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Student-Teacher Alliance Buffers Against the Impact of Moderate Math Anxiety on Course Performance among College Students

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Abstract: Students with math anxiety experience low self-efficacy and high levels of distress when asked to approach math tasks and concepts, which often results in poor course performance. Despite the wealth of research on this construct, relatively little is known about how math anxiety impacts math achievement in college-aged students or what types of classroom-based processes might buffer against this harmful effect. The present study therefore examined the student-teacher alliance as a potential buffer against the detrimental effect of math anxiety on course grades in a sample of non-STEM college students enrolled in a required mathematics course. Students completed questionnaires regarding their math anxiety, overall anxiety, perception of their alliance with their course instructor, and class grade over the course of a semester. Results indicated that, although elevated math anxiety was associated with poorer course performance, this link was weakened for students who perceived themselves to have a stronger relationship with their instructor. However, this moderation effect was present for students with low to moderate, but not high, math anxiety. Findings highlight the importance of college-level math instructors attending to the student-teacher alliance as a potential anxiety mitigation strategy, particularly for students with moderate levels of math anxiety.

Keywords: *math, anxiety, student-teacher alliance, higher education*

Math anxiety, defined as individuals' internalized negative beliefs about their ability to understand and apply mathematical concepts, is an exceedingly common phenomenon among students of all ages (Zhang, Zhao, & Kong, 2019). This is particularly true for female-identified students and students of color, who tend to report higher levels of math anxiety than do their peers (Casanova, Vukovic, & Kieffer, 2021; Young & Young, 2016). The negative impact of math anxiety on math course performance is well-documented, with higher levels of math anxiety predicting poorer math achievement among elementary school, middle school, high school, and college students (Ashcraft & Krause, 2007; Zhang, Zhao, & Kong, 2019). While existing research has identified various strategies for alleviating this anxiety, many of these require individualized interventions that are likely impractical for the everyday classroom (e.g., mindfulness-based cognitive therapy; LaGue, Eakin, & Dykeman, 2019). The present study therefore sought to examine whether the student-teacher alliance might buffer against the harmful impact of math anxiety on course performance.

Math anxiety has well-documented effects on students' emotional functioning. In addition to its impact on self-reported feelings about math (Krinzinger, Kaufmann, & Willmes, 2009), work by Young and colleagues (2012) found that children with high math anxiety exhibit elevated levels of right amygdala activity while completing math tasks, as well as increased functional connectivity between the amygdala and the ventromedial prefrontal cortex. This suggests that these students experience significantly elevated emotional reactivity while completing math tasks and expend more cognitive energy processing these emotions in the moment – a potential mechanism by which math anxiety decreases math performance. Research has also demonstrated that the mere anticipation of math tasks results in neural changes for those with high math anxiety, such that elevated levels of anticipatory math anxiety have been associated with increased activity in brain regions that are associated with threat detection and the anticipation of pain, such as the insular cortex (Lyons & Beilock, 2012). Further, even when not anticipating an impending math task, students with high math

anxiety demonstrate elevated amygdala activity when presented with math-related visual stimuli – a pattern similar to that found in those with specific phobias (Pizzie & Kraemer, 2017).

Math anxiety also has a demonstrated impact on cognitive functioning. For instance, work by Young and colleagues (2012) demonstrated that, while completing math tasks, students with high levels of math anxiety show decreased activity in regions of the prefrontal cortex associated with mathematical reasoning, highlighting another possible mechanism by which math anxiety results in poor math achievement. Yet another potential mechanism might be reductions in memory function, with high math anxiety consistently being linked to poorer working memory capacity in behavioral and neuroimaging studies (Ashcraft & Ridley, 2005; Klados, Paraskevopolous, Pandria, & Bamidis, 2019). Existing research has also connected math anxiety to enhanced negative attentional bias to mathematical stimuli, with this bias potentially resulting in fewer cognitive resources being available to complete the math task at hand (Rubenstein, Eidlin, Wohl, & Akibli, 2015).

These cognitive and emotional consequences of math anxiety often lead to math avoidance for students (Hembree, 1990; Ma & Xu, 2004). This can include attentional avoidance, with work by Pizzie and Kraemer (2017) showing that those with high math anxiety engage in cognitive avoidance of math-related stimuli. This is true at the neural level as well, such that high math anxiety is associated with decreased activity in brain regions required for mathematical reasoning while completing math tasks (Young et al., 2012). Indeed, students often report higher levels of anxiety while anticipating, rather than completing, math tasks, suggesting that highly math-anxious students engage in a form of avoidant emotional coping during math performance (Lyons & Beilock, 2012). This avoidance extends to their coursework as well, with recent research by Daker and colleagues (2021) indicating that math anxiety can longitudinally predict students' avoidance of science, technology, engineering, and mathematics (STEM) courses over the course of their college careers. Ultimately, these various forms of avoidance result in those with high math anxiety self-selecting out of STEM careers, especially among highly math-anxious women (Hembree, 1990; Huang, Zhang, & Hudson, 2019; Levy, Fares, & Rubenstein, 2021; Rinn, Miner, & Taylor, 2013).

