math education in Chilean elementary schools and for designing targeted interventions that may help change the state of affairs (Master & Meltzoff, 2020).

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The current study focuses on child and parental beliefs and feelings about math achievement in the first years of formal education, when children develop key math skills (Lerkkanen et al., 2016). Specifically, this study includes three types of beliefs and feelings related to math achievement: stereotypical beliefs that associate math and gender (i.e., math–gender stereotypes, where math = male), identity beliefs about the participant's own math competence (i.e., math self-concepts), and math anxiety, which is a negative affective reaction that hinders math performance in daily life and academic situations (Gunderson et al., 2012; Meltzoff & Cvencek, 2019). The current study considers beliefs and feelings of *both* mothers and fathers to better understand the development of children's own beliefs about math and their relations to children's early math achievement.

Implicit versus Explicit Beliefs in the Study of Gendered Math Beliefs

Beliefs in both adults and children can operate consciously and deliberately, but also at an unconscious and automatic level (Cvencek et al., 2011). These two types of beliefs can be captured by two different types of measures: implicit and explicit measures (Gawronski & Strack, 2012). Studies that use explicit instruments present statements of the type, "Males have more skills for mathematics," whereby the respondent is aware of what is being asked and has to state his or her degree of agreement with these statements. In contrast, implicit tests are based on an assumption that stereotypes can be activated without bringing them to subjects' attention (Greenwald et al., 2002). Some studies have used a combination of implicit and explicit measures of math-related beliefs in same children (Cvencek et al., 2015; Del Río et al., 2019). The results show that although the two types of measures can be dissociated, they are both useful predictors of math-related outcomes. The combined use of both explicit and implicit measures allows for a more comprehensive model of the role of math beliefs in math achievement.

Children's Implicit and Explicit Gender Beliefs about Math and Math Achievement

To date, only a few studies have assessed both implicit and explicit math–gender beliefs and *also* examined their links to math achievement in children during the early elementary school years, a key stage for the development of children's beliefs about themselves in relation to school disciplines such as math. Among the most prominent types of beliefs about academic subjects that have been explored in children are *math–gender stereotypes* (*math = male*) and *math self-concept* (*math = me*).

With regard to stereotypes, research using a child-friendly adaptation of the adult Implicit Association Test (which assesses implicit beliefs) with elementary school children in the USA found implicit math–gender stereotypes as early as Grade 2 (Cvencek et al., 2011). Furthermore, U.S. children in Grade 2 also demonstrated math–gender stereotypes on explicit measures, but implicit and explicit measures of stereotypes were only weakly correlated. Galdi et al. (2014) found evidence of implicit math–gender stereotypes among Italian girls in Grade 1, but not among boys in Grade 1; implicit stereotypes were also not consistent with children's explicit stereotypes in Grade 1 (Tomasetto et al., 2012). These sets of findings are in line with the understanding that implicit and explicit cognition, while related, potentially tap differentiable processes and that measuring both aspects of cognition within the same children in the same study allows for a richer assessment of the child (Meltzoff & Cvencek, 2019).

At a broader theoretical level, it has been suggested that the development of children's implicit math–gender stereotypes may precede that of explicit math–gender stereotypes during early elementary years (Cvencek et al., 2011; Meltzoff & Cvencek, 2019). This may be one reason for low correlations between the two constructs (in addition to the different "level of operation" tapped by the implicit versus explicit measures). Additional evidence for this hypothesis for the earlier development of the implicit stereotypes has been provided by Del Río et al. (2019) in a study involving Chilean kindergartners. The current study seeks to extend this prior research which only included one age group (kindergartners) in Chile. We do so by investigating the emergence of implicit and explicit math–gender stereotypes across Grades 1, 2, and 3 in a Chilean sample. The value of exploring this

topic in Grades 1–3 derives from the fact that these years constitute a critical developmental time period for math learning and form a foundation for later achievement in school. An example of this formal training concerns basic mathematical concepts such as multiplication, which are first introduced to students in many countries in early elementary school, including both in the USA and Chile (National Governors Association Center for Best Practices, n.d.; Ministry of Education Government of Chile, 2018).

Chilean Children's Beliefs about Math and Math Achievement

In Chile, there is evidence that stereotypes linking gender and math are present even earlier in development than in many other countries. Specifically, it has been shown that by age 5, Chilean boys and girls from low socioeconomic (SES) groups already hold implicit (but not explicit) math–gender stereotypes, associating math with males more than with females (Del Río et al., 2019, 2016). Despite holding these stereotypes about gender, Chilean kindergartners do not yet demonstrate a personal identification with math or language (i.e., self-concept about math or language), and their math–gender stereotypes (about social groups) and math self-concepts (about themselves) are not significantly correlated (Del Río et al., 2019, 2016). The need for more research on math beliefs and achievement is especially desirable for Latin-American societies such as Chile, which are traditionally underrepresented in educational and psychological research, and whose governments are eager for scientific evidence from their own countries, so that educational decisions can be more evidence based.

