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Math anxiety and its relationship with basic arithmetic skills among primary school children

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Math Anxiety and Its Relationship with Basic Arithmetic Skills among Primary School Children

Abstract

Background

Children have been found to report and demonstrate math anxiety as early as the first grade. However, previous results concerning the relationship between math anxiety and performance are contradictory, with some studies establishing a correlation between them while others do not. These contradictory results might be related to varying operationalizations of math anxiety.

Aims

In this study, we aimed to examine the prevalence of math anxiety and its-relationship with basic arithmetic skills in primary school children, with explicit focus on two aspects of math anxiety: anxiety about failure in mathematics and anxiety in math-related situations.

Sample

The participants comprised 1,327 children at grades 2 to 5.

Methods

Math anxiety was assessed using six items, and basic arithmetic skills were assessed using three assessment tasks.

Results

Around one-third of the participants reported anxiety about being unable to do math, one-fifth about having to answer teachers' questions and one-tenth about having to do math. Confirmatory factor analysis indicated that anxiety about math-related situations and about failure in mathematics are separable aspects of math anxiety. Structural equation modeling suggested that anxiety about math-related situations was more strongly associated with arithmetic fluency than anxiety about failure. Anxiety about math-related situations was most common among second graders and least common among fifth graders.

Conclusions

Since math anxiety, particularly about math-related situations, was related to arithmetic fluency even as early as the second grade, children's negative feelings and math anxiety should be identified and addressed from the early primary school years.

Keywords:

Math anxiety

Mathematical skills

Primary school

Math anxiety assessment

Introduction

Math anxiety among primary school children

Math anxiety is usually defined as feelings of tension and anxiety stemming from the manipulation of numbers and solving mathematical problems (Richardson & Suinn, 1972). Previous studies suggest that different types or contexts of mathematical activities can trigger math anxiety—for example, numeric processing (Richardson & Suinn, 1972; Suinn, Taylor, & Edwards, 1988; Wu, Barth, Amin, Malcarne, & Menon, 2012), executing math tasks in front of classmates and errors in math (Jameson, 2013). Although math and test anxiety are correlated (Williams, 1994), they are separable constructs (Dew, Galassi, & Galassi, 1984; Hopko, Mahadeva, Bare, & Hunt, 2003). In his meta-analysis, Hembree (1990) found that math anxiety and test anxiety have only 37% common variance, suggesting that math anxiety comprises a general negative reaction toward mathematics, including not only testing but also math classes and homework.

Most existing studies of math anxiety have involved adults or adolescents, and few studies have focused on young children. However, there is increasing evidence that children report and demonstrate math anxiety as early as the first grade (Ma, 1999; Ramirez, Gunderson, Levine, & Beilock, 2013). Little is known about the developmental course, but some studies suggest that the level of math anxiety increases with age (Dowker, Bennett, & Smith, 2012; Gierl & Bisanz, 1995; Krinzinger, Kaufmann, & Willmes, 2009).

Previous studies have usually found no gender differences in math anxiety among young children (Dowker et al., 2012; Erturan & Jansen, 2015; Harari, Vucovic, & Bailey, 2013; Wu, Willcutt, Escovar, & Menon, 2014), but at a later point during their school career, females seem to be more anxious about mathematics than males (e.g. Else-Quest, Hyde, & Linn, 2010; Hembree, 1990; Kyttälä & Björn, 2010). It remains unclear, however, at which point during their development these differences appear. In sum, more detailed knowledge about the early manifestation of math anxiety and possible gender differences is needed if we are to find ways of circumventing the development of negative attitudes and behavioural responses toward mathematics at an early stage.

