A Multidimensional Examination of Math Anxiety and Engagement on Math Achievement

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Abstract

Background: Math anxiety (MA) and math achievement are generally negatively associated. **Aims:** The current study investigated whether and how classroom engagement behaviors mediate the negative association between MA and math achievement. **Sample:** Data were drawn from an ongoing longitudinal study that examines the roles of affective factors in math learning. Participants consisted of 207 students from 4th through 6th grade (50% female). **Methods:** MA was measured by self-report using the Mathematics Anxiety Scale for Children (MASC; Chiu & Henry, 1990). Students self-reported their engagement in math classrooms using a modified version of the Math and Science Engagement Scale (MSES; Wang et al., 2016). Math achievement was assessed using the Applied Problem, Calculations, and Number Matrices subtests from the Woodcock-Johnson IV Tests of Achievement (Schrank et al., 2014). Mediation analyses were conducted to examine the mediating role of classroom engagement in the association between MA and math achievement. **Results:** Students with higher MA demonstrated less cognitive-behavioral and emotional engagement compared to students with lower MA. Achievement differences among students with various levels of MA were partly accounted for by their cognitive-behavioral engagement in the math classroom. **Conclusions:** Overall, students with high MA exhibit avoidance patterns in everyday learning, which may act as a potential mechanism for explaining why high MA students underperform their low MA peers.

Keywords: math anxiety, learning avoidance, engagement, math achievement, elementary and middle school

A Multidimensional Examination of Math Anxiety and Engagement on Math Achievement

Math anxiety (MA) and math achievement are generally negatively associated (Barroso et al., 2021). In addition, higher MA has also been linked to greater avoidance patterns when selecting math electives, participating in math extracurricular activities, and considering math-specific career paths (Hembree, 1990; LeFevre et al., 1992). It has been proposed that these avoidance behaviors may account for the underachievement in highly math anxious students across developmental stages (Hembree, 1990). However, there is a scarcity of empirical work that investigates (1) whether highly math anxious students in early educational stages (e.g., elementary and middle school) exhibit avoidance behaviors in everyday learning, and (2) whether learning avoidance mediates the negative association between MA and math achievement in early educational stages. Additionally, most of the literature examined MA as a unidimensional rather than multidimensional construct (Lukowski et al., 2019). This may be problematic as different MA dimensions may evince distinct associations with math learning and achievement outcomes (Lukowski et al., 2019). The current study seeks to address these gaps in the literature by examining whether math learning avoidance mediates the negative associations between the multiple dimensions of MA and math achievement in elementary and middle school students. By operationalizing learning avoidance as the lack of cognitive, behavioral, emotional, and social engagement in the math classroom, we aim to answer three main questions: (1) Do students with higher MA engage less in learning in the math classroom? (2) If so, does their lower engagement predict poorer math achievement outcomes? (3) Do the different dimensions of MA and engagement uniquely predict achievement outcomes?

Math Anxiety and Math Achievement

MA is characterized by feelings of helplessness, apprehension, and worry in math situations (Hembree, 1990). An increasing number of studies have pointed to the multidimensionality of MA and highlighted the necessity to investigate these dimensions separately (Chiu & Henry, 1990; Lee, 2009; Lukowski et al., 2019; Maloney et al., 2011; Tsui & Mazzocco, 2007). Chiu and Henry (1990) have identified three unique dimensions of MA: test MA, learning MA, and application MA. Test MA refers to the experience of anxiety prior to or during a math exam; learning MA refers to experiencing anxiety when learning math inside the classroom; application MA refers to anxious feelings experienced when performing math calculations (Chiu & Henry, 1990; Lukowski et al., 2019; Maloney & Beilock, 2012). Chiu and Henry (1990) argue that it is crucial to examine each dimension of MA separately since the effects on a specific outcome may vary dependent upon the dimension of MA being examined. This argument has received some empirical support. For instance, Lukowski and colleagues (2019) found that upon holding general anxiety constant, only application MA was negatively associated with math achievement, while test MA and learning MA were not associated with math achievement.

Despite the multidimensionality of MA, MA has generally been examined as a unidimensional construct (Lukowski et al., 2019) that is negatively associated with math achievement (Barroso et al., 2021; Hembree, 1990; Ma, 1999; Namkung et al., 2019). This negative association is proposed to be partly attributable to learning avoidance in highly MA students (Hembree, 1990). Specifically, a student who experiences the negative physiological and psychological reactions that encompass MA is expected to be less engaged in math-related activities, which deprives them of learning and practice opportunities and paves the way for less desirable math achievement outcomes.

Several studies support this proposition by showing that students with higher levels of MA have greater avoidance when it comes to math related electives, extracurricular activities, college majors, and career paths (Hembree, 1990; LeFevre et al., 1992). Specifically, students with higher MA tend to select fewer advanced math elective courses as well as avoid math-intensive college majors and professions (Hembree, 1990; LeFevre et al., 1992). However, these studies suffer from several major limitations that prevent us from gaining insights into the proposed avoidance mechanism underlying the development of negative math outcomes in math anxious students. First, these existing studies focused exclusively on adolescent and adult samples, and none investigated learning avoidance in younger students. As individual differences in MA emerge as early as kindergarten or first grade (Ganley & McGraw, 2016; Lu et al., 2019), it is unclear whether highly math anxious elementary school students already begin to avoid math-related learning and activities. Understanding avoidance behaviors in younger students is critical because students gain foundational math skills in these early educational stages that have long lasting impact on subsequent math learning (Duncan et al., 2007). The present study addresses this issue by using a sample of elementary and middle school students.

Another major gap in the current literature is that most studies focused on examining distal outcomes, such as avoiding math majors and occupations, which does not inform us about how MA is associated with learning behaviors that contribute to knowledge acquisition and retention (or lack thereof). In other words, these distal behaviors may be consequences of poor math achievement, rather than mediators that account for the association between MA and math achievement. To tackle this issue, studies that examine everyday math learning behaviors (e.g., engaged with the learning materials, participating in math learning activities, time spent learning new strategies, etc.) are needed. One such study examined everyday math learning in afterschool settings in a sample of high school students (Hasty et al., 2020). This study found that math anxious students spent as much time as math non-anxious students on learning math in afterschool settings, such as doing homework and taking afterschool math lessons, which fails to support the proposed avoidance mechanism (Hasty et al., 2020).