Relations between Children's and Parents' Beliefs and Feelings about Math

To understand the beliefs that young children hold about math and about themselves, it is also useful to study the beliefs of their parents (Berkowitz et al., 2015; Del Río et al., 2019). To our knowledge, only two studies have examined *both* fathers' and mothers' math–gender stereotypes and/or math self-concepts during the time that their children were in early elementary school. Tomasetto et al. (2015) usedexplicit tests of math–gender stereotypes and math self-concepts with 6-year-old Italian children and their parents. They found that mothers' math–gender stereotypes predicted girls' math self-perception which, in turn, predicted girls' appraisal of both mothers' and fathers' evaluations of their ability. Data from Chile with younger children (kindergarten), revealed that girls' implicit math self-concepts were positively related to the math self-concept of their mothers and negatively related to that of their fathers (Del Río et al., 2019). The scarcity of research that accounts for both parents' beliefs further underscores the need for more studies examining how parental beliefs about math relate to elementary children's own beliefs about math, especially across the important Grade 1–3 time period.

Parental math anxiety is an additional, related factor of interest. It is an affective parental factor that has been shown to have a formative effect on children's math beliefs. Research has documented how parents' math anxiety interferes with the parents' own math performance in several contexts (Foley et al., 2017). Other work shows that parents' math anxiety has a negative relation to their own math self-concept (see Ahmed et al., 2012), and it is also likely to influence the messages parents convey about math to their children (Maloney et al., 2015). A study conducted with early elementary school children (Grades 1 and 2) showed that when parents are more math-anxious, their children learn significantly less math over the school year and have more math anxiety by the end of the school year (Maloney et al., 2015). Research with kindergartners suggests that there might be some differences between fathers and mothers in terms of the effects of math anxiety. A Chilean study found that mothers' math anxiety (but not fathers' math anxiety) had an indirect effect on children's math outcomes, such that mother's math anxiety influenced the number and quality of math-focused activities they offered to their children at home, which, in turn influenced children's math outcomes (Del Río et al., 2017).

Current Study

The main goal of the present study was to explore the links between Chilean children's and parents' beliefs and feelings about math and children's math achievement during the first three years of primary education (Grades 1–3). This research significantly extends prior work in three ways. First, it assesses multiple constructs – math stereotypes, self-concepts and anxiety – of *both* mothers and fathers as sources of children's own beliefs. Second, it examines these math-related constructs during the first three years of formal schooling (Grades 1–3), an important time in math development. Third, it includes standardized measures of children's early math achievement.

This research pivots around three main questions: (i) Are the parents' math beliefs and feelings related to those of their children? (ii) Do children's math beliefs influence their math achievement? (iii) Do fathers' and mothers' math beliefs and feelings have differential effects on those of their children?

Our most overarching hypothesis was that math beliefs and feelings of parents will predict their child's math-related beliefs, which in turn will predict children's math achievement. We expected that these relations would be evident after controlling for SES, gender of the child, and the mathematical competence of the parents. Beyond this, we had five specific hypotheses: First, in parents, stronger math–gender stereotypes will predict lower math self-concept for mothers, but higher self-concept for fathers (Del Río et al., 2019). Second, children's math self-concept will be positively related to their math achievement, as found by research with older children (Cvencek et al., 2015; Marsh et al., 2005; Susperreguy et al., 2018). Third, parents' math anxiety will negatively predict both their own math self-concept and their children's math self-concept (Ahmed et al., 2012; Soni & Kumari, 2015). Fourth, parental math self-concept will show a positive relationship with their children's math self-concept (Schunk & Pajares, 2002). Fifth, as reported in prior studies in a Chilean context (Del Río et al., 2019), we expected to find indirect effects of mothers' and fathers' math beliefs and feelings on children's math achievement, which we expected to be mediated through children's math self-concept.

Method

Participants

Participants were 267 boys and girls (140 girls) from Grades 1 to 3 and both of their parents, from private and public schools in Santiago, Chile. This study focused on children in Grades 1, 2, and 3 from a larger K–3 study examining parental influences on children's developing academic beliefs. We specifically chose children in the first three years of their education to explore our questions revolving around the links between math-related constructs during the time when formal mathematic instruction begins. The study is somewhat unique in being able to include *both* mothers and fathers. The paternal participants were biological fathers of the children in almost all cases, but other parental figures who lived at home with the children, such as grandparents, mothers' partners, and uncles

Table 1. Demographic characteristics of the analyzed sample.

	Age (years)		*SES*		
			High	Low	Total
Grade	*M*	*SD*	*N*	*N*	*N*
Grade 1	6.85	0.40	49	43	92
Grade 2	7.94	0.42	32	51	83
Grade 3	8.84	0.42	30	49	79
Total	7.88	0.41	111	143	254

SES = Socioeconomic status.

(n = 11 cases) were used when the biological parent was unknown or not present. Table 1 summarizes the demographic statistics for the sample.

Procedure

The protocol and procedures of this study were approved by the Research Ethics Committee from University Diego Portales, Chile. Participation of schools was first authorized by principals. The parents in the grades of interest were then invited by way of letters sent to their homes, and they signed a consent form for their participation. Once the parents agreed to participate, they were evaluated (typically at home) and signed the authorization for their children to participate. Once the children were authorized to participate, their assessments were carried out individually in a quiet place at their school by trained research assistants. All children gave verbal assent to participate. Assessments were conducted using electronic tablets (8-inch screen [20.3 cm]) and paper questionnaires.

