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ORIGINAL ARTICLE

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# Longitudinal and situational associations between math anxiety and performance among early adolescents

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## Abstract

Studies have found math anxiety and achievement to be related from the beginning of formal schooling, but the knowledge regarding the direction of the relationship is vague. The purpose of the present study was to study this relationship. We investigated math anxiety from two points of view: trait and state anxiety. In the first substudy, we investigated the longitudinal relationship between math anxiety and performance from sixth to seventh grade ($n = 848$) with cross-lagged modeling. In the second substudy, we investigated the situational relationship of anxiety and performance by giving the participants ($n = 149$) challenging and nonchallenging math tasks adapted to their skill level, and then examining the association between anxiety and the performance. The results suggest that math anxiety has a small longitudinal effect on performance: High anxiety in sixth grade predicted low performance in seventh grade. Anxiety also had a situational association with performance: when anxiety was aroused, the participants performed more poorly compared to their skill level. The results adduce the two-fold effect of anxiety on achievement: math anxiety seems to have both a real-time association with performance and a long-term effect on the development of basic arithmetic skills.

KEYWORDS
early adolescence, math anxiety, math performance

## INTRODUCTION

### The relationship between math anxiety and performance among sixth and seventh graders

Math anxiety is usually defined as tension and anxiety when manipulating numbers and solving mathematical problems.[1] It has been suggested that even if math anxiety is not an actual disability, it can function as one as a result of its negative personal, educational, and cognitive consequences.[2] It is related to lower math achievement among children from the beginning of primary school[3–8] as well as among adolescents and adults.[9,10] The correlations of math anxiety and achievement have been similar among children and adults: For example, Sorvo *et al.*[8] found a correlation of –0.29 between math anxiety and performance among primary school children, which is approximately the same as reported in the meta-analyses of Hembree[10] (–0.27) and Ma[9] (–0.34) among adolescents and adults, respectively. As for the causality of the relationship, three competing theoretical models have been suggested: the *deficit theory*, which claims that anxiety is a result of poor achievement; the *debilitating anxiety model*, which claims that anxiety debilitates performance; and the *reciprocal theory*, which claims that the two affect each other in a vicious circle.[3] The results of empirical studies concerning the causal relationship between math anxiety and achievement have been contradictory, as different studies give support to different theoretical models.

## Theoretical models of the relationship between math anxiety and achievement

According to the *deficit theory*, difficulties in mathematics leading to negative experiences of performance are likely to generate math anxiety in the future.[11] Difficulty in mathematics has been suggested as a plausible risk factor for math anxiety because children with low mathematical skills are more likely to fall behind their peers, receive negative feedback, and develop negative attitudes toward mathematics.[12] This theory is supported by longitudinal studies among primary school children from grades two to six[13] and secondary and high school students from grades 7 to 12, which indicate that prior low achievement predicts later high math anxiety but not the other way around. In accordance, there are studies indicating that children with mathematical learning difficulties report more math anxiety than their typically achieving peers,[14–16] giving some support to the deficit theory.

The *debilitating anxiety model* suggests that math anxiety affects math performance. Ashcraft and his colleagues have suggested that math anxiety causes an "affective drop" in performance. This means that assessing achievement, particularly under timed, high-stakes conditions, rarely reveals the true ability of individuals with math anxiety but underestimates it.[2] Attentional control theory[17] has also been suggested to explain the immediate effect of anxiety on math performance. Corbetta and Shulman[18] have separated two attentional systems: goal-driven processes, influenced by the individual's current goals, expectations, and knowledge; and stimulus-driven processes, specialized for the perception of unexpected, salient stimuli. In attentional control theory,[19] anxiety is proposed to disrupt the balance between these two attentional systems by enhancing the influence of stimulus-driven processes over goal-driven processes. Thus, task-irrelevant stimuli capture attention more easily, and thereby, shifting attention between and within tasks becomes more difficult.[19]

The debilitating anxiety model is supported by the results of the meta-analysis of Hembree.[10] The findings consistently showed that high math anxiety undermined achievement and that interventions targeted at reducing math anxiety in students with high anxiety can improve their performance to the level of students with low anxiety. Math anxiety in task situations has been found to strain working memory and thus disrupt performance.[20,21] Ashcraft and Kirk[20] noticed that among college students, math anxiety influenced the performance of "dual tasks," in which working memory is taxed by performing two tasks at once. Their interpretation of this result is that aroused math anxiety reduces the working memory capacity. This notion underlines the importance of paying attention to anxiety, especially in mathematics, which requires executing sequential steps of processing while keeping information of the substages in memory.[20]

It also seems that students with high math anxiety might tend to avoid mathematics. Ashcraft[22] suggests, based on previous findings,[23,24] that individuals with high math anxiety are more likely to speed through the math-related problems in order to minimize the time involved in math, which is likely to increase the number of errors. Besides the situational effect, this avoidance behavior also seems to have long-term effects on math performance. Hembree[10] found that students with high math anxiety are less likely to choose mathematics courses in high school and college.

The *reciprocal theory* suggests that math anxiety and achievement affect each other in a vicious circle.[11] This theory is supported by the study of Gunderson *et al.*[5] in which a reciprocal relationship was found between math anxiety and math achievement of first and second graders. Furthermore, Carey *et al.*[11] have suggested that the conflicting results regarding the direction of longitudinal associations between math anxiety and achievement indirectly support the reciprocal model of math anxiety and achievement.

Depending on the age of participants, previous studies might actually shed light on different aspects of a bidirectional relationship. It is possible that the educational stage might affect the relationship between math anxiety and achievement, since the transitions from one educational stage to another seem to have an effect on math-related attitudes and emotions, including math anxiety. Deieso and Fraser[25] compared Australian primary and secondary school students and found that secondary school students reported less involvement, more negative attitudes toward mathematics, less enjoyment of mathematics, and more math anxiety. Furthermore, the previous longitudinal studies indicate that the developmental pathways of math anxiety might not be linear during primary and secondary school periods. Our previous study[13] suggests that the level of math anxiety might even decline during primary school, whereas according to the meta-analysis of Hembree,[10] the level of math anxiety increases during secondary school, peaking in ninth and tenth grades. Ma and Xu[26] investigated the causal relationship between math anxiety and achievement from 7th to 12th grades and found that math anxiety predicted achievement for boys across the whole period, but for girls only at critical points of educational transition. These previous findings advocate the need for future studies on the causal relationship between math anxiety and achievement during the transitional stage from primary to secondary school.

## The views on math anxiety: individual trait and situational state

The conflicting results of the previous studies might be related to the perspective taken on math anxiety and thereby also methodological constraints. Math anxiety, as with emotions in general, can be examined from two points of view: (1) as a habitual, recurring emotion that is typical to some individuals (*trait anxiety*[27] for academic skills; see Pekrun[28]), or (2) as a situation- and time-specific momentary occurrence (*state anxiety*[27,28]). Math anxiety research has typically focused more on anxiety as a trait of an individual than as a situation-specific emotional state.[29]

The mechanisms proposed by the deficit theory (i.e., poor performance causing anxiety) are more likely to be long-term, whereas the debilitating effect of math anxiety suggests more immediate mechanisms (e.g., straining working memory[2]). This could be the reason why results from longitudinal studies[13,26] often support the deficit theory, whereas results from experimental studies[2] often support the debilitating anxiety model.

