

SHORT REPORT

Elementary school teachers' math anxiety and students' math learning: A large-scale replication

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Abstract

A solid foundation in math is important for children's long-term academic success. Many factors influence children's math learning—including the math content students are taught in school, the quality of their instruction, and the math attitudes of students' teachers. Using a large and diverse sample of first-grade students ($n = 551$), we conducted a large-scale replication of a previous study (Proceedings of the National Academy of Sciences of the USA, 2010, 1860; $n = 117$), which found that girls in classes with highly math anxious teachers learned less math during the school year, as compared to girls whose math teachers were less anxious about math. With a larger sample, we found a negative relation between teachers' math anxiety and students' math achievement for both girls and boys, even after accounting for teachers' math ability and children's beginning of year math knowledge, replicating and extending those previous results. Our findings strengthen the support for the hypothesis that teachers' math anxiety is one factor that undermines children's math learning and could push students off-track during their initial exposure to math in early elementary school.

KEYWORDS

academic achievement, elementary school, math anxiety, math learning, teachers

1 | INTRODUCTION

Children's early math knowledge is critical to their later academic achievement, not only in math but also more broadly (Duncan et al., 2007). In attempts to understand how to effectively support children's math achievement, researchers often focus on the math content that children encounter and the quality of their instruction. However, teachers' attitudes about math (e.g., teachers' expectations for their students' success) might also influence children's math achievement (Gershenson et al., 2016; Rosenthal & Jacobson, 1968). In this paper, we explore whether one attitude in particular, teachers' math anxiety, is associated with worse student math learning in

elementary school, and whether the association between teachers' math anxiety and students' math learning varies by student gender.

Math anxiety is characterized by feelings of fear and apprehension regarding mathematics (Ashcraft, 2002; Barroso et al., 2020; Beilock et al., 2017; Hembree, 1990). Worldwide, individuals with high math anxiety are less engaged in and show lower levels of performance in mathematics (Foley et al., 2017). While math anxiety is common in the general population (approximately 25%–30% of people report moderate to high levels of math anxiety; Beilock & Willingham, 2014; Foley et al., 2017), it is particularly prevalent among those who eventually become elementary school teachers (i.e., early education majors; Ganley et al., 2019; Hembree, 1990). In fact, students studying early education have the highest level of



math anxiety of any college major (Hembree, 1990; Kelly & Tomhave, 1985), a concerning finding given that most of the math-related instructions that children receive during their early elementary school years come from their teachers (Cannon & Ginsburg, 2008).

Given that most elementary school teachers in the United States are female (e.g., 85% of pre-kindergarten through 8th grade teachers in Illinois are female; Illinois State Board of Education, 2014), and there are pernicious gender stereotypes about math (Cvencek et al., 2011), it is not surprising that our previous research found that elementary school teachers' math anxiety was negatively associated with their girl but not boy students' math achievement (Beilock et al., 2010). Girls may look to their female elementary school teachers as role models, and seeing their female teachers be anxious about math might give girls the message that math is not for girls. However, recent research examining the relation of the math anxiety of children's primary caregiver (typically the mother) to their children's math learning found a negative association between parent math anxiety and children's math learning for both boys and girls (Berkowitz et al., 2015; Maloney et al., 2015; Schaeffer et al., 2018), suggesting the possibility that caregivers' math anxiety might affect boys as well as girls.

In the current study, we aimed to replicate the Beilock et al. (2010) study with a much larger sample than the original study (Duncan et al., 2014). The benefit of the larger sample-size is twofold. First, the larger sample size allows us to test the replicability of an important and widely cited finding, and second, a larger sample allows us to explore whether the negative association between teachers' math anxiety and children's math learning is found only for girls (as was reported in the Beilock et al., 2010, paper) or for both boys and girls. Whereas the original study involved five schools, 17 1st and 2nd grade teachers, and 117 students (62 girls and 52 boys), the current study includes 22 schools, 40 1st grade teachers, and 551 children (227 girls, 274 boys)—an over 450% increase in student participants from the original study, increasing our power to address this important question.