Given that most formal math learning occurs in the classroom, it is imperative to understand whether and to what degree math anxious students avoid math learning in the classroom setting, and how these classroom avoidance behaviors may contribute to their development of math deficits. In the compulsory educational stage, while complete avoidance of math is essentially impossible, students' avoidance behaviors may take the form of lack of engagement in math class, such as not paying attention to lectures or participating in classroom learning activities (Guthrie et al., 2012). As such, the present study addresses the second limitation in the existing literature by operationalizing learning avoidance as the lack of classroom engagement and examining whether and to what degree students' engagement in the math classroom (1) vary as a function of students' MA levels, and (2) mediate the association between MA and math achievement.

Classroom Engagement

Classroom engagement is a multidimensional construct that is an important predictor for academic outcomes (Hughes et al., 2008). Four dimensions of classroom engagement have been identified: cognitive, behavioral, emotional, and social (Fredricks et al., 2004; Wang et al., 2016). Cognitive engagement refers to partaking in deep learning strategies (e.g., making connections between old and new learning materials), examining new ways to solve a problem, and evaluating previous learning techniques. Behavioral engagement refers to actively listening during class and participating in classroom activities and discussion. Emotional engagement refers to the positive and negative affect associated with the classroom environment and learning tasks. Finally, socially engaged students are those who participate in productive group interactions, follow classroom rules, and collaborate with peers.

Overall, classroom engagement as a unidimensional construct has been found to be positively correlated with academic achievement (Fredricks et al., 2004; Wang et al., 2016; Wang & Holcombe, 2010). However, the strength and direction of the association between each engagement dimension and achievement are not as definitive. While behavioral, cognitive, and emotional engagement are generally found to positively predict academic achievement (Fredricks et al., 2004; Lei et al., 2018), the association between behavioral engagement and academic achievement appears to be the strongest and most robust (Fredricks et al., 2004; Lei et al., 2018; Wang et al., 2016). In a recent meta-analysis, Lei and colleagues (2018) found that the average effect size of the association between behavioral engagement and achievement was stronger than the size of the associations between both cognitive and emotional engagement and achievement. In addition, one recent study shows that neither cognitive nor emotional engagement in the math classroom significantly predicted math achievement above and beyond the effect of behavioral engagement (Wang et al., 2016), similarly suggesting the unique and robust predictive effect of behavioral engagement on academic achievement. The relationship between social engagement and achievement is much less understood due to limited literature examining this association. One study found that social engagement, when examined in conjunction with the other three dimensions of engagement, was negatively associated with math achievement (Wang et al., 2016).

The important questions that remain to be answered are "how engaged are highly math anxious students in the math classroom" and "to what extent do their engagement patterns account for their undesired math performance”. The avoidance mechanism proposes that highly math anxious students take every opportunity to avoid engaging in math-related activities, which hinders the development of math knowledge and skills (Hembree, 1990). Existing studies show that students who experience negative emotions (e.g., anxiety) in the classroom tend to stop paying attention to and taking part in classroom discussion to protect themselves from developing more negative emotions in that context (Chen et al., 2020; Do & Schallert, 2004; England et al., 2017). For example, students with high MA may not answer questions in class due to worrying about answering incorrectly. They may also refuse to ask questions in class to avoid appearing less intelligent than their peers. Therefore, it is possible that highly math anxious students may choose to not engage in the math classrooms by refusing to engage in deep learning strategies (cognitive engagement), not paying attention to the lectures (behavioral engagement), feeling distressed and frustrated (emotional engagement), or failing to participate in teamwork or collaborate with peers (social engagement). These disengagement patterns may, in turn, deprive highly math anxious students of learning and practice opportunities as well as opportunities to receive feedback. This may ultimately result in negative math achievement outcomes. The present study investigates these possibilities.

The Current Study

Taken together, there is a gap in the literature regarding the extent to which highly math anxious students exhibit learning avoidance behaviors in early educational stages, and whether these learning avoidance behaviors contribute to their math achievement development. This knowledge gap is mainly attributable to two limitations in the extant literature, namely (1) the lack of investigation of this issue in the younger student population, and (2) the operationalization of learning avoidance as avoidance of distal outcomes (e.g., career choice).

The current study seeks to bridge this knowledge gap by investigating whether and how learning avoidance behaviors mediate the negative association between MA and math achievement. To address the limitations in the literature, we (1) employed a sample of elementary and middle school students, and (2) operationalized learning avoidance as the lack of engagement in everyday math classrooms. Additionally, considering the multidimensional nature of both MA and classroom engagement, it is possible that different dimensions of these constructs may relate to math achievement in different ways (Fredricks et al., 2004; Lukowski et al., 2019; Wang et al., 2016). Therefore, the present study took a multidimensional approach to investigate the generalizability and specificity of the avoidance mechanism underlying the MA-math achievement association across the multiple dimensions of MA and math engagement.

According to the avoidance hypothesis (Hembree, 1990), we expect that there would be a negative association between MA and math achievement that is mediated by engagement in the math classroom. Regarding the multidimensionality of MA, given that engagement was operationalized in the classroom context, we expect that the negative association between learning MA (defined as anxiety experienced when learning math in class) and math achievement would be mediated by classroom engagement. Classroom engagement may not mediate the associations between test MA and math achievement and between application MA and math achievement, since these constructs are not operationalized specifically in the classroom learning context. Regarding the multidimensionality of classroom engagement, behavioral engagement has been found to predict academic achievement most robustly among all dimensions of classroom engagement (Lei et al., 2018; Wang et al., 2016). As such, we hypothesize that behavioral engagement would most robustly mediate the negative association between MA and math achievement.