Carey *et al.*[11] have hypothesized that using both long-term longitudinal and situational designs might be useful for getting a wider picture of the relationship between math anxiety and achievement. In our understanding, this means that for gaining a more comprehensive understanding of the relationship between math anxiety and achievement, math anxiety should be considered not only as an individual's trait, but also as a situation-specific emotional state. If we want to take into account also the point of view of math anxiety as a momentary, situation-specific emotion, besides asking people to respond based on their *typical* or *reoccurring* emotional reactions in different situations, we also need to ask their feelings right there, *in a specific moment*.[27]

To investigate state anxiety and its relationship with performance, we need to create varying task-performing situations with more and less pressure. One way to manipulate the level of pressure is to apply more and less challenging arithmetic tasks, as previous research suggests that the difficulty of the tasks might affect the level of math anxiety[30,31] as well as the relationship between math anxiety and performance.[23,24,32] Ashcraft and Moore[2] state that the performance of college students in basic arithmetic tasks, which they usually perform somewhat automatically, was not affected by anxiety. In the more complex arithmetic tasks, increased levels of math anxiety seemed to result in either slower or less accurate performance.[23,24] However, there is lack of research about the effect of task difficulty among younger students. Especially in primary school, the variance of arithmetic skills is huge,[33] as some students are not able to perform simple addition tasks automatically, whereas other students might experience hardly any challenges in the school math. If we want to investigate state math anxiety in basic education, the design should take into consideration students' wide range of mathematical skills and its impact on the experienced difficulty: a task that is easy for someone might be challenging for someone else. Thus, instead of using same tasks for all, the tasks should be individually adapted based on the student's performance level in order to provide "challenging" and "not challenging" experiences for all.

## The present study

The aim of the present study was to shed light on the relationship between math anxiety and achievement from two different perspectives in the two substudies. In the first substudy, we examined the developmental relationships between trait math anxiety and achievement during the transition from primary to lower secondary school (i.e., from sixth to seventh grade). In the second substudy, in order to obtain a more comprehensive picture of the relationships between math anxiety and performance, we examined the situational effect of state math anxiety on performance in challenging and nonchallenging real-time math situations among sixth graders. The situational effect of state math anxiety was examined by giving the participants challenging and nonchallenging arithmetic tasks adapted to their skill level. As far as we know, the situational effects of anxiety on performance have previously been investigated only among adults. Thus, more knowledge about the situational effect is needed, especially among younger students, whose mathematical skills are still developing. Adapting the difficulty of arithmetic tasks according to individual skill level enabled us to assess the math anxiety of all students in challenging and nonchallenging mathematical situations.

The research questions were

1. How are trait math anxiety and math performance longitudinally related across the transition from primary school to lower secondary school? On the basis of previous longitudinal studies and the reciprocal theory, we tentatively hypothesized that lower skills would predict higher math anxiety and that higher math anxiety would predict lower math skills.
2. Is state math anxiety situationally associated with math performance among sixth grade students, and does the possible relation vary depending on task difficulty? On the basis of previous research among adults, we hypothesized that state math anxiety assessed after each task would be related to math performance—students with anxiety feelings in a real-time situation would have lower math performance than expected based on their skill level. The relation would be stronger in challenging than nonchallenging tasks.

# STUDY 1

## Materials and methods

### Participants and procedure

A total of 848 sixth grade students (457 girls and 391 boys, aged 12.58–13.75 years; $M = 12.32$, $SD = 0.36$), participated in study 1, in which students were followed from sixth grade (primary school) to seventh grade (lower secondary school). The students came from 56 school classes, ranging in size between 7 and 30 pupils ($M = 21.1$, $SD = 4.66$). The students were assessed twice: in autumn 2014 (T1; grade six fall) and in spring 2016 (T2; grade seven spring).

A total of 96% of the participants were native Finnish speakers, 2% were bilingual (Finnish and some other language), and 2% of the adolescents had a language other than Finnish as their mother language. The data were collected as part of a larger longitudinal study focusing on individual and environment-related factors that promote students' learning and well-being during the transition from primary school to lower secondary school. The participants were recruited from one larger town (where the sample included about half of the age cohort) and one middle-sized town (where the whole age cohort was included in the sample) in central Finland. Both towns also included semirural areas with smaller schools (for a more detailed description of the sample, its recruitment, and demographic characteristics, please see Refs. 34 and 35). Parents gave informed written consent for their child's participation. The parents were advised to discuss the study with their child to also ensure the child's own willingness to participate. The schools and the teachers of the participating classrooms gave their permission for the data to be collected during school hours. The ethics committee of the university gave their statement for the study, and the research practices and procedures were modified according to its recommendations.

The students' data were collected in the classrooms during regular school hours. The data collection included tests of academic skills as well as questionnaires concerning students' motivation, social relationships, and well-being. The tests and questionnaires were administered by trained research assistants in group assessment sessions. The collection of the data included in this study took place in the fall semester of grade six (late September to early November 2014) and in the spring semester of grade seven (early March to early May 2016).

## Measures

*Arithmetic performance*

Basic arithmetic performance was assessed with the 3-min Basic Arithmetic Test.[36,37] In this time-limited, group-administered paper-and-pencil test, the participant is required to complete as many arithmetic operations as possible within a 3-min time limit. The sixth-grade version of the test consists of 10 additions, 11 subtractions, and 7 tasks, including both additions and subtractions or multiplications or divisions, whereas the seventh grade version of the test consists of 8 additions, 11 subtractions, and 9 tasks, including both additions and subtractions or multiplications or divisions. The score was the total number of correct responses, with the maximum score being 28. The scores were standardized according to the mean and standard deviation of the age group.

*Math anxiety questionnaire*

The math anxiety of the participants was assessed with three items from the Achievement Emotions Questionnaire,[38] translated into Finnish and adapted for students from grades six to seven (see also Ref. 39). The questionnaire includes items assessing a broad variety of students' academic emotions toward mathematics and literacy in three learning contexts: learning in general, emotions toward classes, and emotions toward exams. In the present study, we were interested in students' anxiety in mathematics, which was measured with the three items concerning mathematics: "Studying makes me anxious/nervous" (MANX1), "Thinking about lessons makes me nervous" (MANX2), and "I am anxious during tests" (MANX3). The responses were given on a 5-point scale (1 = *disagree*; 5 = *agree*). Cronbach's alpha for the math anxiety scale was 0.64 at T1 (factor score reliability = 0.84) and 0.72 at T2 (factor score reliability = 0.87).

## Statistical analyses

The analyses to investigate cross-lagged associations of math anxiety and math performance from grade six fall to grade seven spring were carried out in the following steps. First, a measurement model with a latent factor for math anxiety at both time points was constructed. In the measurement model, the latent factors were allowed to correlate with each other. The invariance of the math anxiety measure over time was tested by first constraining factor loadings, then the intercepts, and finally residual variances of observed variables equal over time and comparing the nested models of math anxiety against each other using the Satorra–Bentler scaled $\chi^2$ difference test.[40] A significant $\chi^2$ difference test indicates better fit for the model with fewer degrees of freedom (i.e., fewer constraints).

Second, cross-lagged structural equation models for math anxiety and arithmetic performance were constructed. In these models, factor loadings, intercepts, and the residual variances of the observed variables were constrained to be equal across time to ensure invariance of the measurement across time. In addition, stability paths from grade six math anxiety to grade seven math anxiety and from grade six math performance to grade seven math performance, as well as cross-lagged paths from grade six math anxiety to grade seven math performance and from grade six math performance to grade seven math anxiety, were estimated. Grade six math anxiety and grade six math achievement were allowed to be correlated. Similarly, the residuals of the grade seven math anxiety and grade seven math achievement were allowed to be correlated.