Math anxiety and its relationship to performance

It has been suggested that anxiety has an online effect on math performance by straining working memory (Ashcraft & Kirk, 2001) as well as a long-term effect, which leads to the avoidance of situations involving mathematics (Ashcraft & Moore, 2009; Hembree, 1990). This stance is supported by findings showing that math anxiety is related to lower performance in mathematics (e.g. Hembree, 1990; Ma, 1999). This relationship has been found among adolescents and adults in many mathematical subskills, including basic number skills such as counting (Maloney, Risko, Ansari, & Fugelsang, 2010) and magnitude comparison (Ashcraft, 2002; Maloney et al., 2010; Maloney, Ansari, & Fugelsang, 2011) as well as more complex arithmetical operations (Ashcraft & Faust, 1994). However, among primary school children, the relationship between math anxiety and math performance remains unclear. The findings from previous studies have been contradictory, with some studies suggesting that primary school children's math anxiety is not related to performance (Dowker et al., 2012; Haase et al., 2012; Krinzinger et al., 2007; Krinzinger et al., 2009; Thomas & Dowker, 2000; Wood et al., 2012), while others suggest that math anxiety is negatively correlated to performance even at that age (Harari et al., 2013; Jameson, 2013; Vucovic, Kieffer, Bailey, & Harari, 2013; Wu et al., 2012; Wu et al., 2014).

The contradictory findings of previous studies concerning the relation between anxiety and performance in math lead to the question of whether the variation in operationalizing math anxiety might be related to the variation in research findings. To better understand the above-mentioned contradictory findings, we reviewed how earlier studies operationalized math anxiety. From the detailed description of the measures in Table 1, we observe that some studies (Dowker et al., 2012; Haase et al., 2012; Krinzinger et al., 2007; Krinzinger et al., 2009; Wood et al., 2012) measured anxiety or unhappiness with reference to *being unable to do something* in mathematics—in other words, *anxiety about failure in mathematics*. Interestingly, none of these studies have found a relationship between math anxiety and math performance.

Other studies (Ramirez et al., 2013; Wu et al., 2012; Wu et al., 2014) have focused on *anxiety in math-related situations in general* (Table 1). In these studies, the children were asked how anxious they felt when they had to solve mathematical problems or when they were in other situations related to mathematics. In these questions, it was not defined whether the expected result was success or failure. The measures used in these studies are described in Table 1. These studies (Ramirez et al., 2013; Wu et al., 2012; Wu et al., 2014) reveal a connection between math anxiety and performance. Thus, it seems that *anxiety in math-related situations* is specifically related to perfomance in mathematics in contrast to *anxiety about failure in mathematics*. However, because these two dimensions have been examined mainly in separate studies, and thus in separate samples, this conclusion is tentative. Only few studies (Harari et al., 2013; Jameson, 2013; Vucovic et al. 2013) have simultaneously measured both anxiety about failure in mathematics and anxiety in math-related situations and they found an association between anxiety and performance in math. However, because these studies do not analyse or report on anxiety in math-related situations and anxiety about failure in math separately, they do not reveal whether these aspects of math anxiety are differently related to math skill.

Insert Table 1 about here.

The present study

Our aim was to examine math anxiety and its relationship with basic arithmetic skills in second- to fifth-grade students, as knowledge about math anxiety in this age group is scarce. The study is based on a sample of Finnish primary school children. Our first aim was to examine the prevalence of math anxiety among primary school children from second to fifth grade and to explore whether there were any gender or grade-level differences. Second, we examined whether the two ways of operationalizing math anxiety—anxiety about failure in mathematics and anxiety in math-related situations—were two empirically separable aspects of math anxiety. Third, we aimed to study whether the suggested aspects of math anxiety were differently related to basic arihtmetic skills and whether the relationship between math anxiety factors and basic arithmetic skills was independent of gender and grade level. Based on the results of previous studies (e.g. Dowker et al., 2012; Wu et al., 2012), anxiety about math-related situations could be related to basic arithmetic skills, whereas anxiety about failure might not be. However, because there are no previous studies examining these two aspects of math anxiety in the same sample, a strong hypothesis cannot be stated.

Method

Participants

Our study is based on data from the first assessment of a longitudinal study focusing on the development of self-beliefs and academic skills in children. The data for our study were collected in November 2013. A total of 20 schools in urban and semi-urban areas in Finland volunteered to participate, from which the classes were recruited for the study. Written consent was obtained from the guardians of the children, and the research procedure was evaluated by the university ethical committee.