Methods

Participants

Participants are part of an ongoing longitudinal study that examines the roles of affective factors in math learning. Participants were recruited using convenience sampling from a city located in the northwest Texas area. Specifically, announcements regarding the study were posted online via the university mass emailing system as well as various social media platforms. Additionally, families were recruited from school outreach events and by word-of-mouth. Participants consisted of 207 students from 4^{th} through 6^{th} grade (50% female) and one parent for each student. The average age of student participants ranged from 8 to 12 years (M = 10.18, SD = 1.04). Among the 207 students, 68% are White, 8% are African American, 6% are Asian, 2% Native American or Alaska Native, and 15% are other races. In terms of ethnicity, 38% are Hispanic. The distribution of family annual income and highest parental education is shown in Table 1.

Procedure

Each participating family was invited to a lab located at Texas Tech University for a 3-hour visit. At each lab visit, parental consent and child assent were first obtained. Next, both the parent and the child completed a series of computerized tasks (e.g., math problem solving tasks and executive function tasks), standardized achievement tests, as well as questionnaires. For the purpose of this specific study, we examined the data from students’ standardized achievement tests as well as the questionnaire responses of both the student and parent. The study was approved by the Texas Tech University Institutional Review Board (IRB).

Measures

Math Anxiety

Students' MA was measured by self-report using the Mathematics Anxiety Scale for Children (MASC; Chiu & Henry, 1990). This measure consists of 22 items with each item describing a math-related situation that may induce MA. Students provided their responses on a 4-point Likert scale (1 = *not nervous*; 4 = *very, very nervous*) to indicate their level of anxiety in each situation. As shown by Chiu & Henry (1990), the 22 items assessed three dimensions of MA, including seven items that measured test MA, eleven items that measured learning MA, and four items that measured application MA. Sample items for each dimension include: "*Taking an important test in a math class*" for test MA, "*Getting and reading a new math textbook*" for learning MA, and "*Reading and interpreting graphs or charts*" for application MA. Reliability was adequate for each subscale with Cronbach's α being 0.89, 0.85, and 0.63 for test MA, learning MA, and application MA, respectively.

Math Engagement

Students self-reported their engagement in math classrooms using a modified version of the Math and Science Engagement Scale (MSES; Wang et al., 2016). The original MSES contains items that assess engagement in both math and science classrooms, while the current modified version measures math engagement only. Additionally, while the original MSES is designed for middle and high school students, the current version is modified to be more age-appropriate for our sample of upper-level elementary and lower-level middle school students. Specifically, the length of the questionnaire is reduced from 33 items to 20 items. Items are selected to ensure that (1) both positive and negative worded items are covered, and (2) simply worded items are selected. Finally, the original MSES was found to measure four dimensions of engagement, including cognitive engagement, behavioral engagement, emotional engagement, and social engagement. The modified version retains five items for each dimension. Sample items included: "*I think about different ways to solve a math problem*" and "*I do not think that hard when I am doing work for math class*" for cognitive engagement, "*I stay focused in math class*" and "*I do not participate in math class*" for behavioral engagement, "*I look forward to math class*" and "*I think that math class is boring*" for emotional engagement, and "*I try to work with others who can help in math class*" and "*I do not like working with classmates in math class*" for social engagement. Responses were reported using a 5-point Likert type scale (1 = *definitely untrue*; 3 = *neither untrue nor true*; 5 = *definitely true*). The cognitive, behavioral, emotional, and social engagement subscales demonstrated adequate internal consistency with Cronbach's α of 0.65, 0.73, 0.86, and 0.66, respectively.

Math Achievement

Math achievement was assessed using the Applied Problem, Calculations, and Number Matrices subtests from the Woodcock-Johnson IV Tests of Achievement (Schrank et al., 2014). The Applied Problem subtest measures students' ability to complete applied mathematical word problems. The Calculations subtest measures students' computation ability regarding solving a series of arithmetic problems. The Number Matrices subtest measures students' math problem-solving ability in a matrix format. Each of the three subtests had good internal consistency reliability with Cronbach's α of .86, .89, and .91 respectively for Applied Problem, Calculation, and Number Matrices. The raw score for each of the subtest was used for subsequent analyses.

Covariates

Sex. Students' sexes were coded as 1 = male and 2 = female.

Grade. Students self-reported their grade level ranging from 4^{th} - 6^{th} grade.

General Anxiety. Student's general anxiety levels were measured using the Spence Children's Anxiety Scale (Spence, 1997), a self-report 6-item questionnaire with an acceptable internal consistency reliability (Cronbach's α = .82). Students reported their general anxiety levels using a 4-point Likert scale (0 = *never*; 1 = *sometimes*; 2 = *often*; 3 = *always*). Sample items included: "*I worry about things*" and "*When I have problems, my heart beats really fast*." A composite score was created for this scale with higher scores representing greater general anxiety.

Data Analytic Plan

Data preparation was done in SPSS v26 (IBM Corp., 2019). Structural equation modeling was conducted in Mplus v8.4 (Muthén & Muthén, 1998-2017).

To examine if the factor structures proposed by Chiu and Henry (1990) and by Wang and colleagues (2016) adequately captured the dimensions of MA and classroom engagement in the present sample, confirmatory factor analysis (CFA) was conducted for each construct. Specifically, a three-factor structure was tested for MA, with seven items loading on test MA, eleven items loading on learning MA, and four items loading on application MA (Model 1; Chiu and Henry, 1990). A four-factor structure model was tested for classroom engagement, with five items loading on each of the four engagement dimensions (Model 2a; Wang et al., 2016). Finally, a CFA model was tested for math achievement with the three subscale scores being the three indicators (Model 3).

After the measurement models were established, we examined the mediating role of classroom engagement in the association between MA and math achievement (Figures 1-3). We tested the predictive effects of the three dimensions of MA in three separate models to avoid issues of multicollinearity due to the strong correlations among different dimensions of MA. Models 4, 5, and 6 respectively examined the predictive effect of test MA, learning MA, and application MA on math achievement mediated by math engagement. Finally, child sex, grade level, and general anxiety were included as covariates in all the mediation models.