In the final model, only statistically significant paths were presented (Figure 1). To evaluate the overall goodness of fit of the cross-lagged model, the chi-square test, the root mean square error of approximation test (RMSEA),[41] the standardized root mean square error (SRMR),[42] the comparative fit index (CFI),[42] and the Tucker–Lewis index (TLI)[43] were used. For a good model, the $p$ value of $\chi^2$ should be larger than 0.05, the RMSEA less than 0.06, the CFI and TLI greater than 0.90 (acceptable fit) or 0.95 (excellent fit), and the SRMR smaller than 0.08.[43,44]

All the main analyses were conducted using the Mplus program version 7.3.[44] The estimation method used was maximum likelihood with robust standard errors (MLR). In this sample, the proportion of nonresponses in the different variables ranged from 1.52% to 9.42% ($M$ = 5.65%, $SD$ = 3.30%). The parameters of the models were estimated using full-information maximum likelihood estimation with nonnormality robust standard errors (maximum likelihood robust, MLR).[44]

# Results

The descriptive statistics for the observed variables are reported in Table 1, and the correlations between the observed variables are reported in Table 2. Descriptive statistics indicated that the level of math anxiety slightly increased from T1 to T2 ($\chi^2(9) = 44.84$, $p < 0.001$).

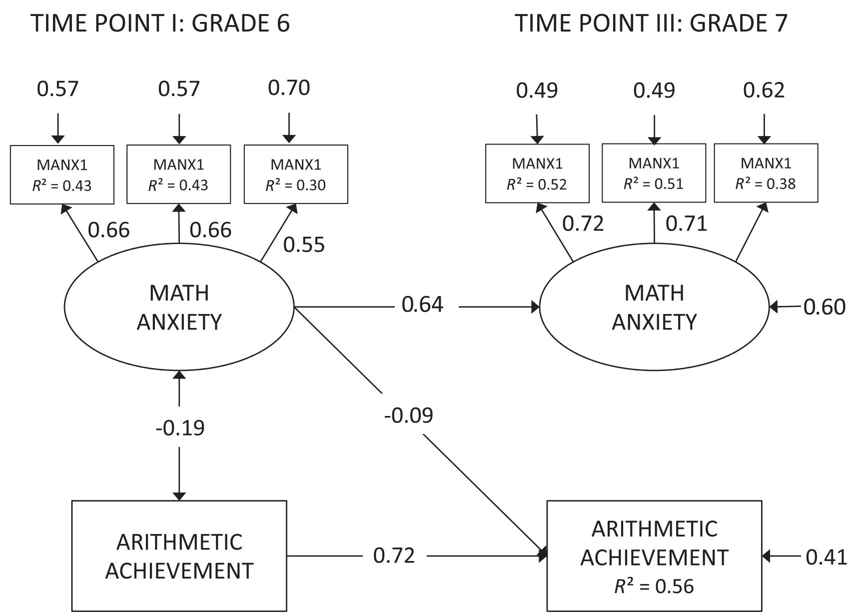


**FIGURE 1** Model for the longitudinal relationships between math anxiety and arithmetic achievement. All estimates are standardized. All paths $p < 0.05$; fit statistics: $\chi^2$ (23) = 98.78, $p = 0.001$; RMSEA = 0.06; CFI = 0.94; TLI = 0.93; SRMR = 0.04

**TABLE 1** Descriptive statistics of observed math anxiety and achievement variables

| Study variables | Time point 1 *M* (*SD*) | Time point 2 *M* (*SD*) | *min* | *max* |
|---|---|---|---|---|
| Math anxiety | | | | |
| "Studying makes me anxious/nervous." (MANX1) | 1.80 (0.97) | 1.94 (1.05) | 1 | 5 |
| "Thinking about lessons makes me nervous." (MANX2) | 1.67 (0.97) | 1.86 (1.07) | 1 | 5 |
| "I am anxious during tests." (MANX3) | 2.10 (1.20) | 2.21 (1.20) | 1 | 5 |
| Math achievement | | | | |
| 3-minute Basic Arithmetic Test (ARI) | 15.38 (3.55) | 17.41 (3.61) | 0 | 28 |

**TABLE 2** Correlations between the observed variables

| | Time point 1 | | | | Time point 2 | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | MANX1 | MANX2 | MANX3 | ARI | MANX1 | MANX2 | MANX3 | ARI |
| Time point 1 | | | | | | | | |
| MANX1 | 1 | | | | | | | |
| MANX2 | 0.40** | 1 | | | | | | |
| MANX3 | 0.37** | 0.37** | 1 | | | | | |
| ARI | −0.16** | −0.08* | −0.10** | 1 | | | | |
| Time point 2 | | | | | | | | |
| MANX1 | 0.29** | 0.31** | 0.18** | −0.10** | 1 | | | |
| MANX2 | 0.24** | 0.36** | 0.16** | −0.03 | 0.53** | 1 | | |
| MANX3 | 0.24** | 0.28** | 0.38** | −0.07* | 0.47** | 0.40** | 1 | |
| ARI | −0.15** | −0.13** | −0.15** | 0.74** | −0.15** | −0.12** | −0.08* | 1 |

*Note*: MANX1, MANX2, MANX3 = math anxiety items; ARI = scores of arithmetic measures.
*$p < 0.05$.
**$p < 0.01$.

**TABLE 3** Invariance comparison for the measurement model of math anxiety over time

| Model | Model $\chi^2$ (*df*) | $\chi^2$ difference test $\chi^2$ (*df*) | *p* |
|---|---|---|---|
| Unconstrained model | 64.00 (8) | – | – |
| Factor loadings of observed variables set to be equal over time | 67.46 (10) | 2.49 (2) | 0.29 |
| Factor loadings and intercepts of observed variables set to be equal over time | 73.47 (12) | 2.59 (2) | 0.27 |
| Factor loadings, intercepts, and residual variances of observed variables set to be equal over time | 75.30 (15) | 3.46 (3) | 0.33 |

*Note*: $\chi^2$ difference test = model compared to previous, less constrained model.

In addition, anxiety was negatively correlated with adolescents' math achievement at both time points.

The measurement model for math anxiety was fully invariant over time (Table 3). The cross-lagged model for math anxiety and achievement is presented in Figure 1. The results showed that even after controlling for previous level of math fluency, high math anxiety at T1 predicted decreased math performance at T2. In turn, math achievement at T1 did not predict subsequent math anxiety at T2.

Additional multigroup analyses were conducted in order to test possible gender differences in the investigated associations. The results of these analyses revealed no significant differences ($p > 0.05$) between girls and boys in the strength of cross-lagged associations between math anxiety and math achievement.

# STUDY 2

## Materials and methods

### Participants and procedure

The participants of study 2 comprised 148 sixth grade students, drawn as a subsample of the overarching longitudinal study's larger community sample of study 1 (see the description of study 1, and see Figure 2 for the sampling procedure). In the fall semester of the sixth grade, the community sample of about 850 students participated in a wider assessment that included an arithmetic group test (the 3-min Basic Arithmetic Test[36,37]). Of the larger sample, 149 students altogether were then selected to participate in individual tests. The sample was nonrandom: 83 of the students scored below the 16th percentile in the arithmetic test and 66 of the participants scored above 16th percentile. Selecting both adolescents with (below the 16th percentile) and without difficulties (scoring above 16th percentile) in arithmetic fluency for a subsample used in the study 2 was part of the sampling procedure of the broader study of which one aim was to investigate learning difficulties. These two groups were matched according to gender distribution and general cognitive ability. The latter was done using the Raven Standard Progressive Matrices test,[45] which consists of diagrams with one part missing, increasing in difficulty. Participants were asked to select the correct part completing each design. In the present study, a shortened version including half of the items (alternating) was used (see also Ref. 46). Responses were scored as correct or incorrect with the maximum score of 30 ($\alpha = 0.81$).