Instruments

Implicit and explicit measures were administered to parents and children, in a counterbalanced order. Both children and parents took a paper-and-pencil math achievement test, which was always administered following the electronic tests. The parents were also administered a math anxiety test at the end of the session.

Children's Measures

The implicit and explicit measures of math self-concept and math–gender stereotypes, as well the math achievement test administered to children follow the same procedures reported in our earlier study with Chilean children (see Del Río et al., 2019, for details).

For the *explicit* math self-concept assessment, children saw two pictures of children (one doing math and another reading), and they were asked to choose the image that best represented themselves. In the explicit math–gender stereotype measure, children completed a task consisting of a pictorial Likert scale, in which they were asked to select one of the two child characters (girl or a boy) who possessed an attribute (i.e., likes math).

For the *implicit* math self-concept task, children completed a Child IAT (Implicit Association Test) measure, which assessed the degree to which children identified with math at a non-conscious level. For the current Child IAT procedures, we closely followed the block structures and algorithms described in detail by Cvencek et al. (2016).

Child IAT is a computerized sorting task for indirectly measuring the strengths of associations among concepts. The task requires sorting of stimulus exemplars belonging to four different categories using just two response options, each of which is assigned to two of the four categories. The underlying principle of the Child IAT is that it is easier to give the same response to items that are associated in memory ("congruent") than to ones that are not ("incongruent"). For example, the paring of *day* with *sun* and *night* with *moon* would be congruent, whereas the pairing of *day* with *moon* and *night* with *sun* would be incongruent, and children would be expected to respond more quickly and with greater facility to the congruent pairings.

For the measurement of math self-concepts, the Child IAT was used. If a child identied with math, the paring of *me/math* and *not-me/reading* would be "congruent." Similarly, the pairing of *me/reading* and *not-me/math* would be "incongruent." Children with positive math self-concepts would be expected to respond more quickly to the congruent versus incongruent pairings. The speed or response (touching a designated response area on the left and right side of the screen) was automatically measured in milliseconds via touch screen technology. The relevant measure that was used for statistical analysis is the difference (in milliseconds) between the responses when faced with congruent versus incongruent stimuli. The test of implicit math–gender

stereotypes followed the same general principles and descriptions as those just described. In this case, children were asked to respond to pictures representing *boys* and *girls* alongside pictures representing either *math* or *reading* (math = images of numbers, a ruler and a calculator; reading = images of letters, books, etc.). For children with math–gender stereotypes, responding to the paring of *boy* pictures and *math* images would be a congruent pairing and would be expected to yield faster responses than the stereotypically incongruent pairing of *girl* pictures and a *math* image (see Cvencek et al., 2011 for detailed discussion).

In line with standard procedures of the IAT scoring, data obtained with implicit measures were analyzed after excluding participants who met any one of three exclusion criteria, as is commonly done in both the adult IAT (Greenwald et al., 2003) and Child IAT literature (Cvencek et al., 2011; Dunham et al., 2006). These established exclusion criteria reduce the erroneous data, increase the sensitivity of implicit measures, and exclude the answers that could be considered as outliers and could bias the results. Importantly, the data reduction did not change the pattern of significant results compared with analyses of the full sample, but it did provide increased power for the statistically significant effects reported below. Specifically, the IAT cases that met the following standard exclusion criteria were not included in the analyses: (a) the participant took 300 ms or longer to respond in 10% or more of trials; (b) the participant had a response error rate of 35% or higher; or (c) the participant had an average response latency of 3 *SD*s over the average response latency of the whole sample. These criteria excluded the IAT data of 13 children. An additional 9 children did not complete IAT tasks, thus providing valid child data for $n = 245$ with implicit and $n = 254$ with explicit measures.

The math achievement test for children consisted of the Applied Problems subtest of the Woodcock-Muñoz Batería III (Muñoz-Sandoval et al., 2005), which asks the child to solve verbal math problems.

Parental Measures

Parents completed the adult versions of the explicit and implicit tests of math self-concepts and math–gender stereotypes explained in the previous section, also administered via an 8-inch tablet. Full descriptions of these procedures are also reported in (Del Río et al., 2019). Parents also completed a math anxiety and a math achievement assessment, as described below.

Math Anxiety Scale. Mothers and fathers responded to a selection of eight items from the short Mathematics Anxiety Rating Scale (sMARS; Alexander & Martray, 1989), which includes questions about how anxious they would feel when faced with different situations that involve using mathematics to perform some actions (for example, "read a receipt after a purchase," "study for a math test"). The answers were rated based on a 5-point Likert scale. A math anxiety score was calculated by averaging the 8 items. The reliability of the scale was Cronbach's $\alpha = .91$ for mothers and $\alpha = .89$ for fathers.

Math Achievement Test. Both parents also completed a math fluency subtest from the Batería III Woodcock-Muñoz achievement scales (Muñoz-Sandoval et al., 2005). This subtest assesses arithmetic fluency through the speed with which the adult performs addition, subtraction, and multiplication. The final score corresponds to the number of correct answers in the time granted (i.e., three minutes).