The sample consists of 1,327 children (48.08% girls) from grades 2 to 5. Of these children, 178 (13.41%) were second graders (*M* = 8.35 years, *SD* = 0.32), 471 (35.49%) were third graders (*M* = 9.34 years; *SD* = 0.31), 383 (28.86%) were fourth graders (*M* = 10.40 years; *SD* = 0.35) and 295 (22.23%) were fifth graders (*M* = 11.39 years; *SD* = 0.36).

Complete data for the measures of math anxiety and basic arithmetic skills were available for 85.2% of the sample. The highest percentage of missing data (6.9% of the children) was obtained for three items assessing negative affective reactions in math-related situations mainly due to absence from school.

Procedure

The assessments were carried out by trained research assisstants over two school days as part of a more extensive questionnaire. The assessment was structured in a way so that none of the math anxiety questions were presented immediately after the basic arithmetic skills tasks.

Measures

Math anxiety

Anxiety about failure in mathematics was assessed with items from the Math Anxiety Questionnaire (MAQ) (Thomas & Dowker, 2000), which were translated into Finnish in cooperation with one of the authors. The original version of the MAQ consists of four different types of questions (Krinzinger et al., 2007): liking mathematics, mathematics self-evaluation, unhappiness about poor performance and math anxiety with regard to several different situations involving mathematics. We used two questions to assess anxiety: how anxious or calm the participant would be if she/he was unable to do something targeting mathematics in general as well as targeting mental calculations. We also included a question targeting math homework. Altogether, anxiety about failure was assessed using three items (Table 2). Children responded on a 5-point scale, which was visualized with pictures of faces varying from very anxious (rated as 5) to very calm (rated as 1).

Anxiety in math-related situations was assessed with three statements on anxiety or tension arousal in situations involving mathematics (Table 2). These items were adopted from a subscale initially designed for measuring affective and physical state sources of self-efficacy, which was based closely on the ideas of Usher and Pajares (2008). The participants responded to each statement using a 7-point scale (1 = false, 2–3 = mostly false, 4 = neither true nor false, 5–6 = mostly true, 7 = true). As most of the children responded 1 = false to the items (51.30–69.38% of children, depending on the item), the categories were combined as follows: 1 = 1, 2 = 2–4, 3 = 5–7.

Basic arithmetic skills

Basic arithmetic skills were assessed using three time-limited paper-and-pencil group tests. Both the two-minute addition fluency test (Koponen & Mononen, 2010a) and the two-minute subtraction fluency test (Koponen & Mononen, 2010b) consist of 60 simple tasks—the addition test with addends smaller than 10 and the subtraction test with results in the range of one to nine. The three-minute basic arithmetic test (Aunola & Räsänen, 2007) consists of 30 addition, subtraction, division and multiplication items. The scores of these tasks were standardized within each grade level.

Statistical analysis

Spearman correlations between the observed variables were calculated using IBM SPSS Statistics (version 22). To compare the distribution of participants reporting anxiety among girls and boys and different grade levels, a cross-tabulation and χ^2 test with adjusted standardized residuals (ASR) were used. For this comparison, we split the sample into two groups: those who reported anxiety (responding to anxiety statements by “mostly true” or “true” or choosing an anxious or very anxious pictorial face) and those who did not. The groups were then cross-tabulated against gender and grade level. ASR indicates the direction and size of the deviation of the observed frequencies in each cell from those expected. An ASR greater than 1.96 indicates that, in the cell in question, there are statistically significantly (at $p < .05$) more children than expected by chance.

The main analyses were conducted using the Mplus software, version 7.3 (Muthén & Muthén, 1998–2012). As some of the variables were categorical, we used weighted least square parameter estimates with a diagonal weight matrix with standard errors (WLSMV) estimator for the analyses (Muthén, 1984). As the missing data were considered random, the full information maximum likelihood procedure (FIML) was used to estimate the parameters. The FIML uses all information in the data without imputing missing values.