The individual assessments were carried out during the sixth grade spring semester. The assessments consisted of challenging and nonchallenging achievement tasks carried out with a computer, and also short questionnaires filled in before and after each task (for procedure of individual assessments and experiment, see also Refs. 45 and 47). Trained assistants carried out the experiment during regular school hours in a camper van equipped with a built-in ambulatory lab, including two computers (a presentation computer with a touchscreen and a measurement computer). Of all the individual tests, in the present study, we focus on the two arithmetic tasks: challenging and nonchallenging, and questionnaire items assessing state math anxiety after each task (the procedure illustrated in Figure 2).

### Measures

*Arithmetical achievement in challenging and nonchallenging arithmetic tasks*

The challenging and nonchallenging arithmetic tasks were arithmetic tasks with a 4-min time limit, both consisting of a maximum of 40 items adopted from the 3-min Basic Arithmetic test.[36,37] For ensuring both challenging and nonchallenging conditions to as many participants as possible, the participants were divided into three different skill levels based on their previous performance in the basic arithmetic test (low performance = lowest quartile; medium performance = between lowest and highest quartiles; and high performance = highest quartile). The arithmetic test items were divided into six difficulty levels (1 = easiest; 6 = most difficult), based on the previous data from sixth grade fall assessment. The challenging and nonchallenging tasks for all three skill levels were then composed of the test items as described in Table 4. The tasks were different between the three skill levels, but the participants within each skill level received similar tasks.

The tasks lasted for 4 min each. All the students did two arithmetic tasks—one easy task and one difficult task—but the order of the task was counterbalanced between the students (Figure 2). Students did not receive any information about the difficulty before the upcoming task. The students made twice as many errors in the challenging task (40.3%; $SD = 24.7$) compared to the nonchallenging (18.4%; $SD = 15.5$), which indicates successful adaptation of the difficulty levels. For more

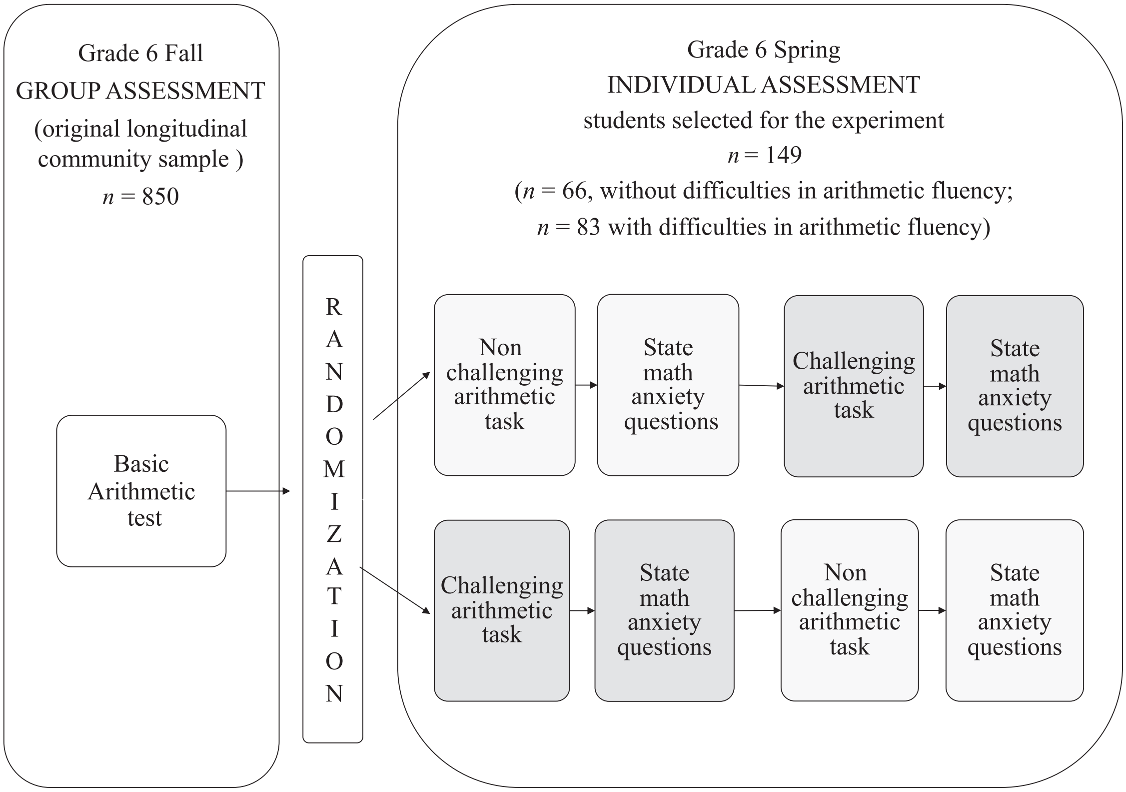


**FIGURE 2** The procedure of study 2

**TABLE 4** Adaptation of the items in the challenging and nonchallenging arithmetic tasks for three skill levels

| | Task | | | | | |
|---|---|---|---|---|---|---|
| | Low performance | | Medium performance | | High performance | |
| | Nonchallenging | Challenging | Nonchallenging | Challenging | Nonchallenging | Challenging |
| Item difficulty levels | 1–2 | 3–4 | 2–3 | 4–5 | 3–4 | 5–6 |

information about the performance of students on different skill levels in the arithmetic tasks, see Table 5.

Students' performance in these achievement tasks was measured as the number of correct answers, the general mean reaction time, the mean reaction time for correct answers, and the percentage of incorrect answers.

*State math anxiety in the challenging and nonchallenging situations*

State math anxiety was assessed with three items of a questionnaire immediately after each arithmetic task (easy and difficult), as part of a wider questionnaire, The Emotions in Achievement Situations scale,[48] which was adapted on the basis of the Achievement Emotions scale (AEQ)[38] and the Positive and Negative Affect Scale (PANAS).[49] The participants were asked how they felt during the task and they responded on a 5-point scale (1 = *disagree*; 5 = *agree*). The items assessing state math anxiety were: "*I was nervous/restless*," "*I was panicky/anxious*," and "*I was worried about how well I can do the task*." Cronbach's alpha for the scale was 0.64 in the easy task and 0.64 in the difficult task, and the factor score reliabilities were 0.92 for the easy tasks and 0.92 for the difficult tasks. For the analyses, we calculated the sum scores of state math anxiety separately for challenging and nonchallenging tasks (Table 6).

## Statistical analysis

The analyses of study 2 were conducted using IBM SPSS Statistics (version 22). First, math anxiety sum scores were used for grouping the participants based on their reported state math anxiety arousal separately in challenging and nonchallenging task-performing situations. The same criterion for math anxiety was used in both easy and difficult tasks, since the items for measuring anxiety were the same for both tasks. The upper quartile for math anxiety sum score (i.e., approximately one and half standard deviation above the mean) in the nonchallenging task was 6 and for the challenging task was 7; the stricter one of them (7) was used as the criterion. Participants with

**TABLE 5** Descriptive statistics of arithmetic achievement and general ability variables for the three skill levels

| | Skill level | | |
|---|---|---|---|
| | Low performance | Medium performance | High performance |
| | *M* (*SD*) | *M* (*SD*) | *M* (*SD*) |
| Grade 6 Fall | | | |
| Basic Arithmetic Test | −1.40 (0.52) | 0.06 (0.30) | 1.09 (0.41) |
| Raven Standard Progressive Matrices Test – shortened version | −0.43 (0.88) | −0.20 (0.81) | −0.41 (0.96) |
| Grade 6 Spring – individual assessment | | | |
| Error rate | | | |
| Nonchallenging task | 21.14% (17.25) | 15.65% (12.14) | 12.11% (10.99) |
| Challenging task | 41.16% (25.29) | 35.19% (24.08) | 48.83% (21.39) |
| Sum of correct answers | | | |
| Nonchallenging task | 17.14 (6.00) | 20.22 (5.03) | 19.39 (4.53) |
| Challenging task | 8.16 (3.74) | 8.38 (4.67) | 5.33 (2.43) |

*Note*: The means of correct answers for Basic Arithmetic Test and Raven Standard Progressive Matrices Test are standardized within the community sample ($n = 850$).