Results

The data analysis was carried out using the data of 250 children (127 girls) and their parents for the implicit measures, and 254 children (131 girls) and their parents for the explicit measures. First, descriptive and inferential analyses were carried out to evaluate the strength of beliefs and feelings about math and gender in both children and their parents (potential differences in terms of gender or grade were examined). Next, path analysis models were used to examine the hypothesis about associations of children's and parents' orientations toward math with children's math achievement.

Table 2. Means and standard deviations for children's and parents' beliefs.

	Girls		Boys		Mothers		Fathers	
Test	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Implicit Math-Self-Concept	−0.03	0.36	−0.02	0.38	−0.04*	0.34	0.14**	0.36
Explicit Math Self-Concept	0.49**	1.22	0.60**	1.31	−0.31**	0.89	0.26**	0.87
Implicit Math–Gender Stereotype	0.08*	0.33	0.07*	0.37	0.24**	0.50	0.21**	0.47
Explicit Math–Gender Stereotype	−0.12	1.28	−0.07	1.42	0.23**	0.64	0.12*	0.62

* Statistically different from value 0, $p < .05$. ** Statistically different from value 0, $p < .001$.

Beliefs of Children and Parents

Table 2 includes the means of math self-concept and math–gender stereotype for children and their parents. For the child measures, on the implicit math–gender stereotypes construct, boys associated *math* with *male,* $t(123) = 2.24$, $p = .027$, and so did girls, $t(120) = 2.69$, $p = .008$. On the explicit math self-concept measure, both genders self-reported identifying with math ("I am a math person") more than with reading, thus demonstrating positive explicit math self-concepts, boys $t(130) = 5.23$, $p < .001$, and girls $t(122) = 4.49$, $p < .001$. In contrast, children's explicit math–gender stereotypes and implicit math self-concepts were not significantly different from 0 (ps > .28).

Parents demonstrated significant math–gender stereotypes on both implicit and explicit measures. On implicit measures, *both* mothers and fathers associated *math* more with the *male* than *female* and thus showed the stereotype. More specifically, the mothers' implicit stereotype was $t(253) = 7.59$, $p < .001$, and the fathers' implicit stereotype was $t(253) = 7.12$, $p < .001$. Similarly, on explicit measures, both mothers and fathers self-reported beliefs linking math more with men than with women. The mothers' explicit stereotype was $t(253) = 5.64$, $p < .001$, and the fathers' explicit stereotype was $t(253) = 3.08$, $p = .002$. Moreover, on the explicit measure, mothers reported statistically stronger math–gender stereotypes than fathers did, $t(253) = 2.04$, $p = .04$; there was no such difference between mothers' and fathers' implicit stereotypes, $p = .48$.

With respect to self-concepts, as we predicted, fathers identified more strongly with *math* than with *language* on both implicit, $t(253) = 6.34$, $p < .001$, and explicit measures, $t(253) = 4.84$, $p < .001$. Mothers' self-concepts, also as predicted, were in the opposite direction, identifying with language on both implicit, $t(253) = -2.03$, $p = .04$, and explicit measures, $t(253) = -5.58$, $p < .001$. Fathers also had significantly stronger math self-concepts than mothers did on both implicit, $t(253) = 5.72$, $p < .001$, and explicit measures, $t(253) = 7.54$, $p < .001$.

Table 3 shows the descriptives for children's math achievement and parents' math anxiety. In terms of children's math achievement (see Table 3), a Gender × Grade analysis of variance (ANOVA), $F = 5.52$, $df = 2$, $p = .004$, revealed a significant difference between boys and girls only in 3rd grade, with

Table 3. Results of children's math achievement test and parents' math anxiety test.

	Math Achievement (Applied Problems)						Math Anxiety Test					
	Girls			Boys			Mothers			Fathers		
Grade	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*
Grade 1	23.47	4.11	43	23.71	4.29	51	2.31	1.04	96	2.26	0.91	96
Grade 2	28.85	3.87	39	27.79	3.72	47	2.41*	0.97	87	1.96*	0.89	87
Grade 3	28.86*	3.85	43	31.95*	4.92	40	2.53*	1.04	83	2.02*	0.76	84
Total	27.00	4.68	125	27.49	5.43	138	2.42*	1.02	266	2.08*	0.85	267

Only the results for valid test were calculated, *N* of total sample is different from the individual test results.
* $p < .05$.

boys exhibiting higher math achievement than girls, $t(81) = 3.20$, $p = 002$. In all grade levels, children

of high SES obtained significantly better scores than their peers of low SES, *t*s > 2.44, *p*s < .02. Mothers had significantly higher math anxiety than fathers, $t(265) = 4.12$, $p < .001$.

Path Analyses

To assess the relation between the beliefs of children and parents and the math achievement of children, path analyses were carried out with a total of 245 cases for the implicit measures and 254 for the explicit measures. The total *n* was different due to the exclusion of cases mentioned earlier. Table 4 shows the correlations between all the variables used in this analysis.