The consequence of most immediate concern to students tends to be their math course performance. Given the aforementioned impact of math anxiety on students' emotional, cognitive, and behavioral functioning, it is unsurprising that elevated math anxiety has been consistently linked to poor performance in math courses, particularly among female-identified students (Ashcraft & Krause, 2007; Van Mier, Schleepen, & Van den Berg, 2019; Zhang et al., 2019). In fact, the inverse relationship between math anxiety and math achievement holds true even when controlling for students' levels of mathematical ability (Daker et al., 2021). It is clear how such a process may create a maladaptive cycle whereby students feel anxious about math, have difficulty completing math tasks to the best of their ability, perform poorly on those tasks, and subsequently perceive their fears regarding their math capacity validated – thereby increasing their anxiety levels.

Math anxiety and math course performance is of particular concern for students in non-STEM majors. Due, in part, to the self-selection bias previously described, students in these majors exhibit significantly higher levels of math anxiety than do their STEM major counterparts, with some suggesting that math anxiety mitigation techniques may be of particular importance for students seeking degrees in these fields (Leppma & Darrah, 2022; Malik, 2014). This is especially true of students who major in fields like psychology, which requires them to complete mathematics courses (e.g., statistics) and apply mathematical knowledge throughout many other courses (e.g., research methods, research seminars; Lester, 2016; Walker & Brakke, 2017). As these students tend to have significant difficulty completing their math-heavy courses and subsequently finishing their degrees in a timely manner, it is crucial to develop manageable classroom strategies for mitigating math anxiety among non-STEM college students.

A variety of interventions have been identified to decrease math anxiety among students. Some are focused on individuals close to these students, such as decreasing teachers' and parents' levels of math anxiety (Maloney, Ramirez, Gunderson, Levine, & Beilock, 2015; Murr, 2001; Uusimaki & Nason, 2004) or increasing caregiver support of students' math efforts (Wang, Borriello, Oh, Lukowski, & Malanchini, 2021). Others suggest major structural changes to math courses, such as creating single-gender math courses (Brunson, 1983; Campbell & Evans, 1997), offering mathematics courses in an online format (Taylor & Mohr, 2001), and designing prerequisite courses specifically aimed at decreasing math anxiety (Iossi, 2007). At the student level, there is compelling evidence for the utility of psychotherapeutic interventions, such as cognitive behavioral therapy or mindfulness-based treatments, to alleviate math anxiety and promote math achievement (Asanjarni & Zarebahramabadi, 2021; LaGue et al., 2019; Samuel, Buttet, & Warner, 2022). While each of these strategies appears useful in decreasing math anxiety, none are focused on shorter-term, class-wide reductions in this anxiety.

The student-teacher alliance offers one potential avenue by which this class-wide decrease in math anxiety might occur. Existing research on elementary and middle school-aged students suggests that this alliance can increase student performance in math classes by decreasing math anxiety (Semeraro, Giofre, Coppola, Lucangeli, & Cassibba, 2020; Zhou et al., 2019), with work by Patrick and colleagues (2003) demonstrating that supportive instructors tend to promote an approach, rather than avoidance, orientation toward challenging or anxiety-provoking mathematical concepts among students. This may be similar to the ways in with the therapeutic alliance in psychotherapy can facilitate decreased avoidance and, subsequently, decreased anxiety in exposure-based treatments for specific phobias (Buchholz & Abramowitz, 2020; Liber et al., 2010). However, given that elementary and middle school students typically experience significantly more interaction with their math instructors, the extent to which these findings generalize to college students is unclear.

The present study therefore aimed to examine the student-teacher alliance as a potential moderator of the link between math anxiety and math course performance among non-STEM college students. It was hypothesized that students who felt a stronger connection to their math instructor would experience a weaker impact of math anxiety on course grades, suggesting that the student-teacher alliance may act as a protective factor which buffers against the harmful impact of math anxiety on achievement.