The weighted least square mean and variance adjusted (WLSMV) estimator was used for CFAs with categorical indicators (i.e., for MA and engagement). The robust maximum likelihood estimator was used for CFA for continuous indicators (i.e., for math achievement). For the mediation analyses, 95% bias corrected bootstrap confidence interval based on 5,000 bootstrap samples are reported. Comparative fit index (CFI) and the root mean square error of approximation (RMSEA) were used to evaluate model fit. The cut-off points for acceptable model fit were CFI > 0.90 and RMSEA < .08 (Hu & Bentler, 1999). In addition to these fit indices, chi-square was also reported.

Results

Descriptive Statistics

Descriptive statistics are presented in Table 2. In general, students reported modest to moderate levels of MA and moderate levels of engagement in the math classroom.

Confirmatory Factor Analyses

All fit indices for the CFA models are presented in Table 3. Model 1 (i.e., CFA for MA) had a good fit. All standardized factor loadings were 0.40 or higher with the exception of one loading on the application MA factor that was 0.25. While the loading for this item was slightly low, given that the overall model provided a reasonable fit to the data and it was consistent with prior research, we elected to retain this model. Omega was respectively 0.88, 0.85, and 0.65 for test, learning, and application MA.

Model 2a (i.e., cognitive, behavior, emotional, and social math engagement factors) had a poor fit to the data. Upon further examination of the data, we found that the cognitive engagement factor and behavioral engagement factor were highly correlated ($r = .92$), suggesting that the 4-factor structure may be a mis-specified model. Therefore, we combined the cognitive engagement and behavioral engagement factors to test a three-factor model instead (Model 2b). Results showed that the more parsimonious three-factor model did not fit worse than the four-factor model, but it can be further improved. Given that each scale contains both positively and negatively worded items, one possible way to improve the model fit is to consider the possible method effect associated with the direction of wording. Previous research shows that there may be additional correlations among negatively worded items above and beyond the substantive factor (Zhang et al., 2016). As such, we included correlations between the residuals of the negatively worded items within each factor (Model 2c), which further improved the fit of this model. The standardized factor loadings were all 0.40 or higher except for one indicator for the cognitive-behavioral engagement with a factor loading of 0.26. Removal of this item did not further improve model fit. Therefore, we used Model 2c as our final measurement model for engagement. Omega was respectively 0.79, 0.78, and 0.61 for cognitive-behavioral, emotional, and social engagement.

Model 3 is the measurement model for math achievement. This is a just-identified model for which model fit cannot be evaluated. All factor loadings were above 0.80, suggesting that these three subscales were coherent indicators of the latent math achievement construct. Omega was 0.87 for math achievement.

Correlations between the main study variables are shown in Table 4. The three dimensions of MA were modestly to moderately negatively correlated with cognitive-behavioral engagement, emotional engagement, and math achievement. MA was not correlated with social engagement. Both cognitive-behavioral and emotional engagement were modestly positively correlated with math achievement, while social engagement was negatively correlated with math achievement.

Structural Equation Model

Fit indices for the three SEM models are presented in Table 3. Models 4, 5, and 6 respectively examined the predictive effects of test MA, learning MA, and application MA on math achievement that were mediated by classroom engagement. All three models had an adequate fit. The predictive effects of the covariates in the three models are presented in Table 5. Overall, sex did not predict any main study variable. Grade positively predicted math achievement and negatively predicted application MA. General anxiety positively predicted all three dimensions of MA. The direct and indirect effects of the three dimensions of MA on math achievement were presented in Figures 1 – 3. The result patterns are highly similar across the three mediation models, which are presented together below.

To address the first research question "Do students with higher MA engage less in learning in the math classroom" as well as the third research question regarding the multidimensionality of MA and engagement, we examined the predictive effects of MA on engagement in the three models. We found that all three dimensions of MA negatively predicted cognitive-behavioral engagement and emotional engagement, suggesting that students with higher MA reported lower cognitive-behavioral and emotional engagement in math class. None of the three dimensions of MA predicted social engagement.

To examine our second research question "Does lower engagement among students with higher MA predict poorer math achievement" as well as the third research question regarding the multidimensionality of MA and engagement, we assessed the indirect effects of MA on math achievement mediated by engagement in the three models. The results showed that all three dimensions of MA indirectly predicted math achievement, which was mediated by cognitive-behavioral engagement. Neither emotional nor social engagement mediated the association between MA and math achievement.

Discussion

The present study tested the learning avoidance account for the negative association between MA and math achievement in elementary and middle school students. We investigated three main research questions: (1) Do highly math anxious students avoid learning by not engaging in the math classroom? (2) If so, does their learning avoidance account for their math underachievement as compared to their non-anxious peers? (3) Do different dimensions of MA and math engagement evince different patterns of associations with math achievement outcomes? In general, our findings suggest that students with higher MA demonstrated less cognitive-behavioral and emotional engagement compared to students with lower MA. Additionally, achievement differences among students with various levels of MA were associated with their different levels of cognitive-behavioral engagement in the math classroom.

In relation to our first research question, results showed that students with high MA demonstrated learning avoidance behaviors in the math classroom by disengaging from deep learning strategies, failing to pay attention or participate, and displaying negative emotions. This finding is consistent with the previous literature which reported that students with high MA tend to avoid math learning by not choosing math electives and college majors (Hembree, 1990; LeFevre et al., 1992). Our study extends this literature by revealing that high MA is associated with not only poor distal learning outcomes, but also undesired classroom learning behaviors in younger students. While younger students do not have the choice to simply avoid taking math courses altogether, those with high MA can still display avoidance by way of investing little mental, behavioral, and emotional effort in the math learning context.

However, our finding differs critically from one recent study that found no difference between high and low MA students in their learning avoidance behaviors (Hasty et al., 2020). This inconsistency may be primarily driven by the different operationalizations of learning avoidance between the two studies. Hasty and colleagues operationalized learning avoidance by the amount of time spent on afterschool learning, which focused on the quantity of learning that occurred in the afterschool context. The present study operationalized learning avoidance as engagement in the math classroom, which focused on the quality of the time spent learning. This critical difference between the two studies may imply that while high and low MA students may appear to spend the same amount of time on learning math (such as taking the same math class and spending the same amount of time doing homework), they may not achieve the same amount of learning.