We tested two models to explain children's math achievement using the same predictors: one with implicit beliefs and feelings and the other with explicit ones. Predictors of children's math achievement were children's math self-concept and parents' math achievement, as well as control variables (i.e., grade, SES). Predictors of children's math self-concept were children's math–gender stereotype and parents' math self-concepts, in accordance with previous findings with Chilean children (Del Río et al., 2019). Parents' math anxiety was introduced as a predictor of children's math self-concept and also as a predictor of parents' math self-concept. Finally, parents' math–gender stereotypes were used as predictors for parents' math self-concepts.

We first tested these models by grade, to evaluate whether there were differences with respect to grade. There were no significant effects, which may be attributable to the relatively small sample sizes and the complexity of these models. We therefore decided to use the sample as a whole and control for grade. We first tested whether the predictive relations were the same for girls and boys, by running multi-group comparisons with constrained and free coefficients. In the constrained models, the coefficients were set to be equal for boys and girls, while in the free model, no such restriction was introduced. The free and constrained models were compared using the chi-squared indices (Klem, 2000). The fit of the free and constrained models were not significantly different, explicit beliefs: $\Delta\ \chi^2 = 11.66$, $df = 14$, $p = .63$; implicit beliefs: $\Delta\ \chi^2 = 19.96$, $df = 14$, $p = .13$. Thus, we assumed boys' and girls' math achievement to be similarly related to the other variables and we therefore ran subsequent models pooling boys and girls.

Fit of each final model was measured by using the three most recommended fit indices (Hu & Bentler, 1999). As recommended (Jackson et al., 2009), a good fit was indicated by three tests. First, a good fit was indicated by having a chi-square (χ^2) value that was not statistically significant. Second, the Root Mean Square Error of Approximation (RMSEA; a measure based on the non-centrality parameter) should have values less than .10 to indicate adequate model fit for RMSEA, or values around .06 to indicate good or excellent fit (Hu & Bentler, 1999). Third, the Comparative Fit Index (CFI) was utilized, because – unlike some of the less restricting indices – it pays a penalty for every estimation parameter added. CFI values greater than .85 indicate acceptable model fit (Bollen, 1989; Watkins, 1989). Both models (i.e., using both implicit and explicit measures) met these three criteria and are reported in Figures 1 and 2.

The model with explicit beliefs measures exhibited good fit ($\chi^2 = 59.86$, $df = 53$, $p = .24$; RMSEA = 0.023; CFI = 0.973; Figure 1). Children's scores in the applied problems test were mainly predicted by SES and grade level (older children and those from high SES had a higher score than children from younger grades and low SES). Children's math self-concept had also a significant positive path to math achievement ($B = 0.20$, $p < .001$). Additionally, mothers' math anxiety had a marginally significant (negative) effect on their children's math self-concept ($B = -0.12$, $p = .07$). The indirect effect from the mothers' anxiety on children's math scores, however, was not significant. As expected, the math anxiety of both parents was significantly and negatively related to their own self-concept (mothers, $B = -0.43$, $p < .001$; fathers, $B = -0.27$, $p < .001$), whereas gender stereotypes about math had a significant and negative contribution on the self-concept of mothers and a significant and positive one on the self-concept of fathers (mothers, $B = -0.17$, $p = .002$; fathers $B = 0.23$, $p < .001$).

Table 4. Correlations among variables.

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Grade Level	–																			
2	Gender	.06	–																		
3	Children's Math Achievement	.55***	−.05	–																	
4	Fathers' Math Achievement	.06	.03	.28***	–																
5	Mothers' Math Achievement	−.03	−.04	.27***	.490***	–															
6	Fathers' Math Anxiety	−.12	−.03	−.19**	−.34***	−.16**	–														
7	Mothers' Math Anxiety	.09	−.01	−.03	−.12*	−.39***	.07	–													
8	SES	−.13*	.004	.25***	.51***	.52***	−.19**	−.19**	–												
9	Children's Implicit Self-concept	−.14*	−.02	−.03	−.01	.05	.07	−.05	.07	–											
10	Children's Implicit Stereotype	.02	.01	−.04	.01	−.05	−.01	.05	−.06	.02	–										
11	Children's Explicit Self-concept	.01	−.04	.20**	−.02	.05	−.04	−.13*	−.05	.02	.13*	–									
12	Children's Explicit Stereotype	.03	−.02	.002	.04	.03	−.06	−.06	.04	.04	.07	−.005	–								
13	Mothers' Implicit Self-concept	−.06	−.05	−.04	−.05	.01	.10	−.20**	.001	.03	.08	.08	−.05	–							
14	Fathers' Implicit Self-concept	.001	−.03	−.06	.06	.06	−.20*	−.03	.07	−.09	−.05	−.07	.01	−.09	–						
15	Mothers' Explicit Self-concept	−.04	−.01	−.04	.03	.30***	−.05	−.44***	.01	−.02	−.12	.07	−.03	.31***	.04	–					
16	Fathers' Explicit Self-concept	.04	.05	.03	.22***	.01	−.28***	−.04	.05	−.04	.05	.09	−.01	.02	.22***	.04	–				
17	Mothers' Implicit Stereotype	.03	.08	.02	−.01	−.11	−.16*	.17**	−.04	−.14*	−.07	−.02	.08	−.29***	.06	−.26***	.10	–			
18	Fathers' Implicit Stereotype	−.04	−.01	−.06	.10	.03	−.16*	−.03	.08	−.12	.05	.01	−.02	.08	.18**	.05	.23***	.08	–		
19	Mothers' Explicit Stereotype	<.001	−.02	.06	.14*	.02	−.01	.11	.24***	.06	−.02	−.03	.17**	−.14*	.10	−.24***	.11	.25***	−.09	–	
20	Fathers' Explicit Stereotype	.10	−.11	.05	.06	−.09	−.04	.08	.05	−.001	−.03	−.03	−.01	−.03	.10	−.10	.25***	.03	.10	.13*	–

* $p < .05$. ** $p < .01$. *** $p < .001$.