Method

Participants

Participants were recruited from two sections of the author's Advanced Statistics for Psychology course. All students enrolled in this course were invited to participate in the present study in exchange for extra credit and the opportunity to win a $10 gift card in a raffle. Students who did not wish to participate were offered an alternative extra credit opportunity. Out of 43 total students enrolled in this course, 41 elected to participate in the study (age M = 22.31 years, SD = 4.91). Sample characteristics are presented in Table 1. All procedures in this study were approved by the Institutional Review Board.

Table 1. Sample characteristics.

Characteristic	*n*	%
Gender		
Male	7	17.1%
Female	28	68.3%
Non-binary	1	2.4%
Race/Ethnicity		
White	26	63.4%
Black	3	7.3%
Hispanic/Latinx	3	7.3%
Native American	3	7.3%
Other	1	2.4%
Parent Education		
High School or Equivalent	5	12.2%
Associate's Degree	5	12.2%
Bachelor's Degree	11	26.8%
Master's Degree	13	31.7%
Doctoral Degree	2	4.8%

Note: 5 participants declined to provide demographic information.

Measures

Math anxiety

The Math Evaluation Anxiety subscale of the Math Anxiety Rating Scale – Revised (MARS-R-MEA; Hopko, 2003) was administered to assess students' performance-based mathematics anxiety. Students were asked to rate their typical anxiety levels in situations such as "thinking about an upcoming math test one day before" on a scale from 0 (no anxiety) to 4 (high anxiety). Cronbach's alpha for this subscale was .84.

Student-teacher alliance

The Learning Alliance Inventory (LAI; Rogers, 2012) was administered to assess the strength of the student-teacher relationship. This measure assesses students' sense of their bond with the instructor ("My teacher and I have connected"), the instructor's competency ("My teacher welcomes all student input and feedback"), and their investment in the course ("The things we are doing in this course are helping me learn") on a scale from 1 (not at all) to 7 (very much). Cronbach's alpha for this measure was .91 at Time 1 and .94 at Time 2.

Trait anxiety

The Trait subscale of the State-Trait Anxiety Inventory (STAI-T; Spielberger, 1983) was administered to assess overall levels of general (i.e., not math-specific) anxiety. Students indicated the degree to which they generally feel "nervous and restless" or "calm, cool, and collected" (reverse-coded) on a scale from 1 (almost never) to 4 (almost always). Cronbach's alpha for this measure was .94.

Course performance

Student self-reported their final letter grade (e.g, A, A-, B+) at the end of the semester.

Procedures

One week after the start of the course, students were sent a link inviting them to provide their informed consent to participate in the present study and complete Time 1 questionnaires (demographics, STAI-T, LAI). They completed Time 2 questionnaires (MARS-R-MEA, LAI) in the same manner during the last week of the semester, and they provided their final course grades once the semester had concluded. Missing data were as follows: MARS-R-MEA $n = 0$, LAI-1 $n = 5$, LAI-2 $n = 2$, STAI-T $n = 5$, grade $n = 14$. Cases were excluded listwise in analyses, bringing the total number of usable participants to 23. In order to examine changes in the student-teacher alliance over the course of the semester, an LAI difference score was computed for each participant by subtracting their Time 1 LAI score from their Time 2 score (i.e., $LAI_{diff} = LAI_{Time2} – LAI_{Time1}$). All analyses were conducted using SPSS version 27 and Hayes' PROCESS version 4 (Hayes, 2022).

Results

A moderated regression analysis was conducted with LAI_{diff} scores entered as a predictor, final course grades entered as an outcome variable, MARS-R-MEA scores entered as a moderator, and STAI-T scores entered as a covariate. The overall model was significant, suggesting that these factors have a significant impact on math course performance, $F(4, 18) = 4.22, p = .014$. Consistent with hypotheses, results indicated that students performed more poorly in the course when they had higher levels of math anxiety, $t(18) = -2.57, p = .019$, and a weaker bond with the instructor, $t(18) = 2.58, p = .019$. Unexpectedly, students also performed more poorly when they had lower levels of trait anxiety, in contrast with present findings for math-specific anxiety, $t(18) = 2.54, p = .021$. This pattern of results remains intact when controlling for students' math anxiety at Time 1, though this was not of primary interest to the present study ($F(5, 17) = 3.66, p = .02$).

Findings also indicated a significant moderation effect, $t(18) = -2.47, p = .004$, such that students with low to moderate math anxiety performed better in their statistics course when the student-teacher alliance was strong (low anxiety: $t(18) = 2.66, p = .016$; moderate anxiety: $t(18) = 2.79, p = .035$). The student-teacher alliance did not impact course grades for students with high levels of math anxiety, $t(18) = -0.37, p = .717$. This suggests that a strong student-teacher alliance enhances performance only among students who experience elevated anxiety related to course content and may not have a significant impact on low-anxiety students. See Figure 1 for an illustration of this interaction.