This claim is supported by the findings to our second research question, which shows that the cognitive-behavioral dimension of engagement mediated the negative associations between MA and math achievement. This finding suggests that students with high MA are not as engaged in the classroom cognitive-behaviorally as their low MA peers, which may explain the math performance difference between these two groups of students. Students with higher MA are shown to pay less attention to lectures, participate and practice less in the math classroom, and are less likely to reflect on their learning strategies and past mistakes. Additionally, such a lack of cognitive-behavioral engagement is associated with inefficient information acquisition and few practice opportunities, which ultimately results in poorer academic skills and slow academic progress (Fredricks et al., 2004; Lei et al., 2018; Wang et al., 2016). These critical differences in the mental and behavioral effort in the formal math learning setting likely account for the math achievement gap between students with low versus high MA.

Our third research question concerns the multidimensionality of MA and math engagement and the variability of findings across their respective dimensions. Inconsistent with our hypotheses, all three dimensions of MA negatively predicted cognitive-behavioral engagement and emotional engagement but not social engagement. This suggests that the association between MA and students' learning avoidance (as operationalized by classroom engagement) is not attributable to anxiety in a specific context; rather, it is likely attributable to a general experience of anxiety across all math-related situations.

In relation to the multidimensionality of engagement, we found that only cognitive-behavioral engagement was positively associated with math achievement. While emotional engagement was positively correlated with math achievement, it did not uniquely predict math achievement independent of the effect of cognitive-behavioral engagement. Additionally, social engagement negatively predicted math achievement. These results are consistent with the existing studies (Lei et al., 2018; Wang et al., 2016), highlighting the unique and robust positive effect of cognitive and behavioral engagement on achievement outcomes. It is worth noting that while MA negatively predicted both cognitive-behavioral engagement and emotional engagement, only the former mediated the negative association between MA and math achievement. This finding suggests that negative emotions in the math classroom alone are not sufficient to produce negative performance outcomes. Rather, it is when such negative emotions translate into actions (e.g., lack of attention and participation) that we observe negative learning outcomes. Finally, social engagement negatively predicted math achievement. It is possible that socially engaged students rely on peers for support, where too much support seeking leaves them little room for independent work and ultimately negatively impacts their learning and performance (Skinner & Saxton).

Finally, several findings regarding the effects of the covariates are worth noting. Sex did not predict any main variable, suggesting no sex differences in MA, classroom engagement, and math achievement. These results align with recent meta-analytic findings of negligible differences in math achievement and small differences in MA between male and female students, which are likely undetectable by the present sample size (Else-Quest et al., 2010; Hyde, 2014). General anxiety was positively associated with all three dimensions of MA. This is consistent with the literature, suggesting that students with more general anxiety are more likely to experience domain-specific anxiety such as MA (Hembree, 1990).

Limitations

The present study has several limitations. The first limitation is the use of a cross-sectional design, which limits our ability to make causal inferences among the study variables. While it is possible that students with higher MA have poorer math performance due to their avoidance behaviors in the classroom, it is also possible that students who struggle with math are more likely to develop MA (Gunderson et al., 2018; Song et al., 2021; Wang et al., 2020), which results in difficulties in classroom engagement. Future research needs to examine these associations in a longitudinal design to further inform us the temporal precedence in the association among MA, math engagement, and math achievement. Regarding the MA measurement, it is possible that this explicit measure of MA did not account for all dimensions of students' anxiety experiences. Recent research suggests that implicit measures of MA capture processes that are distinct from explicit measures of MA, and that both types of measures contribute to explain math behaviors (Ouimet et al., 2009; Schmitz et al., 2019). Future studies would benefit from examining MA both explicitly and implicitly to provide a more comprehensive understanding of the physiological and psychological processes experienced by students with MA. Additionally, the cognitive engagement dimension was not distinguishable structurally from the behavioral engagement dimension in the current sample. The scale was originally developed for upper middle and high school students. Students in our sample may be too young to differentiate questions regarding cognitive versus behavioral engagement. Finally, both MA and engagement were self-reported, which may have resulted in an inflation of correlation between the two constructs as a result of shared informant. Future studies would benefit from a multi-informant approach to assess classroom engagement.

Conclusion and Implications

Our findings critically contribute to the literature by showing, for the first time, that high MA students not only exhibit avoidance in everyday learning in elementary and middle school, but their learning avoidance also partly explains why they underperform their low MA peers on math achievement tests. Elementary and middle school aged students do not have the option to avoid math-related courses altogether; thus, they may channel their MA through mentally, behaviorally, and emotionally disengaging from the unavoidable classroom learning, which may result in poorer achievement outcomes. While math teachers may not be able to identify students with high MA or know how to treat or mitigate students' MA, signs of cognitive and behavioral engagement (or lack thereof) are readily observable. The present findings suggest that identifying and addressing the lack of these observable engagement behaviors may break the negative link between MA and math achievement. Therefore, by creating an environment where cognitive and behavioral engagement is monitored, encouraged, and fostered, educators can help promote math achievement and academic successes among highly math anxious students.

Declaration of Interest:

The authors report no conflict of interest.