**TABLE 6** Math anxiety scores in nonchallenging and challenging arithmetic tasks

| Arithmetic task | *M* (*SD*) | Observed min | Observed max |
|---|---|---|---|
| Nonchallenging | 5.21 (2.06) | 3 | 12 |
| Challenging | 5.80 (2.36) | 3 | 15 |

anxiety sum scores of 3–6 in a task were categorized as reporting "no math anxiety arousal," whereas participants with anxiety sum scores of 7–15 in a task were categorized as reporting "math anxiety arousal." Based on this categorization, the participants were divided into four groups: 1 = no anxiety arousal in either of the tasks (sum score of 3–6 in both tasks; $n$ = 97); 2 = anxiety arousal in easy tasks (sum score of 7–12 in the easy tasks and 3–6 in the difficult tasks; $n$ = 5); 3 = anxiety arousal in the difficult tasks (sum score of 3–6 in the easy tasks and 7–12 in the difficult tasks; $n$ = 23); and 4 = anxiety arousal in both tasks (sum score of 7–12 in both tasks; $n$ = 23). Because of its small size, group 2 was left out of the analyses. One of the participants who did not respond to math anxiety items at all was also excluded from the analyses. One-way analysis of variance (ANOVA) indicated that there was no mean-level difference between the anxiety groups in their performance in the previous autumn arithmetic group test (part of study 1) ($F(3,144) = 2.48$, $p = 0.06, \eta^2 = 0.12$).

The analyses were then accomplished by conducting two sets of repeated measures ANOVAs, with the scores of arithmetic performance (the sum score of correct answers and the mean reaction time in general) as dependent variables, anxiety group as a between-subjects factor, and the difficulty of the task (nonchallenging/challenging) as the within-subject factor. Before the analyses, we tested equality of variances between groups, and Levene's test showed that the assumption of equality of variances was met.

As follow-up analyses to examine whether the effect in the mean reaction time could be explained by differences in reaction time specifically for either correct or incorrect answers, we then conducted two more sets of repeated ANOVAs with reaction time for correct and incorrect answers separately as dependent variables, anxiety group as a between-subjects factor, and the difficulty of the task (nonchallenging/challenging) as the within-subject factor.

To make sure that the results were not biased because of the task adaptation (participants in different performance levels getting different tasks), we then reconducted the analyses with performance scores standardized separately within the three performance levels (low, medium, and high). Consequently, each student's standardized performance score represents the student's performance in relation to average performance in their own skill level in the assigned task that was either challenging or nonchallenging.

Finally, we conducted two sets of repeated ANOVAs *separately for every anxiety group*, with the standardized scores of sum of correct answers and the overall mean reaction time as dependent variables and the difficulty of the task as within-subject factor. Using standardized scores in these analyses enables examining whether participants' performance differed from their expected performance level when state math anxiety occurred.

## Results

Repeated measures ANOVAs revealed a main effect of difficulty of the task (nonchallenging/challenging) on both the sum score of correct answers $F(2,140) = 454.27$, $p < 0.01$, ${\eta_p}^2 = 0.76$ and the overall mean reaction time $F(2,140) = 248.73$, $p < 0.01$, ${\eta_p}^2 = 0.64$. In addition, the analyses revealed an interaction effect of math anxiety group and the difficulty of the task, for both the sum score of correct answers ($F(2,140) = 4.97$, $p < 0.01$, ${\eta_p}^2 = 0.07$; Figure 3) and the overall mean reaction time ($F(2,140) = 5.26$, $p < 0.01$, ${\eta_p}^2 = 0.07$; Figure 4).

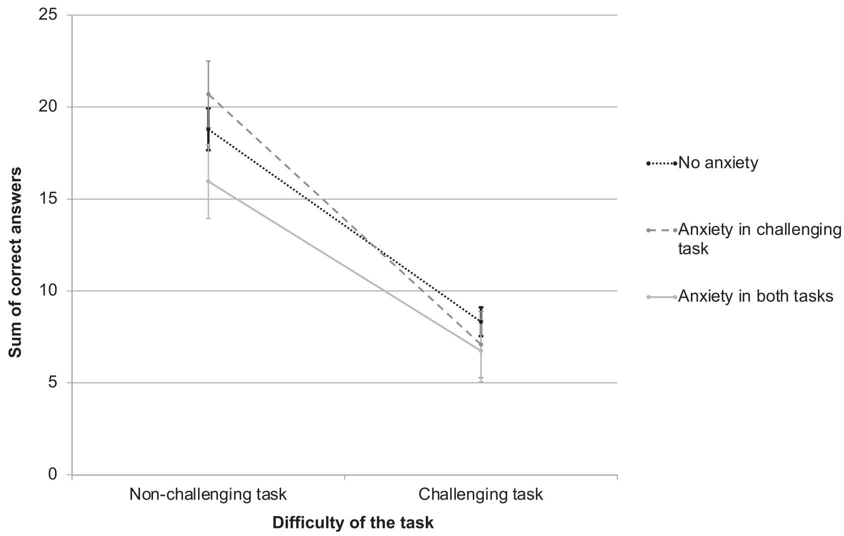


**FIGURE 3** Means for the sum of correct answers for the three anxiety groups in nonchallenging and challenging tasks. Note that the scores are standardized within the difficulty level. Error bars represent the 95% confidence interval

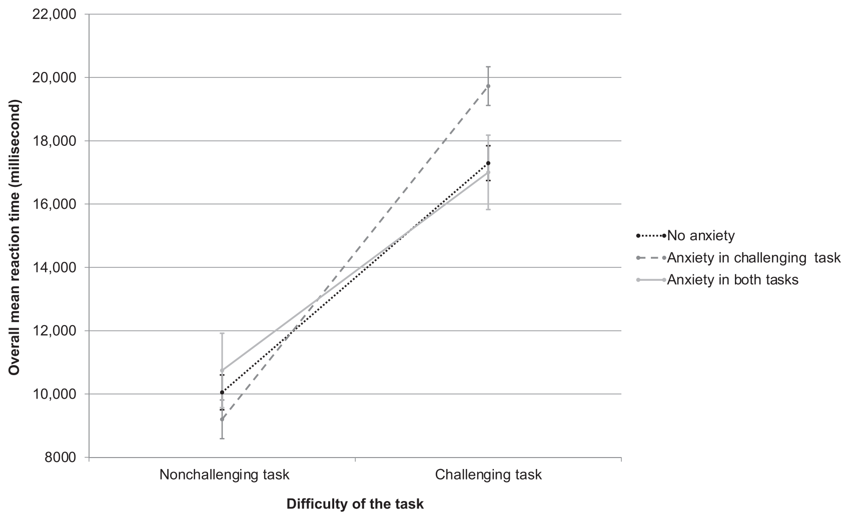


**FIGURE 4** Means for the overall mean reaction times for the three anxiety groups in nonchallenging and challenging tasks. Note that the scores are standardized within the difficulty level. Error bars represent the 95% confidence interval

There was no interaction effect of math anxiety group and difficulty of the task for the mean reaction time *in either correct or incorrect answers*, indicating that participants performed slower in the task if they reported anxiety arousal, regardless of whether they had answered correctly.