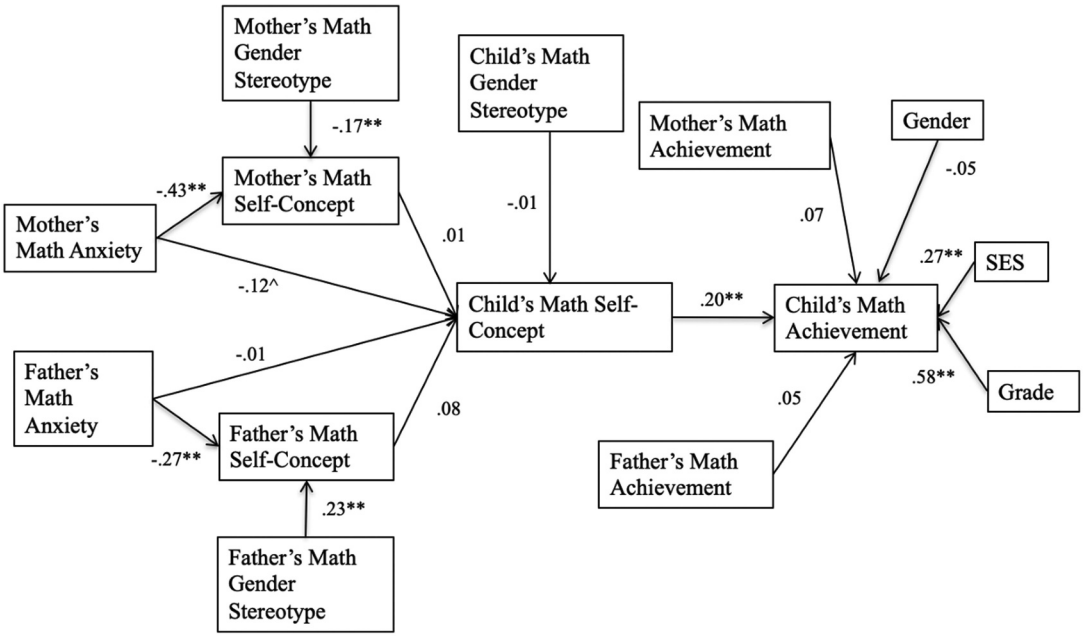

Figure 1. Model predicting children's math achievement, with *explicit* beliefs for children and standardized coefficients for the final (constrained) model. SES = Socioeconomic status. ^ $p = .07$. * $p < .05$. ** $p < .01$.

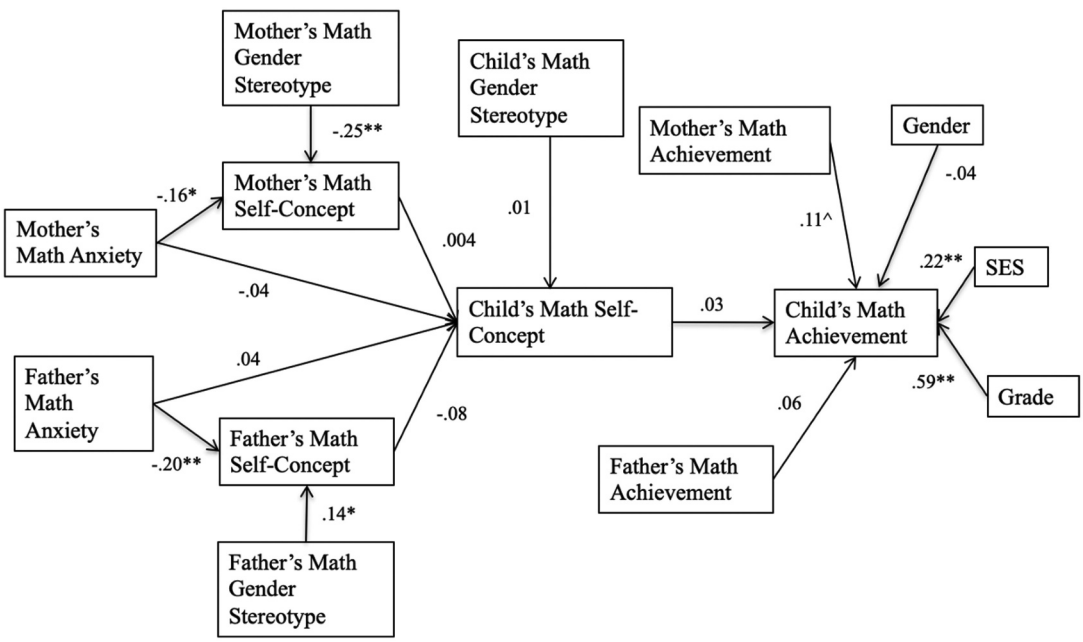

Figure 2. Model predicting children´s math achievement, with *implicit* beliefs for children and standardized coefficients for the final (constrained) model. SES = Socioeconomic status. ^ $p = .06$. * $p < .05$. ** $p < .01$.