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Table 1

Distribution of Family Income and Parental Education

	Category	*N*	%
Annual Household Income	Less than $20,000	18	9
	$20,000 or more but less than $40,000	28	14
	$40,000 or more but less than $60,000	36	18
	$60,000 or more but less than $80,000	29	14
	$80,000 or more but less than $100,00	38	19
	$100,000 or more but less than $150,000	30	15
	$150,000 or more	23	11
Parental Highest Level of Education	Grades 7-12 (without graduating high school)	7	3
	Graduated high school or high school equivalent	13	6
	Some college	37	18
	Graduated from 2-year college	14	7
	Graduated from 4-year college	57	28
	Attended graduate/professional school w/o graduating	10	5
	Completed graduate/professional school	63	30
	Other	4	2

Table 2

Descriptive Statistics for Items

	M	*SD*	Min	Median	Max
MA					
Item 1	1.51	.73	1	1	4
Item 2	1.79	.74	1	2	4
Item 3	1.35	.69	1	1	4
Item 4	1.33	.68	1	1	4
Item 5	1.68	.88	1	1	4
Item 6	1.66	.81	1	2	4
Item 7	1.86	.90	1	2	4
Item 8	1.66	.93	1	1	4
Item 9	1.90	1.00	1	2	4
Item 10	1.54	.84	1	1	4
Item 11	1.96	.94	1	2	4
Item 12	1.36	.74	1	1	4
Item 13	1.50	.78	1	1	4
Item 14	1.86	.89	1	2	4
Item 15	2.62	1.04	1	3	4
Item 16	2.46	1.05	1	2	4
Item 17	2.01	1.08	1	2	4
Item 18	2.08	.99	1	2	4
Item 19	1.88	.87	1	2	4
Item 20	2.83	1.08	1	3	4
Item 21	2.49	1.07	1	2	4
Item 22	2.80	1.08	1	3	4
Math Engagement					
Item 1	3.88	1.18	1	4	5
Item 2	3.66	1.29	1	4	5
Item 3	4.23	1.05	1	5	5
Item 4 (negatively worded)	2.56	1.43	1	2	5
Item 5 (negatively worded)	2.62	1.53	1	3	5
Item 6	3.70	1.23	1	4	5
Item 7	4.16	1.08	1	4.5	5
Item 8	4.17	1.02	1	4	5
Item 9 (negatively worded)	1.87	1.31	1	1	5
Item 10 (negatively worded)	1.56	1.08	1	1	5
Item 11	3.41	1.41	1	4	5
Item 12 (negatively worded)	2.37	1.38	1	2	5
Item 13 (negatively worded)	2.79	1.46	1	3	5
Item 14 (negatively worded)	2.66	1.52	1	3	5

Item 15 (negatively worded)	2.20	1.46	1	1	5
Item 16	3.77	1.10	1	4	5
Item 17	3.59	1.23	1	4	5
Item 18	3.96	1.18	1	4	5
Item 19 (negatively worded)	2.33	1.40	1	2	5
Item 20 (negatively worded)	2.02	1.26	1	1	5
Math Achievement					
Applied Problem	35.94	5.21	21	36	52
Calculation	30.02	5.90	13	30	49
Number Matrices	14.68	5.95	0	14	28
General Anxiety	2.10	.68	1	2	4

Note. MA = math anxiety.

Table 3

Fit Indices for the CFA and Structural Equation Models

Models	Chi-Square (df)	CFI	RMSEA
Model 1 – MA CFA	321.04 (206)*	.97	.05
Model 2a – Math Engagement 4 factors CFA	475.30 (164)*	.89	.10
Model 2b – Math Engagement 3 factors CFA	480.14 (167)*	.89	.10
Model 2c – Math Engagement 3 factors with Correlated Residuals CFA	392.31 (154)*	.92	.09
Model 3 – Math Achievement CFA	.00 (0)*	1.00	.00
Model 4 – Test MA Mediation	837.33 (489)*	.91	.06
Model 5 – Learning MA Mediation	822.13 (489)*	.90	.06
Model 6 – Application MA Mediation	726.01 (426)*	.91	.06

Note. MA = math anxiety; * indicates statistical significance under Type I error rate of .05

Table 4

Correlations between Main Study Variables

	1	2	3	4	5	6
1. Test MA	1					
2. Learning MA	.86*	1				
3. Application MA	.80*	.89*	1			
4. Cognitive-behavioral engagement	-.36*	-.37*	-.38*	1		
5. Emotional engagement	-.51*	-.54*	-.36*	.76*	1	
6. Social engagement	-.02	-.03	-.02	.76*	.50*	1
7. Math achievement	-.28*	-.28*	-.55*	.25*	.19*	-.15*

Note. MA = math anxiety; * denotes statistical significance under type I error rate of 0.05.

Table 5

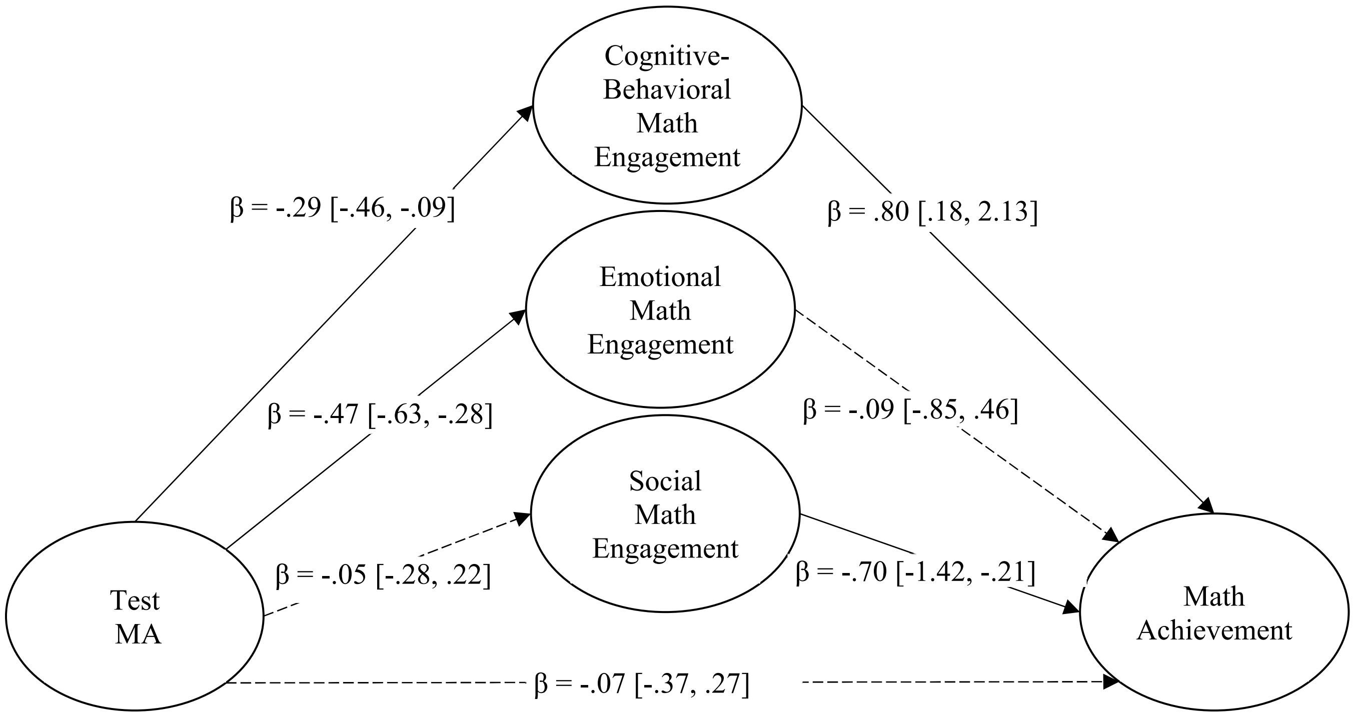
Effects of Covariates in the Mediation Models: Standardized Path Estimates and 95% Bias Corrected Bootstrap Confidence Intervals