To make sure that the results about the interaction effect were not biased because of the task adaptation (participants on different performance levels getting different tasks), analyses were then reconducted with performance scores standardized separately within the performance levels. Analyses with standardized scores still revealed the interaction effect of math anxiety group and the difficulty of the task, for both the sum score of correct answers ($F(2,140) = 4.22$, $p = 0.02$, $\eta_p{}^2 = 0.06$) and the overall mean reaction time ($F(2,140) = 6.65$, $p < 0.01$, $\eta_p{}^2 = 0.09$).

Finally, as follow-up analysis, in order to interpret the abovementioned interaction effects, we conducted two sets of repeated ANOVAs (with the standardized scores of sum of correct answers and the overall mean reaction time as dependent variables and the difficulty of the task as within-subject factor) *separately for every anxiety group* (Table 7). The results indicated that the students who reported math anxiety arousal only in the challenging tasks had relatively less correct answers in these tasks and also performed more slowly in them compared to nonchallenging tasks. Among students who either did not report anxiety arousal at all or reported it in both tasks, there were differences in their performance in the two levels of task difficulty.

## Additional analyses: controlling trait math anxiety

Additional analyses showed that high trait anxiety was equally related to higher state anxiety during relatively less ($r = 0.35$, $p < 0.001$) and relatively more ($r = 0.39$, $p < 0.001$) challenging math tasks. Adding trait anxiety as a covariate in the analyses of study 2 did not change the results, and trait anxiety as a covariate was not statistically significant.

# DISCUSSION

The aim of the present study was to shed light on the relationship between math anxiety and performance. Unlike in majority of previous studies, the relationship was examined from two perspectives: first,

**TABLE 7** Results of repeated ANOVAs for the different math anxiety groups

| | Standardized scores for sum of correct answers | | | Standardized scores for overall mean reaction time | | |
|---|---|---|---|---|---|---|
| | Nonchallenging task | Challenging task | | Nonchallenging task | Challenging task | |
| Anxiety group | *M* (*SD*) | *M* (*SD*) | *F* (*df*) | *M* (*SD*) | *M* (*SD*) | *F* (*df*) |
| No anxiety arousal | 0.08 | 0.11 | 0.08 | −0.03 | −0.05 | 0.05 |
| | (0.99) | (0.98) | (1.96) | (1.03) | (1.04) | (1.96) |
| Anxiety arousal in challenging task only | 0.41 | −0.20 | 6.96* | −0.35 | 0.41 | 15.75** |
| | (0.73) | (1.04) | (1.22) | (0.53) | (0.87) | (1.22) |
| Anxiety arousal in both tasks | −0.42 | −0.29 | 0.44 | 0.23 | −0.11 | 2.90 |
| | (0.82) | (0.97) | (1.22) | (1.02) | (0.96) | (1.22) |

*$p < 0.05$.
**$p < 0.01$.

developmentally focusing on trait anxiety with a longitudinal design, with predicting change in both constructs, when controlling for previous levels; and second, cross-sectionally focusing on the situational effect of state math anxiety on performance in more and less challenging math task situations.

Based on the previous research, we hypothesized (study 1) that we would find a reciprocal relationship between math anxiety and skill development in our longitudinal study (i.e., lower performance in sixth grade would predict higher math anxiety in seventh grade and that higher math anxiety in sixth grade would predict lower math performance in seventh grade, when controlling for the levels of math anxiety and performance from the previous time point). The only longitudinal effect found was a small negative effect of previous math anxiety on later performance. This result suggests that, in addition to a small cross-sectional association at sixth grade, math anxiety uniquely affected skill development over and above skill level from the previous time point (stability correlation of performance was 0.74, $p < 0.001$) during the transition from primary to secondary school. In addition, we found a situational association between math anxiety and math performance (study 2). The association was consistent across the subgroups composed based on their reports of anxiety across the challenging and nonchallenging task situations; when the participants were given easy and difficult arithmetic tasks adapted to their skill level, the students reporting anxiety only in the difficult task performed relatively lower in the difficult than in the easy task, whereas as those reporting similar level of anxiety across situations performed similarly in both tasks. In other words, it seems that arousal of anxiety was related to underperformance.

The results regarding the longitudinal relationship between math anxiety and achievement (study 1) give only partial support for the previous research suggesting a reciprocal relationship between math anxiety and achievement[5] and are contradictory to those of previous longitudinal studies that have found a longitudinal relationship between low performance and high anxiety.[13,26] However, the reciprocal relationship between math anxiety and achievement cannot be completely ruled out based on these results. It is possible that the relationship, or its direction, varies depending on the stage of schooling. In the present study, math anxiety and achievement were examined over the transition stage from primary to secondary school, whereas the previous studies have focused on either primary school children[13] or secondary and high school students.[26] The transitional stage from primary to secondary school has also previously been found to be related to increasing math anxiety, negative changes in students' attitudes toward mathematics, and decreasing enjoyment of mathematics.[25]

The finding that math anxiety longitudinally predicted lower achievement raises the question of the mechanisms via which math anxiety affects the development of arithmetical skills. One explanation might be that if, as has been suggested, anxiety disrupts the attentional system (attentional-control theory[19]) and burdens working memory,[20] as a more habitual trait, it might affect learning situations continuously, and thus disrupt skill learning and fluency development. Also, the avoidance behavior previously noticed as more common among math-anxious individuals[10] might explain the developmental effect; it is plausible that avoidance of math-related situations leads to a smaller amount of exercise which, in turn, results in slower development of mathematical skills.

In study 2, we examined the situational association between math anxiety and performance. In previous research among college students,[23,24] math anxiety has been found to have only a minimal situational effect on simple, single-digit arithmetic problems, but a notable effect on more complex, two-column problems, where individuals with high math anxiety made more errors and had slower performance. In the present study, the participants were primary school students with a large interindividual variation of mathematical skill levels. Thus, instead of categorizing arithmetic tasks as generally simple and complex, we aimed to provide all participants individually nonchallenging and challenging tasks, relative to their skill level. All the groups reacted faster and had more correct answers in the nonchallenging task compared to the challenging task, which indicates successful adaptation of the difficulty level.

Most of the students (66%) did not report anxiety at all in either of the tasks, whereas about 16% reported at least some levels of anxiety in both tasks and 16% only in the difficult task. Only few students (3%) reported anxiety in the easy task only. Those students reporting anxiety only in the difficult task had less correct answers and performed more slowly, relative to the other groups, in the difficult task compared to the easy task. The result that participants performed better when they did not feel anxious indicates a situational relationship between math anxiety and performance. It seems that, at least for the students reporting anxiety only in the challenging task, the results are in line with previous studies among college students,[23,24] indicating that math anxiety is related to both speed and accuracy of mathematical performance also among sixth graders.

The results of study 1 give support to the debilitating anxiety theory, in which the relationship between math anxiety and performance is explained by the debilitating effect of math anxiety on performance.[11] It is notable that the effect size of a cross-lagged effect from math anxiety to subsequent math achievement was small when controlling for the previous level of math achievement. The relatively small effect size of the cross-lagged effect compared to that of the cross-sectional association between anxiety and achievement partly reflects the high stability of math achievement across time (stability correlation was 0.74, $p$ <0.001), which leaves only little room to predict change. Besides, the cross-sectional correlations between latent factors of math anxiety and math performance were small, that is, –0.19 at T1 and –0.09 at T2. Although Hembree[10] reported somewhat higher average correlation (–0.27) between math anxiety and math performance across 150 studies, the individual studies included in the meta-analyses vary substantially with regard to the magnitude of estimated correlation between math anxiety and performance.