The aspects of math anxiety and the structure basic arithmetic skills were investigated using confirmatory factor analysis (CFA). We constructed the hypothetical two-factor model of math anxiety in which items MA1–MA3 (Table 2) were supposed to load on the “Anxiety about failure” factor and MA4–MA6 on the “Anxiety in math-related situations” factor. The two factors were set to correlate with each other. In addition, a competing one-factor model was constructed to confirm the superiority of the two-factorial model of math anxiety.

We evaluated the overall goodness-of-fit of the CFA models using the χ^2 test, the root mean square error of approximation test (RMSEA; Steiger, 1990), the comparative fit index

(CFI; Bentler, 1990) and the Tucker-Lewis index (TLI; Hu & Bentler, 1999). For a good model fit, the *p*-value of the χ^2 test should be greater than .05, the RMSEA less than .06 and the CFI and TLI greater than .95 (Hu & Bentler, 1999).

We compared the nested theoretical models of math anxiety (i.e. two factors vs. one factor) using the χ^2 difference test (Asparouhov & Muthen, 2006). A significant χ^2 difference test denotes that the model with fewer degrees of freedom (i.e. fewer constraints) fits the data better, whereas a non-significant difference test denotes that the simpler model with greater degrees of freedom (i.e. more constraints) is not significantly worse than the model with fewer degrees of freedom.

After choosing the best math anxiety model, the invariance of the math anxiety model separately across genders and grade levels was examined using multigroup invariance comparison tests. The group invariance was tested by comparing the fit of the baseline model (i.e. the parameters of the model were freely estimated in all groups under investigation) to that of the constrained model (i.e. the parameters were constrained to be equal across the groups) using the χ^2 difference test (Satorra & Bentler, 2001).

Finally, we explored the associations between the dimensions of math anxiety and basic arithmetic skills. Before the examination, the factorial structure of basic arithmetic skills was checked using CFA and the Satorra-Bentler scaled χ^2 difference test. The relationship between the math anxiety factors and basic arihtmetic skills were examined using structural equation modeling (SEM). The goodness-of-fit of the SEM model was evaluated using the same overall indices as in the math anxiety models.

Results

The prevalence of math anxiety

The descriptive statistics for the observed variables are reported in Table 2 and the correlations between the observed variables in tables 3 and 4. As shown in Table 5, the proportion of participants reporting anxiety varied from 8.8 to 27.4%, depending on the math anxiety variable. More girls relative to boys reported anxiety about answering teachers' questions in math class, and in most of the items, there were relatively more second graders and fewer fifth graders reporting anxiety (Table 5).

Insert tables 2–5 here.

The two ways of operationalizing math anxiety

The two-factor model of math anxiety fit the data well ($\chi^2(8) = 18.74$, $p <.05$; RMSEA = .03, CFI and TLI = 1.00), whereas the one-factor model did not ($\chi^2(9) = 1807.80$, $p < .001$; RMSEA =.39, CFI = .69; TLI = .49). Moreover, the χ^2 difference test confirmed that the best approximation of the data was achieved with the two-factorial model ($\chi^2(1) = 883.54$; $p < .001$). All loadings and residual variances in the two-factor model were statistically significant and positive (Figure 1). A significant correlation was found between the two math anxiety factors: *Anxiety about failure* and *Anxiety about math-related situations*. The factor loadings and thresholds of the observed variables of the two-factorial math anxiety model were invariant across genders and all grade levels (Table 6).

Insert Table 6 here.

Math anxiety in relation to basic arithmetic skills

Before examining the associations between the math anxiety factors and basic arithmetic skills, the factorial structure of arithmetic skills was checked and found to be satisfactory. The final basic arithmetic skill model was a saturated model ($\chi^2(0) = 0$, $p = .000$; RMSEA =

.00, CFI and TLI = 1.00; SRMR = .00). The factor loadings were high (between .78 and .94), and the residual variances of the observed variables were positive and statistically significant. The basic arithmetic skills model was fully invariant between genders and grade levels (Table 7). As the arithmetic measures were standardized within grade levels, the test of between-grades invariance of the intercepts was not relevant.

