MIND, BRAIN, AND EDUCATION

Teachers' Spatial Anxiety Relates to 1st- and 2nd-Graders' Spatial Learning

Elizabeth A. Gunderson[1], Gerardo Ramirez[2], Sian L. Beilock[3], and Susan C. Levine[3]

ABSTRACT— Teachers' anxiety about an academic domain, such as math, can impact students' learning in that domain. We asked whether this relation held in the domain of spatial skill, given the importance of spatial skill for success in math and science and its malleability at a young age. We measured 1st- and 2nd-grade teachers' spatial anxiety ($N = 19$) and students' spatial skill ($N = 132$). Teachers' spatial anxiety significantly predicted students' end-of-year spatial skill, even after accounting for students' beginning-of-year spatial skill, phonological working memory, grade level, and teachers' math anxiety. Since spatial skill is not a stand-alone part of the curriculum like math or reading, teachers with high levels of spatial anxiety may simply avoid incorporating spatial activities in the classroom. Results suggest that addressing teachers' spatial anxieties may improve spatial learning in early elementary school.

Teachers strive to maximize student learning across the school year, but some teachers consistently produce greater student achievement gains than others (e.g., Kane & Staiger, 2008; Sanders & Horn, 1998). In order to understand why, a large body of research has examined how commonly measured teacher characteristics—such as teachers' own standardized test scores, degrees attained, and certification status—predict student achievement (for a review, see Wayne & Youngs, 2003). Only recently have researchers begun to take note of the impact that teachers' emotional reactions to a given subject area can have on student achievement. For instance, recent research has established that elementary-school teachers' feelings about mathematics can impact their students' math achievement (Beilock, Gunderson, Ramirez, & Levine, 2010). When female 1st- and 2nd-grade teachers have high levels of math anxiety (i.e., fear and apprehension about math), their female students improve less in math over the course of the school year. Further, the relation between teachers' math anxiety and girls' math learning is accounted for by an increase in girls' endorsement of the stereotype that boys are better at math than girls. This suggests that when female teachers display their nervousness about math, this confirms the societal stereotype that math is for boys. Girls in these classrooms, who look to their teacher as a same-gender role model, begin to endorse this negative self-relevant stereotype and consequently show reduced achievement gains in math.

The aforementioned work is important for understanding how teachers' feelings about the subject areas they teach relate to student achievement. However, teachers' emotional stances towards other important domains of learning that are not formally part of the curriculum but are strongly related to academic success, such as spatial skill, also need to be understood. In this article, we ask whether teachers' emotional reaction to the prospect of engaging in spatial activities (what we will refer to as "spatial anxiety") relates to children's improvement in spatial skill (the ability to maintain and manipulate visuospatial representations). This investigation is pressing in light of recent work demonstrating that spatial skills are malleable: early experiences at home and at school can improve children's spatial thinking (Huttenlocher, Levine, & Vevea, 1998; Levine, Ratliff, Huttenlocher, & Cannon, 2012; Pruden, Levine, & Huttenlocher, 2011; Uttal et al., 2012). Moreover, spatial skills are a critical component of students' success in math as well as their long-term achievement and participation in the STEM disciplines (e.g., Casey, Nuttall, & Pezaris, 2001; Gunderson, Ramirez, Beilock, & Levine, 2012; Wai, Lubinski, & Benbow, 2009). Finally, spatial anxiety has been shown to be a valid construct that predicts reduced use of adaptive navigational strategies in adults (Lawton, 1994) and reduced performance on a mental rotation task in young children (Ramirez, Gunderson, Levine, & Beilock, 2012).