2 | METHOD

2.1 | Participants

2.1.1 | Children

Five hundred fifty-one children (277 girls, 274 boys) from across the Chicagoland area participated. The mean age of children was 87.53 months ($SD = 9.83$ or 7 years 3.54 months). Students were recruited by contacting area schools. All students attended co-educational classes and schools for all subjects. We assessed children's math knowledge at the beginning (within the first 12 weeks of the school year) and end (during the last 12 weeks of the school year) of the school year to examine growth in math learning over the year. Forty-three students dropped out of the study between fall and spring testing. Another 33 students for whom experimenters failed

Research Highlights

- We investigated the relation between teachers' math anxiety and students' math learning over the course of 1st grade, replicating and extending previous findings using a much larger sample.
- Higher teacher math anxiety was associated with lower end of year math knowledge for both girls and boys, even after accounting for teachers' math ability and children's beginning of year math knowledge.

to establish basal or ceiling due to administration errors (22 in the fall and 11 in the spring) were removed from all subsequent analyses. This research was conducted as part of a larger study investigating whether a parent-based math intervention had a positive effect on children's math achievement (Berkowitz et al., 2015; Schaeffer et al., 2018). Families were randomly assigned to receive either a parent math intervention (in the form of a semi-structured, educational app designed for families to engage with alongside children) or an experimenter created parent reading control app that shared many features with the math app but that was not focused on math content. We found that the association between teachers' math anxiety and children's math learning did not significantly differ by experimental condition, so we included both intervention and control students in our current study.

2.1.2 | Teachers

We recruited 40 1st grade teachers from 22 area schools. All of their classrooms were participating in our larger study examining the impact of a parent-based intervention (Berkowitz et al., 2015). While we did not exclude male teachers, all of the 1st grade teachers at participating schools were female. Early elementary school teachers in the United States are almost exclusively female (over 90%); thus, it is not surprising that our sample includes only female teachers. Two teachers, with 62 children between their two classrooms, did not complete the measure of math anxiety and thus are not included in these analyses, leaving us with 38 teachers in our sample.

2.2 | Materials and procedures

2.2.1 | Child tasks

Math knowledge was measured using the Applied Problems subtest of the Woodcock-Johnson III Tests of Achievement, administered during the fall and spring of first grade (Woodcock et al., 2001). This subtest consists of orally and visually presented word problems involving arithmetic calculations of increasing difficulty. The Woodcock-Johnson is a nationally normed, comprehensive



test battery used to assess achievement of individuals between the ages of 2 and 90 years. This set of tests is a valid and reliable measure of math achievement for participants between the ages of 2 and 99 (Woodcock et al., 2001). Median reliability coefficient alphas for all age groups for the standard battery of the WJ III ranged from 0.81 to 0.94. Form A was used for the fall administration and Form B was used in the spring. Testing continued until basal and ceiling were established. All analyses were performed on students' Applied Problems W scores, obtained by transforming students' raw scores into Rasch-scaled scores with equal intervals, which is recommended for studies looking at individual growth (Woodcock, 1999).

2.2.2 | Gender stereotype endorsement task

Additionally, as in the Beilock et al. (2010) study, we assessed students' endorsement of stereotypical gender beliefs using the same procedure they used. In particular, we asked students to draw "a student who was good at math" and a "student who was good at reading," and noted whether participants reported drawing a male or female figure (Steele, 2003). Students completed those two drawings in both the fall and spring of first grade. A combined measure of gender ability beliefs was formed by assigning a score of 1 to drawings of a boy and a score of 0 to drawings of a girl, then subtracting the reading drawing score from the math drawing score (math drawing–reading drawing). Thus, the scores ranged from 1 to –1, with scores of 1 reflecting the traditional gender belief that boys are good at math and girls are good at reading.

2.2.3 | Teacher tasks

As in the Beilock et al. (2010) study, teachers' math anxiety was assessed by administering the short Mathematics Rating Scale sMARS (25 items) during the middle of the first-grade school year (Alexander & Martray, 1989). Teachers indicated how anxious they would feel engaging in activities like "reading a cash register receipt after you buy something" or "calculating a tip at a restaurant" on a five-point scale from low anxiety to high anxiety. All analyses were performance on the average of the 25 items.