The fit of the model with implicit measures was also good ($\chi^2 = 64.73$, $df = 53$, $p = .13$; RMSEA = 0.030; CFI = 0.928). However, none of the implicit beliefs of children, mothers, or fathers explained any variance in the children's math achievement (see Figure 2).

Discussion

This study involved a comprehensive examination of the relation between beliefs and feelings about math in Grade 1–3 Chilean children and their parents. We tested *both* parents as well as the children. The test protocol was quite comprehensive. We used both explicit and implicit tests. In addition, we obtained children's actual math achievement. The results showed that both boys and girls in Grades 1–3 hold implicit math–gender stereotypes that associate math with males, and that both boys and girls at these ages in Chile explicitly identify with math more than with language (explicit self-concept) . These explicit identifications with math (i.e., math self-concepts) were predictive of math achievement.

Empirical and Theoretical Contributions

The results advance our understanding in six ways. First, the results provide new insights into the development of implicit and explicit math–gender stereotypes and math self-concepts. Previous studies with younger children (Del Río et al., 2016) reported that boys of all SES levels, but only low-SES girls, exhibited the math–gender stereotype that *math = boys*. In the current study with older Chilean children, participants from all SES backgrounds showed this stereotype. This could be preliminary evidence that in Chile the prevailing social stereotypes about gender and math first emerge for subsets of children as early as kindergarten, and then are exhibited in a broader set of children in very early primary school. In the current study, math–gender stereotypes were clearly evident on implicit measures and not on explicit measures (see Table 2), providing further indication that implicit stereotypes may develop in a way that conforms to the stereotypes in the surrounding culture before explicit stereotypes. Additionally, this study fleshes out needed information about developmental changes in self-concepts: Whereas in our previous study (Del Río et al., 2019) the young children tested (kindergarten children) did not yet demonstrate either an implicit or explicit personal identification with language or math, children in Grades 1–3 in the current study have begun to identify with math, as evident from our results obtained with explicit measures.

This raises a question of whether and when, the math–gender stereotypes may begin to negatively influence girls' self-concepts about math, possibly giving rise to gender differences in math self-concepts. In the current study, we did not see any evidence of this pattern: both boys and girls explicitly self-reported identifying with math. However, we did find that gender differences in math achievement (favoring boys) became evident in Grade 3 (see Table 3). It is possible that the early presence of math–gender stereotypes in both girls and boys (as demonstrated here), in combination with observed information about boys' higher achievement in math (also observed in Grade 3 here), may over time, give rise to gender differences in math self-concepts. Prior studies with U.S. children have demonstrated that significant gender differences in math self-concepts become evident in Grades 4–5, which is an older age group than we tested. It will be useful to examine how these patterns play out in subsequent school grades in Chilean schools, especially if the emergent gender differences in math achievement (demonstrated here in Grade 3) continue to persist or widen.

Second, the data from mothers in this study, who showed lower math self-concepts compared to fathers (as predicted), support the idea that the positive math self-concept found in Chilean girls in Grade 1–3 could be transitory. As evident from mothers' data at older ages, over time, societal stereotypes may have differential effect on math self-concepts of girls versus boys, so that one could expect the math self-concepts of girls to weaken (i.e. become more negative) as they become older. The lack of effect of the math–gender stereotype on young girls' early math self-concept could also explain why the best-fitting model (reported here) is the one in which the paths are assumed to be the same for boys and girls. The literature shows that the math self-concepts of boys and girls begin to differ later in students' development, and that this can affect their math achievement (Kurtz-Costes et al., 2008; Spencer et al., 2016).

Third, we found the beliefs of fathers and mothers are strongly in the expected direction and fit with the literature on math–gender stereotypes in adults. Fathers identified with math (positive math self-concept) and show the stereotype that associates math with males, whereas mothers tend to identify more with language and also report the math–gender stereotype that associates math with males. Importantly, it was also observed that mothers have greater math anxiety than fathers (see also Del Río et al., 2017). The current results point to a potential account for this overall pattern: Mothers may experience math anxiety, in part, as a consequence of pervasive societal stereotypes they encounter in their daily lives. The work from the stereotype threat literature suggests that stereotypes can create anxiety, which can negatively impact perceptions of one's own math ability (i.e., math self-concepts; Schmader et al., 2004).