[1]Department of Psychology, Temple University
[2]Department of Psychology and Graduate School of Education and Information Studies, University of California, Los Angeles
[3]Department of Psychology, University of Chicago

Address correspondence to Elizabeth A. Gunderson, Temple University, Department of Psychology, 1701 North 13th St., Philadelphia, PA 19122; email: liz.gunderson@temple.edu

For these reasons, we asked whether, similar to the domain of math, teacher spatial anxiety predicts student achievement in the spatial domain. Our main hypothesis was that teachers' anxieties about spatial activities would influence their students' spatial learning. Furthermore, unlike teachers' math anxiety, we predicted this relation would not vary as a function of student gender, for two reasons. First, 1st- and 2nd-graders may not be as aware of gender stereotypes favoring males in the domain of spatial skill as they are of gender stereotypes relating to math and reading, since spatial skill is not part of the elementary-school curriculum and is therefore a less-clearly-defined construct than math or reading. If students are unaware of gender stereotypes about spatial skills, they may be less likely to pick up on cues from their teacher that confirm or deny the stereotype. Second, because spatial skill is not a stand-alone part of the curriculum like math and reading, teachers have more discretion in integrating spatial learning into the classroom (Krakowski, Ratliff, Gomez, & Levine, 2010). Whereas teachers are required to teach math regardless of their math anxiety, teachers' spatial anxiety may actually impact whether and how they "spatialize" their curriculum. This may result in fewer opportunities for spatial learning in classrooms where teachers have higher compared to lower spatial anxiety. Therefore, we predicted that students' growth in spatial skill across the school year would vary directly as a function of teachers' spatial anxiety, regardless of student gender.

METHOD

Nineteen teachers (17 females) and 132 1st- and 2nd-grade students (88 first graders; 71 females) participated as part of a larger longitudinal study. Students completed an 8-item mental rotation task, adapted from the Spatial Relations subtest of the Primary Mental Abilities Readiness Level (Thurstone, 1974), at the beginning and end of the school year (about 6 months apart). Children were shown an incomplete square and were asked to choose which of four shapes would complete the square. The task involved forming and maintaining a visual representation of each shape and mentally rotating the pieces so they fit together. We also measured phonological working memory using the Digit Span subtest of the Wechsler Intelligence Scale for Children-Third Edition (Wechsler, 1991), as a control measure. Here, students repeated orally presented number sequences in forward and backward orders. Number sequences increased in length until the student responded incorrectly on two trials at the same sequence length. Total digit span score, the sum of correct trials on the forward and backward digit span tasks, was our measure of phonological working memory.

Teachers completed the Spatial Anxiety Questionnaire (SAQ) at the end of the year (Lawton, 1994). The 8-item SAQ asked teachers to rate how anxious they would feel in different situations involving spatial navigation, such as "Finding your way around in an unfamiliar mall." Responses were recorded from 1 (low anxiety) to 5 (high anxiety), and were averaged to form an overall SAQ score for each teacher. Teachers also completed the 25-item short Math Anxiety Rating Scale (sMARS; Alexander & Martray, 1989) as a control measure. Similarly to the SAQ, teachers' responses were recorded on a scale from 1 (low anxiety) to 5 (high anxiety) and were averaged to form an overall sMARS score for each teacher.

RESULTS

Table 1 provides descriptive statistics for all measures. Teachers' mean levels of math and spatial anxiety were very similar (spatial anxiety $M = 2.45$, $SD = 0.71$; math anxiety $M = 2.45$, $SD = 0.83$). The range of teachers' spatial anxiety (1.13–3.63) was slightly more restricted than that of teachers' math anxiety (1.60–4.16). Nevertheless, the number of teachers who reported anxiety scores above 3.00 (the theoretical midpoint of the 1–5 scale) was similar for spatial anxiety (4 of 19) and math anxiety (5 of 19).

Given that previous studies have often found gender differences in mental rotation tasks (e.g., Levine, Huttenlocher, Taylor, & Langrock, 1999), we examined whether this was the case in our sample. We found no gender differences in children's mental rotation scores at either the beginning (males: $M = 4.59$, $SD = 1.66$, females: $M = 4.63$, $SD = 1.50$, $t(130) = 0.16$, $p = .87$) or the end of the school year (males: $M = 5.41$, $SD = 1.73$, females: $M = 5.24$, $SD = 1.53$, $t(130) = -0.60$, $p = .55$).