Again, following Beilock et al.'s (2010) procedure, teachers' math knowledge for instruction was assessed by the using the Elementary Number Concepts and Operations subtest of the Content Knowledge for Teaching Mathematics measure (Hill et al., 2004). This task measured teachers' math knowledge for classroom math instruction and included questions about addition, subtraction, multiplication, division, and fractions. The measure consisted of 25 multiple choice questions. Questions left blank were treated as incorrect.

2.3 | Comparison to Beilock et al. (2010) procedure

Overall, the procedure employed for this study is very similar to the methodology used in Beilock et al. (2010). Notably, the same

measures were used. One difference was that, in the 2010 paper, 17 first and second-grade teachers were recruited from five public elementary schools within a large midwestern city. While the sample in the current study is larger in size, it includes only first grade (no second grade) teachers. In both studies, teachers' math anxiety was assessed using the sMARS, and teacher math knowledge was assessed using the Elementary Number Concepts and Operations subtest of the Content Knowledge for Teaching Mathematics Measure. Students' math knowledge was assessed using the Woodcock-Johnson III applied problems subtest. In Beilock et al. (2010), student measures were collected in the first two and last 2 months of the school year, whereas in the study reported here, student measures were collected in the first 3 and last 3 months of the school year because of the additional testing time needed to collect data on substantially more participants. In short, we have maintained the core measures used in the Beilock et al. (2010) study, but we have increased the sample size to allow for both a replication and to allow for a more detailed exploration of the role of student gender in relation to the effect of teachers' math anxiety on students' math achievement.

3 | RESULTS

3.1 | Descriptive statistics

After the removal of participants for the reasons described above, 497 children (251 girls, 246 boys) completed the Applied Problems subtest at the beginning and end of the school year in their classrooms. Fall math achievement on the Woodcock-Johnson Applied Problems subtest ranged from 393 to 507 ($M = 457.81$, $SD = 16.84$) and in the spring ranged from 424 to 526 ($M = 472.95$, $SD = 19.64$). For teachers, math anxiety scores on the sMARS ranged from 1.08 to 4.20 out of a possible 5 ($M = 2.11$, $SD = 0.74$).

3.1.1 | The relation between teachers' math anxiety and children's math learning

We first asked whether there was any relation between teachers' math anxiety and students' beginning of year math achievement, using hierarchical linear modeling (HLM) to account for the nested nature of the data (students nested within teachers). There was no relation between teachers' math anxiety and students' beginning of the year math achievement ($B = -0.66$, $t = -0.60$, $p = 0.55$). This finding is important in that it gives us confidence that any relation between teachers' math anxiety and children's math knowledge at the end of the year is the result of teachers' interactions with children over the course of the school year and not a result of low-performing children coincidentally being placed in higher math anxious teachers' classrooms.

We next examined whether teachers' math anxiety was associated with students' end of year math achievement. We specified a

two-level model to predict children's end of year math achievement. The first level (i.e., the student level) included children's fall math achievement as a predictor of children's spring math achievement in order to serve as a control variable. The second level (i.e., the teacher level) included teachers' math anxiety as a predictor of children's spring math achievement. Replicating the findings from Beilock et al. (2010), we found that teachers' math anxiety was negatively associated with children's math achievement at the end of the school year ($B = -1.69$, $t = -2.65$, $p = 0.01$). Indeed, the higher a teachers' math anxiety was, the less math their students learned over the course of the school year (Figure 1a).

In our previous study, teachers' math anxiety was significantly associated with girls' math achievement but not boys' math achievement (Beilock et al., 2010), but other research on caregiver math anxiety suggests that it may affect both girls and boys. Therefore, in this higher-powered sample, we examined the interaction between student gender and teachers' math anxiety to test whether the association between teachers' math anxiety and children's math learning differed by student gender. Again, we specified a two level HLM to predict children's end of year math achievement. Children's fall math achievement, as a control variable, and children's gender were included as predictors of children's spring math achievement