	Model 4 Test MA Mediation	Model 5 Learning MA Mediation	Model 6 Application MA Mediation
Sex → MA	.10 (-.04, .24)	.08 (-.09, .23)	-.03 (-.19, .14)
Sex → Cognitive-behavioral engagement	.04 (-.11, .18)	.03 (-.12, .18)	.00 (-.15, .14)
Sex → Emotional engagement	-.06 (-.22, .09)	-.07 (-.23, .08)	-.12 (-.28, .04)
Sex → Social engagement	.03 (-.14, .21)	.04 (-.14, .20)	.03 (-.16, .20)
Sex → Math achievement	-.09 (-.32, .08)	-.09 (-.32, .08)	-.12 (-.33, .04)
Grade → MA	.07 (-.06, .20)	.03 (-.12, .17)	-.17 (-.31, -.03)*
Grade → Cognitive-behavioral engagement	.03 (-.13, .18)	.02 (-.13, .17)	-.05 (-.20, .11)
Grade → Emotional engagement	-.05 (-.21, .10)	-.07 (-.22, .08)	-.15 (-.31, .02)
Grade → Social engagement	-.02 (-.19, .15)	-.02 (-.19, .14)	-.05 (-.21, .13)
Grade → Math achievement	.39 (.17, .58)*	.39 (.16, .57)*	.31 (.07, .50)*
General anxiety → MA	.38 (.23, .51)*	.36 (.21, .50)*	.48 (.35, .62)*
General anxiety → Cognitive-behavioral engagement	-.13 (-.33, .06)	-.14 (-.33, .06)	-.08 (-.29, .13)
General anxiety → Emotional engagement	-.08 (-.24, .08)	-.08 (-.24, .10)	-.07 (-.27, .13)
General anxiety → Social engagement	.12 (-.12, .33)	.13 (-.12, .37)	.16 (-.10, .40)
General anxiety → Math achievement	.01 (-.20, .34)	.00 (-.19, .35)	.13 (-.08, .44)

Note. MA = math anxiety; * indicates statistical significance under the Type I error rate of .05

Figure 1

Standardized Path Estimates and 95% Bias Corrected Bootstrap Confidence Intervals for Direct and Indirect Effects of Test Math Anxiety on Math Achievement Mediated by Math Engagement.