As a preliminary analysis, we found a significant negative correlation between teachers' spatial anxiety and students' end-of-year mental rotation score, partialling out students' beginning-of-year mental rotation score, grade level, and phonological working memory, $r(127) = -.20$, $p < .05$. To examine the specificity of these results to teachers' spatial anxiety, as opposed to general academic anxiety, we also partialled

Table 1
Descriptive Statistics for All Measures

	Mean (SD)	*Range*
Teacher measures ($N = 19$)		
Spatial anxiety (SAQ)	2.45 (0.71)	1.13–3.63
Math anxiety (sMARS)	2.45 (0.83)	1.60–4.16
Student measures ($N = 132$)		
Beginning-of-year mental rotation (# correct of 8)	4.61 (1.57)	0–8
End-of-year mental rotation (# correct of 8)	5.32 (1.62)	1–8
Beginning-of-year phonological working memory score	10.03 (2.48)	2–17

out teachers' math anxiety (in addition to the other control measures specified above). The partial correlation between teachers' spatial anxiety and students' end-of-year mental rotation score remained significant, $r(126) = -.21$, $p < .05$.

For our main analyses, we conducted hierarchical linear model (HLMs), which account for the nesting of students within classrooms. We found that teachers' spatial anxiety significantly predicted students' end-of-year mental rotation score, $\gamma_{01} = -0.39$, $t = -2.22$, $p < .05$, controlling for grade level, students' beginning-of-year mental rotation score, and students' beginning-of-year phonological working memory (Table 2, Model 1). In Model 2 (Table 2) we also controlled for teachers' math anxiety in addition to our other control measures. We found the same effect—teachers' spatial anxiety significantly predicted children's end-of-year mental rotation score, $\gamma_{01} = -0.48$, $t = -2.38$, $p < .05$, even after teachers' math anxiety was controlled.

Finally, we examined whether the impact of teachers' spatial anxiety differed as a function of student gender. Although we did not predict such an interaction, we felt it was important to test for one given previous research showing that female teachers' math anxiety was related to girls', but not boys', math achievement (Beilock et al., 2010). In Model 3 (Table 2), the coefficient $\gamma_{31,}$ which represents the interaction between teachers' spatial anxiety and student gender, was not significantly different from zero, $\gamma_{31} = -0.50$, $t = -1.48$, $p = .14$.[1]

DISCUSSION

When 1st- and 2nd-grade teachers had higher levels of spatial anxiety, their students performed less well on a mental rotation task at the end of the school year than when teachers had lower spatial anxiety, even after accounting for students' beginning-of-year mental rotation skill, phonological working memory, grade level and teachers' math anxiety. To our knowledge, this is the first study to show that teachers' spatial anxiety relates to students' improvement in the academically relevant domain of spatial skill.

Additional research is needed to determine the specific mechanisms that account for the relation between teachers' spatial anxiety and students' spatial learning. Previous work has shown that female teachers' math anxiety was related to girls', but not boys', math achievement, a relation that was mediated by girls' endorsement of math-gender stereotypes (Beilock et al., 2010). In this work, we found a different pattern of results where teachers' spatial anxiety was related to both boys' and girls' spatial learning. This suggests that the mechanisms relating teacher anxiety and student achievement may differ for the domains of math versus spatial skill. Since spatial skill is not an academic subject area, we hypothesize that teachers with high levels of spatial anxiety simply avoid introducing spatial activities in the classroom, limiting students' opportunities to engage in spatial reasoning and therefore decreasing spatial learning (Levine et al., 2012). Of course, other mechanisms may also explain the relation between teachers' spatial anxiety and students' spatial learning. For example, teachers with high spatial anxiety may choose less effective spatial activities or present them in a less effective manner than teachers with low spatial anxiety. Teachers with higher levels of spatial anxiety may also be less supportive of students who engage in spatial thinking (e.g., diagramming a math word problem), thus depressing students' ability to practice spatial thinking in the classroom.