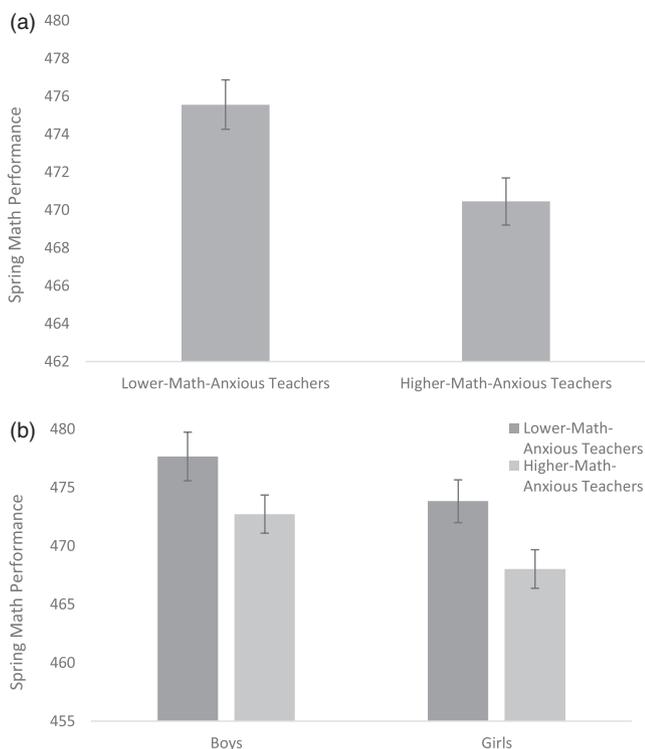


FIGURE 1 Panel (a) shows children's math learning as a function of teachers' math anxiety. Panel (b) shows children's math learning across the school year as a function of teachers' math anxiety, split by children's gender. Math learning is measured as performance on the Woodcock-Johnson III in the spring of the school year (controlling for fall Woodcock-Johnson III scores). Teachers' math anxiety is depicted as a median split of the continuous variable for illustrative purposes here; all analyses were conducted using the continuous measure of teachers' math anxiety

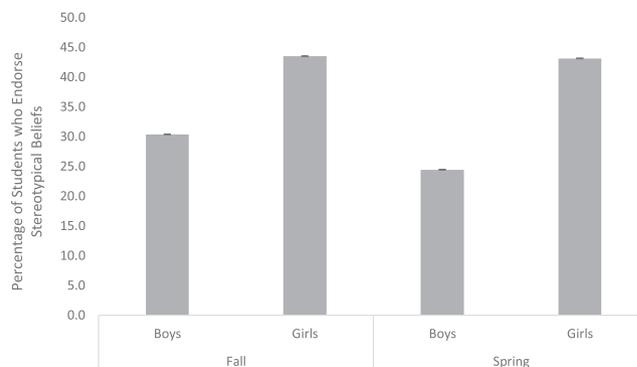


FIGURE 2 Percentage of children who reported stereotypical gender ability beliefs as function of the time of year and children's gender. Children who drew a boy as a being good at math and a girl as being good at reading were categorized as having stereotypical beliefs, as in Beilock et al. (2010). There was no significant association between teachers' math anxiety and children's stereotypical gender ability beliefs in this study

in the first level (i.e., the student level). Teachers' math anxiety was included as a predictor of children's spring math achievement in the second level (i.e., the teacher level). We also included the cross-level interaction between teachers' math anxiety and children's gender. Although teachers' math anxiety was indeed a significant negative predictor of children's spring math achievement ($B = -1.77$, $t = -2.68$, $p = 0.01$), there was not a significant interaction between teachers' math anxiety and children's gender ($B = 0.06$, $t = 0.16$, $p = 0.87$), indicating that teachers' math anxiety was associated with worse math learning similarly for both boys and girls (Figure 1b).