Fourth, our results support at least speculative inferences about the intergenerational transfer of orientations toward math. We found some evidence to suggest that children's (explicit) math self-concept (i.e., "I am a math person") is negatively (marginally) associated with the math anxiety of their mothers, suggesting that mothers feelings about math may influence the math beliefs of their children. Previous research has shown that, when math-anxious parents report helping children with their math homework less often, children's math achievement and beliefs about math tend not to be related to parents' math anxiety (Maloney et al., 2015). This raises an intriguing possibility that a combination of (i) high parental math anxiety and (ii) low frequency of parental assistance with child's math homework may attenuate the effects of parental feelings on children's math-related outcomes. In the current study, the fathers' math anxiety was not related to their children's beliefs, but mothers' math anxiety was found to be related to children's math self-concept. This may be due to fathers' lower frequency of academic help to their children, relative to what mothers provide (see Del Río et al., 2017). Subsequent studies, of both quantitative and perhaps of an introspective, qualitative nature, could deepen our understanding of the differential roles that mothers and fathers have in the development of these beliefs in children, in order to clarify the precise nature of their children's math socialization.

Fifth, regarding the role of children's own beliefs about math in shaping their mathematical achievement, we found that children's explicit math self-concepts contribute significantly to explaining their math achievement. This is consistent with international (Marsh et al., 2005; Susperreguy et al., 2018) and Chilean data with older children (Villarroel, 2001). This link has been reported robustly with older children (Coyne et al., 2014), but this study suggests that younger children's explicit beliefs about math and gender may already be influencing their math achievement. This finding is relevant, because it suggests that children's own beliefs, as well as those of their parents, may have an effect on their math learning in the first years of early elementary school.

Sixth, this study also adds to the small body of literature comparing implicit and explicit measures of beliefs and feelings. As in other studies (Cvencek et al., 2011; Galdi et al., 2014), our current results show a dissociation between implicit and explicit measures in children. In contrast to that previous research, however, this study shows that only explicit measures are predictive of other constructs. It is not immediately clear why the contribution of self-concept to achievement was manifest only on the explicit measures. It could be that implicit measures are influenced by earlier experiences and developmental events (Rudman, 2004), as well as the messages (including preverbal and indirect ones) that children receive from parents from an early age, which are now operating at an unconscious level. Explicit measures, on the other hand, are arguably more related to recent events rather than the early unconsciously processed experiences. While children's math self-concepts are still developing, their explicit understanding of themselves as a learner in math context may be more in line with their *current* experiences in school (including the results of math tests) than with any preverbal or indirect messages they might have been exposed to earlier in development. Another related possible explanation is that the actual effect of self-concept is small, and that the reliance on language in both of the explicit measures and the math achievement tests may have boosted the effect, making it visible.

Limitations and Future Directions

The present study has some limitations that constrain the implications of our findings. The study uses cross-sectional data, which did not allow us to evaluate whether the relations demonstrated here are sustained over time. Future research could investigate the stability of these relations during the elementary school years through longitudinal studies. Additionally, we used a convenience sample from Santiago Metropolitan area, and although its demographic characteristics are fairly typical of the public and private school population, it is not valid to draw inferences about the general Chilean school population from this sample. Finally, the study was correlational in nature and not an intervention study of the type that allows firm causal inferences. Based on the current work and others studies in the literature, one might be able to design interventions specifically aimed at selected aspects of the models presented here. For example, one could intervene on maternal math anxiety, or parental stereotypes, or children's beliefs about math and build more thorough causal models (for further discussion of theories and designed interventions in this area, see Master & Meltzoff, 2020).

Implications for Educational Policy

The current pattern of findings underline the need to design and implement educational policies during the first years of school that work toward equal opportunities for boys and girls to learn math. This can be done primarily by preventing the development of children's beliefs that link math to a gender, or giving children tools to allow them to "resist" stereotypes, even if those stereotypes are prominent in the culture. One useful step might be to work with teachers, both preservice and in-service, to bring about awareness of their own implicit and explicit math beliefs and anxiety about math, and how parental and teacher views can influence child development. Similarly, making teachers aware of the role that children's own stereotypes play in their development will also be useful information. In Chile, this might be especially true in first three grades of primary education, because, as our results show, this is the time when math–gender stereotypes become evident in Chilean children and gender differences in math achievement of Chilean boys and girls emerge.

Of equal importance will be efforts to strengthen the school-family bond in order to help parents and children see that math can be fun for everyone (rather than just for males, as might be conveyed by the societal stereotype). Parents who do not feel comfortable with math themselves can be brought closer to everyday math through interactive homework that gives them an opportunity to play and interact with their children around math in meaningful and motivating ways. Sending home games, puzzles, or projects that require parents and children to use math together, may have a positive impact through changing beliefs and emotions about math; moreover math objects and tasks can be designed in ways that are appealing to children (Paz-Albo Prieto et al., 2017). Future research could begin approaching these strategies in an experimental manner, seeking interventions that impact children's and parents' approach to math at home. Finally, this study also suggests that the relation between schools and parents should be strengthened, since the academic results of children are strongly related to the construction of their beliefs about "who does math" and the children's own math self-concept, which themselves develop via interaction with their parents and school experiences.

Acknowledgments

The authors thank the participant families and research assistants for their important work with data collection.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

Funding

Support for this research was provided by grants of the Chilean Ministry of Education through its National Fund for Research and Development in Education (FONIDE, Grant Number FON1700003), the Chilean National Fund of Scientific and Technology Development (CONICYT FONDECYT) through Grant No. 1180675, as well as grants from the National Science Foundation (HRD-1661285 and SBE-1640889) and the Bezos Family Foundation.

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