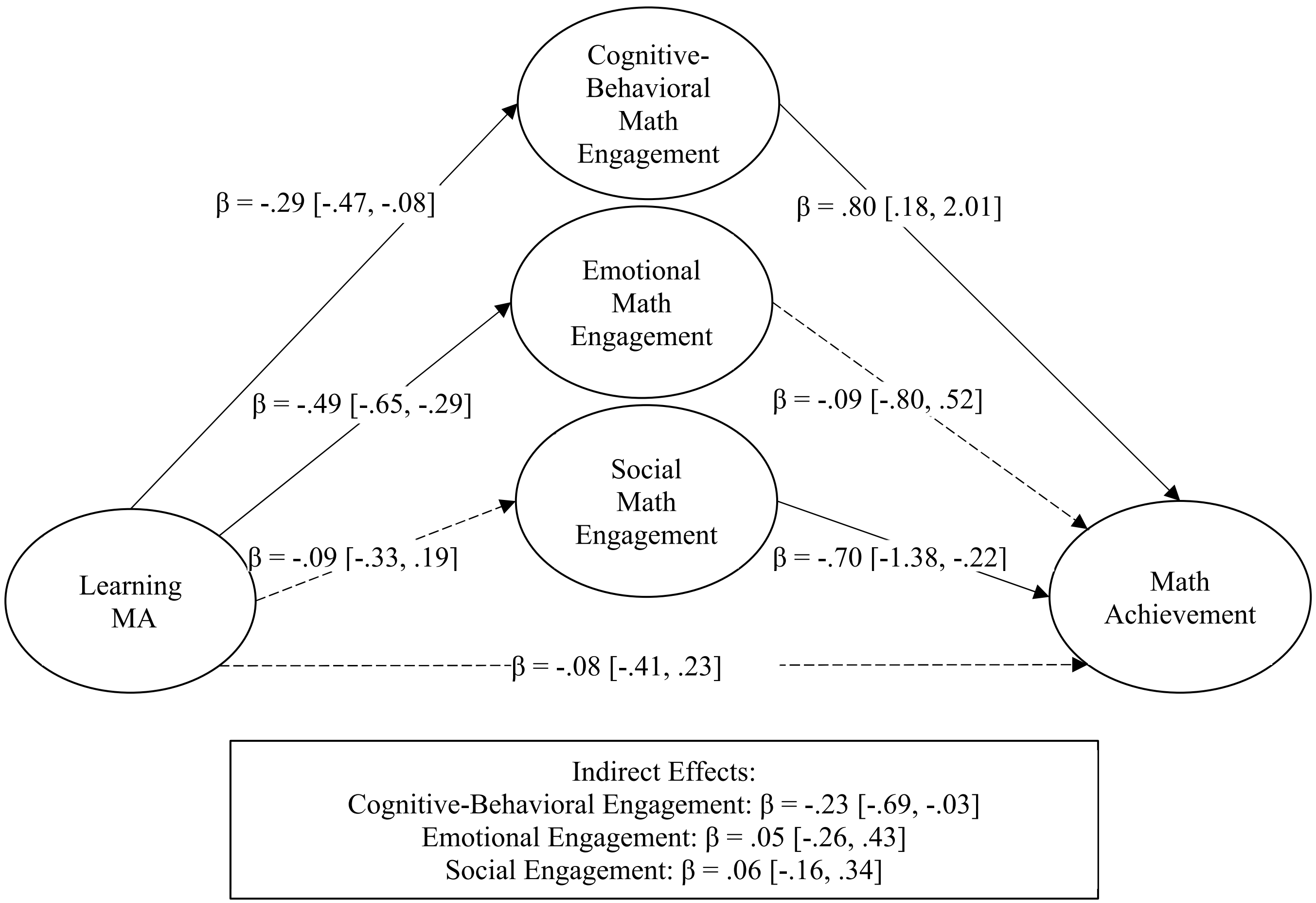


Indirect Effects:
Cognitive-Behavioral Engagement: β = -.24 [-.61, -.04]
Emotional Engagement: β = .04 [-.22, .43]
Social Engagement: β = .04 [-.20, .27]

Note: MA = math anxiety. Non-significant pathways are dashed. Child sex, grade level, and general anxiety were included in the model as covariates but are not shown in the figure for simplicity of presentation.

Figure 2

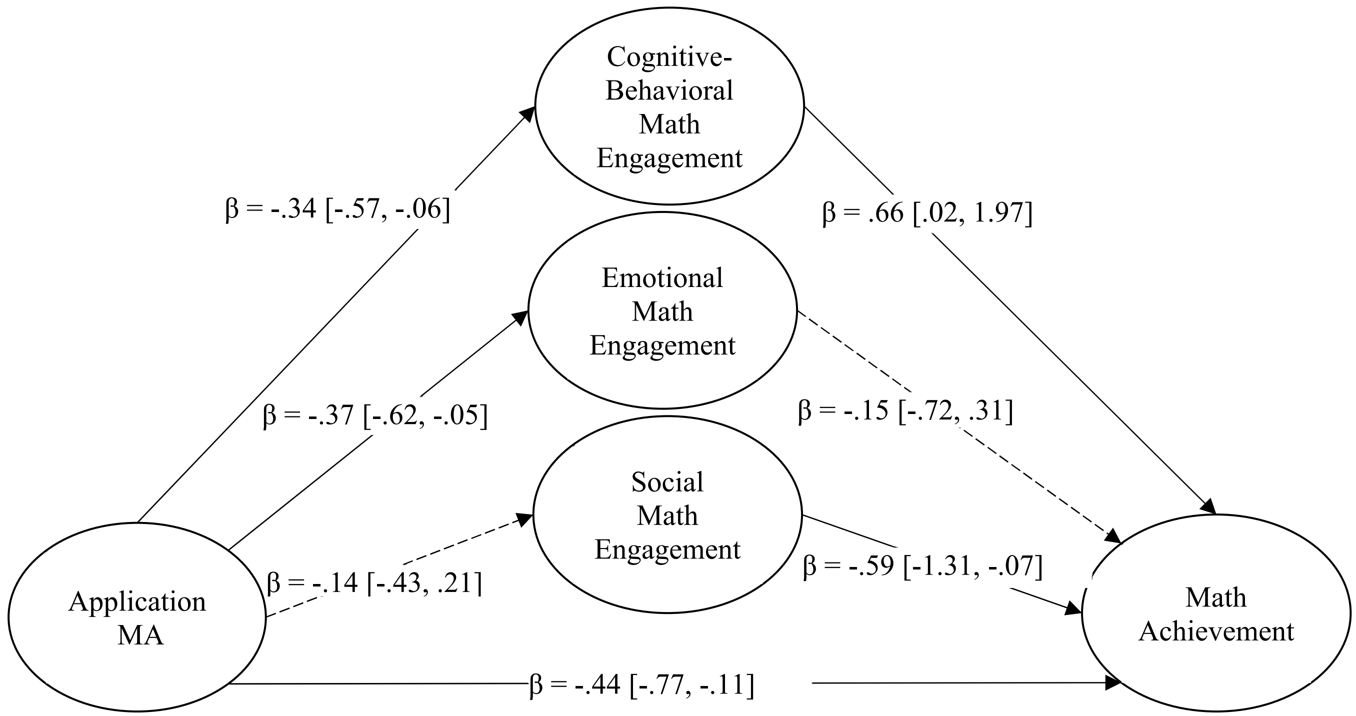
Standardized Path Estimates and 95% Bias Corrected Bootstrap Confidence Intervals for Direct and Indirect Effects of Learning Math Anxiety on Math Achievement Mediated by Math Engagement.



Note: MA = math anxiety. Non-significant pathways are dashed. Child sex, grade level, and general anxiety were included in the model as covariates but are not shown in the figure for simplicity of presentation.

Figure 3

Standardized Path Estimates and 95% Bias Corrected Bootstrap Confidence Intervals for Direct and Indirect Effects of Application Math Anxiety on Math Achievement Mediated by Math Engagement.



Indirect Effects:
Cognitive-Behavioral Engagement: β = -.22 [-.82, -.01]
Emotional Engagement: β = .06 [-.11, .38]
Social Engagement: β = .08 [-.14, .44]

Note: MA = math anxiety. Non-significant pathways are dashed. Child sex, grade level, and general anxiety were included in the model as covariates but are not shown in the figure for simplicity of presentation.