Given the importance of spatial skill for STEM achievement, our findings highlight the need to address teachers' negative feelings about spatial activities. Recent research suggests that teachers' spatial anxiety can be reduced through a week-long professional development intervention where teachers learn about how to teach spatial reasoning and collaborate with researchers to develop spatial activities for the classroom (Ping et al., 2011). Following the intervention and 1 year of

Table 2
Hierarchical Linear Models (HLMs) Predicting Students' End-of-Year Mental Rotation Scores ($N = 132$ Students, $N = 19$ Teachers)

	Model 1	*Model 2*	*Model 3*
Intercept			
Intercept, γ_{00}	5.33*** (0.13)	5.34*** (0.13)	5.32*** (0.14)
Teacher spatial anxiety, γ_{01}	−0.39* (0.17)	−0.48* (0.20)	−0.38* (0.18)
Teacher math anxiety, γ_{02}	—	0.17 (0.19)	—
Grade level, γ_{03}	0.66* (0.31)	0.78* (0.33)	0.64 (0.31)
Student beginning-of-year mental rotation score			
Intercept, γ_{10}	0.26** (0.09)	0.26** (0.09)	0.25** (0.09)
Student beginning-of-year phonological working memory score			
Intercept, γ_{20}	0.06 (0.06)	0.06 (0.06)	0.07 (0.06)
Student gender (female = 0, male = 1)			
Intercept, γ_{30}	—	—	0.25 (0.27)
Teacher spatial anxiety, γ_{31}	—	—	−0.50 (0.34)

Note. Numbers in parentheses are SEs. All variables are centered at the grand mean. Random effects are included for the overall intercept.
*$p \le .05$. **$p < .01$. ***$p < .001$.

implementation, teachers reported significantly lower levels of spatial anxiety (compared to before the intervention). This change was specific to spatial anxiety, as opposed to reading anxiety. This is consistent with previous work on teachers' math anxiety, showing that when teachers took a pre-service course focused on *how* to teach math concepts, their math anxiety declined more than when they took a pre-service course focused directly on the math concepts themselves (Tooke & Lindstrom, 1998). In other words, pre-service and professional development activities targeting *how to teach* math and spatial concepts hold promise for reducing teachers' anxiety about these domains. This study suggests that reducing teachers' spatial anxiety has the potential to improve children's spatial skill, which may have the important benefit of improving children's interest and achievement in mathematics as well as STEM-related fields more broadly.

Acknowledgments—Research supported by National Science Foundation Spatial Intelligence and Learning Center Grant (to S.L.B. and S.C.L.), by National Science Foundation Grants BCS-0751336 and CAREER DRL-0746970 (to S.L.B.), and by National Center for Education Research Grant R305C050076 (to E.A.G. and G.R.)

NOTES

1 We also conducted the three HLM models reported in Table 2 excluding the two male teachers and their students. Restricting the sample to female teachers ($N = 17$) and their students ($N = 124$) allowed us to parallel the analyses conducted in Beilock et al. (2010). The pattern of results remained the same, such that teacher spatial anxiety predicted students' end-of-year spatial skill in each model (p's $< .052$). Further, when examining only female teachers and their students, the interaction between teacher spatial anxiety and student gender remained nonsignificant, $\gamma_{31} = -0.44$, $t = -1.27$, $p = .21$.

REFERENCES

Alexander, L., & Martray, C. (1989). The development of an abbreviated version of the Mathematics Anxiety Rating Scale. *Measurement and Evaluation in Counseling and Development*, *22*(3), 143–150.