Insert Figure 1 about here.

The association between math anxiety and basic arithmetic skills was then examined. The estimated model and its fit indices are presented in Figure 1. According to the χ^2 difference test ($\chi^2(1) = 15.80$; $p < .001$), a high level of *Anxiety about math-related situations* was more strongly associated with low basic arithmetic skills than a high level of *Anxiety about failure*. The relationships between the math anxiety factors and the basic arithmetic skills factor were similar between genders ($\chi^2(2) = 2.28$; $p = .32$) and grade levels ($\chi^2(6) = 2.89$; $p = .82$).

Insert Table 6 here.

Since the math anxiety factors correlated moderately, further analyses were needed to ascertain which part of the variance of math anxiety is related to basic arithmetic skills: the unique variance of *Anxiety about math-related situations* and/or the variance common to both factors. To clarify this issue, we further elaborated the model presented in Figure 1. First, we examined whether the unique variance of *Anxiety about failure* and the variance shared by *Anxiety about failure* and *Anxiety about math-related situations* were related to basic arithmetic skills (Figure 2). Two specific factors were created: one factor captured the whole variance of *Anxiety about math-related situations*, including that part of the variance of *Anxiety about failure* which was common to both factors. The other specific factor captured the residual variance of *Anxiety about failure* (i.e. the unique variance of this factor). As shown in Figure 2, *Anxiety about math-related situations* (including its common variance with the *Anxiety about failure* factor) was more strongly related to basic arithmetic skills than the unique variance of *Anxiety about failure* ($\chi^2(1) = 16.37$; $p < .001$).

Insert Figure 2 about here.

Second, we examined whether the unique variance of *Anxiety about math-related situations* and the variance shared by both factors were related to basic arithmetic skills (Figure 3). Again, two specific factors were formed: one specific factor captured the whole variance of *Anxiety about failure*, including that part of the variance of the *Anxiety about math-related situations* factor which was common to *Anxiety about failure*. The other specific factor captured the residual variance of *Anxiety about math-related situations* (i.e. the unique variance of this factor). The unique variance of the *Anxiety about math-related situations* factor was as strongly related to basic arithmetic skills as the *Anxiety about failure* factor (including the common variance of the two factors), $\chi^2(1) = .09$; $p = .77$.

Insert Figure 3 about here.

Discussion

Our study aimed to investigate the manifestation of math anxiety among primary school children. The results showed that children report math anxiety as early as the second grade. Around one-third of all children reported anxiety about being unable to do a mental calculation task, math homework or something in math in general. About one-fifth of the children reported anxiety about having to answer teachers' questions in math class, and one tenth reported anxiety about starting to do math or tension about having to do math. More girls relative to boys reported anxiety about having to answer teachers' questions in math class. Anxiety about math-related situations was most common in second grade and least common in fifth grade.

We also investigated different aspects of math anxiety which have been used in previous studies and their association with basic arithmetic skills. Our results suggest that anxiety about math-related situations and anxiety about failure in mathematics are separable but correlated. Both of these aspects were negatively related to basic arithmetic skills, the former more strongly than the latter. When both factors were included in the same model, anxiety about math-related situations continued to demonstrate a unique association with basic arithmetic skills, above and beyond its shared variance with anxiety about failure. In contrast, anxiety about failure was only weakly uniquely related to arithmetic skills after taking into account its shared variance with anxiety about math-related situations. The model was similar among girls and boys and grade levels, and neither gender nor grade level affected the relationship between math anxiety and basic arithmetic skills.