The underlying association between anxiety and performance may be complex and even nonlinear; sometimes, a certain level of anxiety and stress can also signal about the subjective importance of the task and subsequently boost better concentration and better task performance. Hence, it might also be that only particularly high levels of anxiety hinder performance in demanding situations or that there is interindividual variation in the effects of anxiety, meaning that some children are especially vulnerable for detrimental effects of math anxiety. In future studies, it might be useful to measure less stable and maybe more complex math skills—in the present study, we focused on basic arithmetic skills. Besides, since we assessed math anxiety and performance in a 1-year follow-up only, we cannot conclude that prior math anxiety would predict performance through all schooling. More longitudinal studies with longer follow-up periods and measures of math skills—not just basic arithmetical skills but also more complex skills with less stability—are needed to explore the long-term developmental relationships. Moreover, applications of person-centered approaches would be useful for exploring different developmental pathways and possible nonlinear associations between adolescents' math anxiety and performance also.

Unfortunately, causal claims about the situational association between math anxiety and performance cannot be made based on the results of study 2. Since the students reporting anxiety only in the difficult task performed relatively lower in the difficult than in the easy task, compared to their skill level, it seems that anxiety is somehow related to *underperformance*. One explanation for this result is that math anxiety arousal disrupts performance. However, it also might be that students' own estimates of failure or underperformance in challenging tasks causes anxiety arousal. Furthermore, it might be both math anxiety disrupting performance and underperformance arousing anxiety in vicious circle. In the future research, situational study designs should be developed to be able to test this causal relationship explicitly.

There are some other limitations concerning our math anxiety measures that should be noted. In the present study, we investigated math anxiety from two perspectives: trait and state anxiety.[27,28] However, the dimensionality of math anxiety was not considered; math anxiety can be divided into different dimensions based on whether it arises in testing, problem-solving, or social situations.[1,50,51] In both substudies, the math anxiety scale consisted of only three items, which also affected the reliability of the scale. Despite somewhat low Cronbach's alpha (0.64 at the first time point and 0.72 at the second time point), the factor score scale reliability of math anxiety was nevertheless high (0.84 at the first time point and 0.87 at the second time point), and the interitem correlations of anxiety items ranged from 0.37 to 0.40 ($p$ < 0.001) at time 1 and from 0.40 to 0.57 ($p$ <0.001) at time 2. Three items have also previously been found satisfactory for measuring math anxiety and other academic anxieties.[52,53] Furthermore, general anxiety that has been found to be highly correlated with math anxiety[54] was not controlled for in the present study. However, the results of the study of Carey *et al.*[50] suggest that math anxiety is a unique construct, separate from both test anxiety and general anxiety. Finally, in study 2, we used quite lenient cutoff criteria (upper quartile, i.e., approximately one and half standard deviation above the mean) for dividing the participants into math anxiety groups. Future studies with tighter cutoff scores for math anxiety are needed in order to shed light on the mechanisms, especially among severely anxious adolescents.

The results suggest that the relationship between math anxiety and performance is two-fold: math anxiety is both situationally and longitudinally related to math performance. Math anxiety was viewed from two perspectives—as an individual trait (trait anxiety)[27,28] and as an emotional state (state anxiety)[27,28]—in order to get a wider and more complete picture of the relationship between math anxiety and performance. Based on the results of additional analyses, the two views are somehow related. Nevertheless, controlling for trait anxiety did not change the situational relation between math anxiety and performance; therefore, it seems that the situational effect of math anxiety was a result of a situational emotional state rather than just a permanent tendency to feel anxious about mathematics. However, in future research, different study designs would be needed to explore the relationship between the two views more deeply, as well as the causal directions in the relationship between situational math anxiety and performance.

## CONCLUSIONS

Some practical implications can be proposed based on these results. In the school, teachers should be increasingly aware of math anxiety and its consequences. The results of the present study should be taken into consideration in two ways. First, teachers should pay specific attention to the students who continuously seem to become anxious in situations related to mathematics, because math anxiety, as an individual trait, seems to have a longitudinal effect on the development of mathematical skills. Second, in effective math instruction, arousal of stress and anxiety should be minimized. Since math anxiety has a situational effect on performance, the students learn less efficiently when feeling anxious. Additionally, the students should be made more aware of the effect of emotions on both learning and performing.

The results of the present study, along with previous research, underline the complex relationship between math anxiety and performance. They adduce the two-fold relationship between anxiety and achievement: math anxiety seems to have both a real-time association with performance when occurring and a long-term effect on the development of basic arithmetic skills. In future, for gaining more comprehensive understanding, the research should take into account both perspectives: math anxiety as a situational state and as an individual trait, especially when investigating the mechanisms behind the relationship between math anxiety and achievement.

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### AUTHOR CONTRIBUTIONS

R.S. analyzed and interpreted the data and drafted the manuscript. N.K. designed and coordinated the study and participated in the interpration of the data and drafting the manuscript. T.K., T.A., H.V., and M.A. participated in the interpration of the data and the results and drafting the manuscript. T.A. partipated in the design and coordination of the study and revising the intellectual content of the manuscript.

### COMPETING INTERESTS

The authors declare no competing interests.

### PEER REVIEW

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### REFERENCES

1. Richardson, F. C., & Suinn, R. M. (1972). The Mathematics Anxiety Rating Scale: Psychometric data. *Journal of Counseling Psychology*, *19*, 551–554.
2. Ashcraft, M. H., & Moore, A. M. (2009). Mathematics anxiety and the affective drop in performance. *Journal of Psychoeducational Assessment*, *27*, 197–205.
3. Carey, E., Devine, A., Hill, F., & Szűcs, D. (2017). Differentiating anxiety forms and their role in academic performance from primary to secondary school. *PLoS One*, *12*, e0174418.
4. Cargnelutti, E., Tomasetto, C., & Passolunghi, M. C. (2017). The interplay between affective and cognitive factors in shaping early proficiency in mathematics. *Trends in Neuroscience and Education*, *8–9*, 1–36.
5. Gunderson, E. A., Park, D., Maloney, E. A., Beilock, S., & Levine, S. (2018). Reciprocal relations among motivational frameworks, math anxiety, and math achievement in early elementary school. *Journal of Cognition and Development*, *19*, 21–46.
6. Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2013). Math anxiety, working memory, and math achievement in early elementary school. *Journal of Cognition and Development*, *14*, 187–202.
7. Wu, S., Amin, H., Barth, M., Malcarne, V., & Menon, V. (2012). Math anxiety in second and third graders and its relation to mathematics achievement. *Frontiers in Psychology*, *3*, 162.
8. Sorvo, R., Koponen, T., Viholainen, H., Aro, T., Räikkönen, E., Peura, P., Dowker, A., & Aro, M. (2017). Math anxiety and its relationship with basic arithmetic skills among primary school children. *British Journal of Educational Psychology*, *87*, 309–327.
9. Ma, X. (1999). A meta-analysis of the relationship between anxiety toward mathematics and achievement in mathematics. *Journal for Research in Mathematics Education*, *30*, 520–540.
10. Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education*, *21*, 33–46.
11. Carey, E., Hill, F., Devine, A., & Szücs, D. (2016). The chicken or the egg? The direction of the relationship between mathematics anxiety and mathematics performance. *Frontiers in Psychology*, *6*, 1987.
12. Ashcraft, M. H., Krause, J. A., & Hopko, D. R. (2007). Is math anxiety a mathematical learning disability? In D. B. Berch & M. M. M. Mazzocco (Eds.), *Why is math so hard for some children? The nature and origins of mathematical learning difficulties and disabilities* (pp. 329–348). Paul H. Brookes Publishing Co.
13. Sorvo, R., Koponen, T., Viholainen, H., Arobc, T., Räikkönend, E., Peuraa, P., Tolvanene, A., & Aro, M. (2019). Development of math anxiety and its longitudinal relationships with arithmetic achievement among primary school children. *Learning and Individual Differences*, *69*, 1-238.
14. Wu, S. S., Willcutt, E. G., Escovar, E., & Menon, V. (2014). Mathematics achievement and anxiety and their relation to internalizing and externalizing behaviors. *Journal of Learning Disabilities*, *47*, 503–514.
15. Rubinsten, O., & Tannock, R. (2010). Mathematics anxiety in children with developmental dyscalculia. *Behavioral and Brain Functions*, *6*, 1–13.
16. Passolunghi, M. C. (2011). Cognitive and emotional factors in children with mathematical learning disabilities. *International Journal of Disability, Development and Education*, *58*, 61–73.
17. Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion*, *7*, 336-353.
18. Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*, 201–215.
19. Derakshan, N., & Eysenck, M. W. (2009). Anxiety, processing efficiency, and cognitive performance. *European Psychologist*, *14*, 168–176.
20. Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General*, *130*, 224.
21. Ramirez, G., Chang, H., Maloney, E. A., Levine, S. C., & Beilock, S. L. (2016). On the relationship between math anxiety and math achievement in early elementary school: The role of problem solving strategies. *Journal of Experimental Child Psychology*, *141*, 83–100.
22. Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current Directions in Psychological Science*, *11*, 181-185.