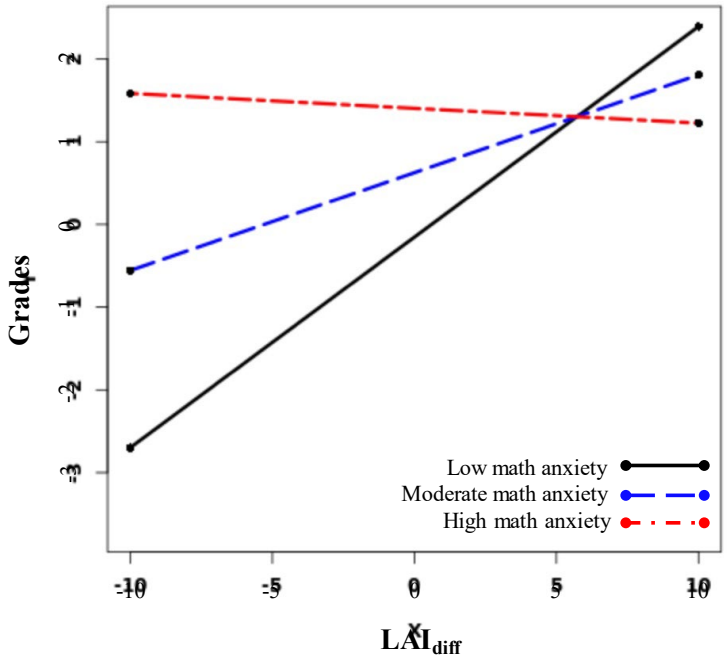

Figure 1. Interactions between LAI_{diff} and MARS-R-MEA scores for student course grades.

Discussion

The present study sought to examine whether a strong student-teacher alliance could buffer against the impact of math anxiety on course performance among non-STEM college students. Findings replicated existing work demonstrating that math anxiety has a detrimental impact on course performance, such that higher levels of math anxiety were associated with poorer final course grades. Also consistent with past work, results indicated that a stronger student-teacher alliance predicted better math performance, as indicated by higher grades. Moderation hypotheses received partial support, such that students with low to moderate math anxiety experienced less grade degradation when the student-teacher alliance was strong. However, among students with high math anxiety, the student-teacher alliance had no impact on their course performance. Surprisingly, results also indicated that students with low levels of trait anxiety performed more poorly in their statistics course than did students with higher trait anxiety.

The finding that the student-teacher alliance moderates the link between math anxiety and course performance is consistent with previous work by Semeraro, Zhou, and colleagues (2020; 2019), which demonstrated that a strong relationship between a student and their instructor can act as a protective factor against the harmful academic effects of moderate anxiety among elementary and middle school students. This echoes similar work in the field of psychotherapy research, which has consistently highlighted the therapeutic alliance as a key facilitator of positive therapeutic change and psychotherapy goal attainment (e.g., Arnow et al., 2013; Misdrahi, Petit, Blanc, Bayle, & Llorca, 2012; Ormhaug, Jensen, Wentzel-Larsen, & Shirk, 2014). In the present study, the protective effects of the student-teacher alliance may be attributed to the secure base effect, in which a supportive relationship is thought to provide a safe space from which an individual feels more confident taking appropriate risks and approaching anxiety-provoking stimuli (Bowlby, 2005; Feeney, 2004; Marmarosh et al., 2014). Indeed, existing work has demonstrated that teachers can act as a secure base for children in preschool through middle school, though this has not been examined among students in adolescence

or early adulthood (Al-Yagon & Mikulincer, 2006; Sierra, 2012). Such an interpretation is also consistent with research by Patrick and colleagues (2003) showing that a strong student-teacher alliance decreases student avoidance of math tasks among elementary and middle schoolers, suggesting that students are more willing to approach anxiety-provoking mathematical stimuli when they perceive their instructor to be a secure base for such behavior. As decreased avoidance of anxiety-inducing stimuli is a primary mechanism of change for evidence-based treatments for anxiety disorders (Buchholz & Abramowitz, 2020), it is possible that a strong student-teacher alliance provides a secure base from which students with moderate math anxiety feel increasingly comfortable approaching, rather than avoiding, math stimuli, thus improving overall course performance.