3.2 | The relation between teachers' math anxiety and children's gender ability beliefs

We next explored whether teachers' math anxiety was associated with students' endorsement of stereotypical gender beliefs. Beilock et al. (2010) proposed that teachers' math anxiety hinders girls' math achievement through girls' relatively increased acceptance of traditional gender roles with the idea being that when girls saw their female teachers (who they identified with based on their gender) display anxiety about math, the girls then could internalize that negativity about math as meaning something negative about girls and math generally. Contrary to that the findings reported in Beilock et al. (2010), we did not find a relation between teachers' math anxiety and children's stereotype endorsement for children identifying with either gender (girls: $r = -0.04$, $p = 0.59$; boys: $r = -0.03$, $p = 0.71$). However, we did find that girls were significantly more likely to hold the traditional gender stereotype than boys by the fall of first grade (see Figure 2). One reason for the non-replication of the association between teachers' math anxiety and girls' gender stereotype beliefs is that students in this study, as compared to the Beilock et al. (2010) study, entered the school year already endorsing math-related gender stereotypes at a high rate. Indeed, in the present sample, during



the fall, 43.5% of girls and 30.4% of boys already endorsed the dual stereotypes that “boys are good at math and girls are good at reading” whereas gender stereotype endorsement rates were much lower in the Beilock et al. (2010) sample. Many students already endorsing gender stereotypes in the current sample may well have made the children less sensitive to cues from their teacher about gender stereotypes.

4 | DISCUSSION

In the current study, we sought to replicate and extend the results of Beilock et al. (2010) with a larger sample. Replicating their overall finding, we too found that when elementary school teachers were anxious about math, their students learned less math across the school-year. Importantly, unlike the previous work that showed the influence of teachers' math anxiety was limited to female students, in this higher-powered study, we found a negative relation between teachers' math anxiety and children's math achievement for both boys and girls, consistent with recent research on other caregivers' math anxiety (i.e., mothers' math anxiety) and children's math learning in elementary school (Maloney et al., 2015; Schaeffer et al., 2018). The current study thus serves an important role in that we replicate a finding that has been largely influential in both the scientific literature (e.g., the Beilock et al., 2010 paper has been cited 1170 times as of December 2020) and in the media more generally (Altmetric lists it as being in the 99th percentile of research outputs of comparable release date). Furthermore, the observation that teachers' math anxiety is associated with worse math learning for both girls and boys is important because failing to recognize that teachers' math anxiety could undermine boys' math learning too could have resulted in interventions targeted at girls specifically, overlooking half of the students potentially affected in classrooms of highly math anxious teachers.

The replication of the relation between teachers' math anxiety and student math learning adds to existing studies showing that the math anxiety of important adults in young children's lives—both teachers and parents—is negatively associated with children's math learning. Several, non-mutually exclusive mechanisms may explain the observed negative relation between teachers' math anxiety and children's math learning in the context of children's math learning at school. First, higher math anxious teachers may provide less overall math instruction than lower math anxious teachers, reflecting the general tendency of math anxious adults to avoid math activities (Choe et al., 2019; Hembree, 1990). Second, teachers' math anxiety may be associated with lower quality math instruction. Consistent with this hypothesis is the fact that Akinsola (2008) found a relation between teachers' math anxiety and worse problem-solving strategies applied by teachers in the classroom when teaching math. Third, math anxious teachers may have fundamentally different attitudes about the importance of math and may expect less from their students in terms of math learning. These lower expectations of their students, either explicitly or implicitly, may influence their students'

personal interest in and motivation around math (Ramirez et al., 2018; Yeager et al., 2014). For example, Mizala et al. (2015) found that math anxious pre-service elementary school teachers had lower expectations for their students' future success. Although researchers have begun to piece together the ideas for mechanisms underlying the negative relation between teachers' math anxiety and children's math learning, additional research is needed that explores the theoretically and practically important fact that when teachers are higher in math anxiety, their students are learning less math over the school year.

Overall, our results support the highly cited initial report by Beilock and colleagues (2010) that elementary school teachers' math anxiety is associated with less student math learning. Given that this effect replicated, future research may do well to focus on developing interventions that on reduce teachers' math anxiety or mitigate negative behaviors associated with their anxiety as an effective strategy to improve students' math achievement (Rozek et al., 2019; Rozek et al., 2019; Tooke & Lindstrom, 1998). It is also possible that increasing the number and quality of math pedagogy courses required for pre-service teachers, or adding math specialists to schools, might help to lessen any negative impact of teachers' math anxiety on children's math learning. In conclusion, this study highlights the negative relation between elementary school teachers' math anxiety and the math learning of both girls and boys, and suggests that effective teacher training must attend not only to content and pedagogy but also to the attitudes and beliefs that teachers hold about math.

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