23. Ashcraft, M. H., & Faust, M. W. (1994). Mathematics anxiety and mental arithmetic performance: An exploratory investigation. *Cognition & Emotion*, *8*, 97-125.
24. Faust, M. W. (1996). Mathematics anxiety effects in simple and complex addition. *Mathematical Cognition*, *2*, 25-62.
25. Deieso, D., & Fraser, B. J. (2019). Learning environment, attitudes and anxiety across the transition from primary to secondary school mathematics. *Learning Environments Research*, *22*, 133–152.
26. Ma, X., & Xu, J. (2004). The causal ordering of mathematics anxiety and mathematics achievement: A longitudinal panel analysis. *Journal of Adolescence*, *27*, 165–179.
27. Spielberger, C. D. (1966). Theory and research on anxiety. *Anxiety and Behavior*, *1*, 3–22.
28. Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review*, *18*, 315–341.
29. Goetz, T., Bieg, M., Lüdtke, O., Pekrun, R., & Hall, N. C. (2013). Do girls really experience more anxiety in mathematics? *Psychological Science*, *24*, 2079–2087.
30. Conlon, R. A., Hicks, A., Barroso, C., & Ganley, M. C. (2021). The effect of the timing of math anxiety measurement on math outcomes. *Learning and Individual Differences*, *86*, 101962.
31. Szczygieł, M., & Pieronkiewicz, B. (2021). Exploring the nature of math anxiety in young children: Intensity, prevalence, reasons. *Mathematical Thinking and Learning*, https://doi.org/10.1080/10986065.2021.1882363
32. Trezise, K., & Reeve, R. A. (2018). Patterns of anxiety in algebraic problem solving: A three-step latent variable analysis. *Learning and Individual Differences*, *66*, 78–91.
33. Aunola, K., Leskinen, E., Lerkkanen, M.-K., & Nurmi, J.-E. (2004). Developmental dynamics of math performance from preschool to grade 2. *Journal of Educational Psychology*, *96*, 699.
34. Mauno, S., Hirvonen, R., & Kiuru, N. (2018). Children's life satisfaction: The roles of mothers' work engagement and recovery from work. *Journal of Happiness Studies*, *19*, 1373–1393.
35. Hirvonen, R., Väänänen, J., Aunola, K., Ahonen, T., & Kiuru, N. (2018). Adolescents' and mothers' temperament types and their roles in early adolescents' socioemotional functioning. *International Journal of Behavioral Development*, *42*, 453–463.
36. Aunola, K., & Räsänen, P. (2007). The 3-minute basic arithmetic test. Unpublished.
37. Räsänen, P., Salminen, J., Wilson, A. J., Aunioa, P., & Dehaene, S. (2009). Computer-assisted intervention for children with low numeracy skills. *Cognitive Development*, *24*, 450–472.
38. Pekrun, R., Goetz, T., Frenzel, A. C., Barchfelda, P., & Perrye, R. P. (2011). Measuring emotions in students' learning and performance: The Achievement Emotions Questionnaire (AEQ). *Contemporary Educational Psychology*, *36*, 36–48.
39. Sainio, P. J., Eklund, K. M., Ahonen, T. P. S., & Kiuru, N. H. (2019). The role of learning difficulties in adolescents' academic emotions and academic achievement. *Journal of Learning Disabilities*, *52*, 287–298.
40. Satorra, A., & Bentler, P. M. (2001). A scaled difference chi-square test statistic for moment structure analysis. *Psychometrika*, *66*, 507–514.
41. Steiger, J. H. (1990). Structural model evaluation and modification: An interval estimation approach. *Multivariate Behavioral Research*, *25*, 173–180.
42. Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin*, *107*, 238.
43. Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*, 1–55.
44. Muthén, L. K. (2017). *Mplus users guide (version 8). [Google Scholar]*. Los Angeles, CA: Muthén & Muthén.
45. Lehikoinen, A., Ranta-Nilkku, E., Mikkonen, J., Kaartinen, J., Penttonen, M., Ahonen, T., & Kiuru, N. (2019). The role of adolescents' temperament in their positive and negative emotions as well as in psychophysiological reactions during achievement situations. *Learning and Individual Differences*, *69*, 116–128.
46. Kanerva, K., Kiistala, I., Kalakoski, V., Hirvonen, R., Ahonen, T., & Kiuru, N. (2019). The feasibility of working memory tablet tasks in predicting scholastic skills in classroom settings. *Applied Cognitive Psychology*, *33*, 1224–1237.
47. Päivinen, M., Eklund, K., Hirvonen, R., Ahonen, T., & Kiuru, N. (2019). The role of reading difficulties in the associations between task values, efficacy beliefs, and achievement emotions. *Reading and Writing*, *32*, 1723–1746.
48. Kiuru, N., Pakarinen, E., Vasalampi, K., Silinskas, G., Aunola, K., Poikkeus, A.-M., Metsäpelto, R.-L., Lerkkanen, M.-K., & Nurmi, J.-E. (2014). Task-focused behavior mediates the associations between supportive interpersonal environments and students' academic performance. *Psychological Science*, *25*, 1018–1024.
49. Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, *54*, 1063.
50. Carey, E., Hill, F., Devine, A., & Szűcs, D. (2017). The Modified Abbreviated Math Anxiety Scale: A valid and reliable instrument for use with children. *Frontiers in Psychology*, *8*, 11.
51. Gierl, M. J., & Bisanz, J. (1995). Anxieties and attitudes related to mathematics in grades 3 and 6. *Journal of Experimental Education*, *63*, 139–158.
52. Gogol, K., Brunner, M., Goetz, T., Martin, R., Ugen, S., Keller, U., Fischbach, A., & Preckel, F. (2014). "My Questionnaire is Too Long!" The assessments of motivational-affective constructs with three-item and single-item measures. *Contemporary Educational Psychology*, *39*, 188–205.
53. Núñez-Peña, M. I., Guilera, G., & Suárez-Pellicioni, M. (2014). The Single-Item Math Anxiety Scale. *Journal of Psychoeducational Assessment*, *32*, 306–317.
54. Betz, N. E. (1978). Prevalence, distribution, and correlates of math anxiety in college students. *Journal of Counseling Psychology*, *25*, 441–448.


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