As noted, the finding that the student-teacher alliance did not impact the course performance of students with high math anxiety was unexpected. However, the qualitative differences between moderate and high anxiety, including their impact on functional impairment, are well-documented. The Yerkes-Dodson Law, for instance, asserts that, while moderate anxiety can motivate adaptive behavior under the right circumstances, severe anxiety is typically maladaptive (Deshpande & Kawane, 1982; Mellifont, Smith-Merry, & Scanlan, 2016). Further, common correlates of anxiety, such as maladaptive, action-inhibiting thought processes, increase linearly with anxiety levels, such that those with moderate levels of anxiety have significantly fewer of these cognitions than do those with high anxiety (Galassi, Frierson, & Sharer, 1981). In the context of the therapeutic alliance, work by Mason, Driessen, and colleagues (2015; 2010) indicates that highly anxious clients respond differently to clinician characteristics than do low-to-moderately anxious clients, as do clients with moderate vs. high levels of depressive symptoms. Furthermore, the therapeutic alliance has been shown to play less of a role in clients' treatment progress among those with greater symptom severity, with highly anxious clients often requiring more intensive intervention (Cohen, Kim, Van, Dekker, & Driessen, 2020; Leichsenring, 2001). It appears, then, that for students with high levels of math anxiety, the student-teacher alliance alone is insufficient to protect against the maladaptive effects of this anxiety on their course performance.

The finding that students with lower trait anxiety earned poorer grades in their statistics course may also be interpreted in the context of the Yerkes-Dodson Law. Prior research has demonstrated that students with low math anxiety tend to perform worse than do students with moderate levels of math anxiety, ostensibly due to the motivating effect that adaptive levels of anxiety typically have on behavior (Deshpande & Kawane, 1982; Keller, 2010; Mellifont et al., 2016; Wang et al., 2015). This might be particularly relevant in the context of required mathematics courses for non-STEM majors, as low motivation is consistently highlighted as a key factor impeding student success in these classes (Acee & Weinstein, 2010; Lavasani, Weisani, & Ejei, 2011; Roberts & Glynn, 1979; Vaessen et al., 2016). It therefore appears that significantly low levels of trait anxiety may hinder student performance in mathematics courses by decreasing motivation to approach unappealing stimuli (e.g., math homework).

Present findings have implications for both classroom instruction and education research. With respect to practical applications, this work suggests that college-level math instructors should be particularly attentive to the alliances they are forming with each of their students over the course of each semester, particularly if they are teaching a course designed for non-STEM majors. This might be facilitated by smaller class sizes, informal review sessions, offering praise for effort in addition to grade-based outcomes, and periodic assessment of students' perceptions of this alliance throughout each semester (Blatchford, Bassett, & Brown, 2011; Ferrandino, 2016; McGrath & Van Bergen, 2015). These findings also suggest that students with significantly elevated levels of math anxiety would likely benefit from more direct, intensive interventions, such as referrals to individual psychotherapy services to learn mindfulness and cognitive restructuring skills to support course performance, as the student-teacher alliance alone is unlikely to produce a sufficient protective buffer against poor course outcomes

(Asanjarni & Zarebahramabadi, 2021; LaGue et al., 2019; Samuel et al., 2022). Regarding research implications, present results highlight the importance of examining student-teacher relationships outside of the preschool, elementary school, and middle school contexts in which they are typically studied, as these relationships continue to impact student outcomes into their college years despite the limited contact that undergraduate students often have with their instructors. Further, findings underscore the importance of considering the full spectrum of anxiety, rather than categorizing students as anxious vs. not anxious, when examining the impact of math anxiety on academic functioning – a concept that is consistent with proposed changes to the current diagnostic system for anxiety disorders (Cuthbert & Insel, 2013).

The present study is not without limitation. As instructor warmth and other alliance-promoting factors were not experimentally manipulated, causation cannot be explicitly inferred from these findings. Further, sampling from the author's own course necessitated a non-double-blind study design, which may have introduced experimenter bias and issues with demand characteristics. While anonymized and computerized data collection procedures hopefully helped to minimize these concerns, future studies should strive to replicate this work in a way that addresses these potential issues by either (1) experimentally manipulating instructor behavior, perhaps in a shorter-term laboratory setting, or (2) sampling across courses with different instructors and using hierarchical linear modeling to account for natural variability in instructor behavior. Replication is particularly important in this case given the relatively small sample, and future studies should strive to recruit from a more diverse pool of students in order to enhance the generalizability of these findings – which is particularly important given the documented differences in math anxiety and performance based on gender and racial identity. Finally, future studies should continue to examine the full spectrum of student anxiety levels, including recruiting students with clinically significant levels of anxiety, in order to further clarify the protective role of the student-teacher alliance on math achievement.

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