Beilock, S. L., Gunderson, E. A., Ramirez, G., & Levine, S. C. (2010). Female teachers' math anxiety affects girls' math achievement. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(5), 1860–1863. doi:10.1073/pnas.0910967107

Casey, M. B., Nuttall, R. L., & Pezaris, E. (2001). Spatial-mechanical reasoning skills versus mathematics self-confidence as mediators of gender differences on mathematics subtests using cross-national gender-based items. *Journal for Research in Mathematics Education*, *32*(1), 28–57. doi:10.2307/749620

Gunderson, E. A., Ramirez, G., Beilock, S. L., & Levine, S. C. (2012). The relation between spatial skill and early number knowledge: The role of the linear number line. *Developmental Psychology*, *48*, 1229–1241. doi:10.1037/a0027433

Huttenlocher, J., Levine, S., & Vevea, J. (1998). Environmental input and cognitive growth: A study using time-period comparisons. *Child Development*, *69*, 1012–1029. doi:10.2307/1132360

Kane, T. J., & Staiger, D. O. (2008). Estimating teacher impacts on student achievement: An experimental evaluation. *NBER Working Paper Series, No. 14607*.

Krakowski, M., Ratliff, K. R., Gomez, L. M., & Levine, S. C. (2010). Spatial intelligence and the research-practice challenge. In K. Gomez, L. Lyons, & J. Radinsky (Eds.), *Learning in the disciplines: Proceedings of the 9th International Conference of the Learning Sciences (ICLS)* (Vol. 1, pp. 556–563). Chicago, IL: International Society of the Learning Sciences.

Lawton, C. A. (1994). Gender differences in way-finding strategies: Relationship to spatial ability and spatial anxiety. *Sex Roles*, *30*, 765–779.

Levine, S. C., Huttenlocher, J., Taylor, A., & Langrock, A. (1999). Early sex differences in spatial skill. *Developmental Psychology*, *35*, 940–949.

Levine, S. C., Ratliff, K. R., Huttenlocher, J., & Cannon, J. (2012). Early puzzle play: A predictor of preschoolers' spatial transformation skill. *Developmental Psychology*, *48*, 530–542. doi:10.1037/a0025913

Ping, R. M., Bradley, C., Gunderson, E. A., Ramirez, G., Beilock, S. L., & Levine, S. C. (2011, July). *Alleviating anxiety about spatial ability in elementary school teachers*. Paper presented at the Annual Meeting of the Cognitive Science Society, Boston, MA.

Pruden, S. M., Levine, S. C., & Huttenlocher, J. (2011). Children's spatial thinking: Does talk about the spatial world matter? *Developmental Science*, *14*, 1417–1430. doi:10.1111/j.1467-7687.2011.01088.x

Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2012). Spatial anxiety relates to spatial abilities as a function of working memory in children. *Quarterly Journal of Experimental Psychology*, *65*, 474–487. doi:10.1080/17470218.2011.616214

Sanders, W. L., & Horn, S. P. (1998). Research findings from the Tenessee Value-Added Assessment System (TVAAS) database: Implications for educational evaluation and research. *Journal of Personnel Evaluation in Education*, *12*, 247–256.

Tooke, D. J., & Lindstrom, L. C. (1998). Effectiveness of a mathematics methods course in reducing math anxiety of preservice elementary teachers. *School Science and Mathematics*, *98*(3), 136–140.

Thurstone, T. G. (1974). *PMA readiness level*. Chicago, IL: Science Research Associates.

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2012). The malleability of spatial skills: A meta-analysis of training studies. *Psychological Bulletin*. doi:10.1037/a0028446

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, *101*, 817–835. doi:10.1037/a0016127

Wayne, A. J., & Youngs, P. (2003). Teacher characteristics and student achievement gains: A review. *Review of Educational Research*, *73*(1), 89–122.

Wechsler, D. (1991). *Wechsler intelligence scale for children* (3rd ed.). San Antonio, TX: The Psychological Corporation.