There were no gender differences in anxiety about failure, which is consistent with previous research on primary school children (Dowker et al., 2012). There were relatively more girls than boys reporting anxiety about having to answer teachers' questions in math class, and the mean of anxiety about math-related situations was higher among girls than boys. This result is in line with studies of adolescents and adults indicating greater math anxiety in females than males (e.g. Else-Quest et al., 2010; Hembree, 1990). One possible explanation for the higher math anxiety in females might be the *stereotype threat*: females might be at risk of the stereotypical assumption that they are not as good at math as males (Steele, 1997). It has been suggested that the gender-based stereotypical beliefs of adults affect achievement differently between girls and boys (Jacobs, Davis-Kean, Bleeker, Eccles, & Malanchuk, 2005) and that children endorse the stereotype that "math is for boys" as early as in second grade (Cvencek, Meltzoff, & Greenwald, 2011). However, general anxiety is more common among girls than boys (e.g. Simonoff et al., 1997), so conclusions of gender differences should be made with caution. Children's stereotypical beliefs and relationship with math anxiety and achievement should be further explored, particularly in relation to culture and society, since stereotypical gender-based expressions are cross-culturally inconsistent (Dowker, 2005; Passolunghi, Rueda Ferreira, & Tomasetto, 2014).

The existence of math anxiety in early grades has also been noted in previous research (Ma, 1999; Ramirez et al., 2013). However, our study suggests that grade level has an effect on the proportion of participants who report anxiety in primary school. There were some differences between grade levels in the prevalence of anxiety about failure: there were relatively more fourth graders than expected reporting anxiety about being unable to do a mental calculation or something in mathematics, in general, and fewer fifth graders than expected reporting anxiety about being unable to do mental calculations. A substantial number of participants from all grades reported anxiety about being unable to do math homework.

In the items assessing anxiety about math-related situations, in general, the grade differences were more notable: there were more second graders and fewer fifth graders than expected reporting anxiety in all these items, and over 15% of second graders but less than 5% of fifth graders reported anxiety about starting to do math or tension about having to do math. Moreover, there were more third graders than expected reporting anxiety about having to answer teachers' questions. This result—representing a higher proportion of younger and a lower proportion of older children reporting math anxiety—is interesting, considering previous research suggesting that anxiety increases with age (Dowker et al., 2012; Gierl & Bisanz, 1995). Young children's stronger negative affective reactions in math-related situations might be elevated by the fact that they are still adjusting to school and have not yet developed adequate coping strategies for facing the difficulties of learning mathematics. Another possible explanation is that young children tend to use the extremes of the scale. However, in this case, the same kind of effect should have been found in anxiety about failure, which was not the case. It is also possible that some features of the Finnish school support system or mathematics education, such as the relatively extensively offered part-time special education (Kivirauma & Ruoho, 2007), lead to a reduction in mathematics anxiety over time. As this study was cross-sectional, no firm conclusions can be made regarding causal relationships or the development of math anxiety. More diverse research on math anxiety is needed.

Our results on the different kinds of relationships between math anxiety and arithmetic fluency support the assumption that varying operationalizations of math anxiety might explain the contradictory results in previous math anxiety research among primary school children (Dowker et al., 2012; Haase et al., 2012; Krinzinger et al., 2007; Krinzinger et al., 2009; Vucovic et al., 2013; Wood et al., 2012; Wu et al., 2012; Wu et al., 2014). In our study, anxiety about failure in mathematics was close to normally distributed among all age groups. Further, roughly one-third of our participants reported anxiety about failure. Anxiety about math-related situations was more dichotomic by distribution, and its prevalence in the whole sample varied from nine to 19%, depending on the item.

One possible explanation for the finding that anxiety about math-related situations was more related to basic arithmetic skills than anxiety about failure might be that the anxiety experienced by low- and high-achieving students stems from different kinds of experiences. One can assume that children with low basic skills in mathematics become anxious in various kinds of situations involving mathematics and calculations because of their earlier failures and negative experiences. By contrast, children across all skill levels can feel anxious about being unable to do something. Further, “concern over mistakes” has also been seen as a dimension of perfectionism (Frost, Marten, Lahart, & Rosenblate, 1990), which is also present among gifted students (Parker, 1997) and may, at least in its lighter forms, even stimulate healthy needs for achievement (Parker, 2000; Wang et al. 2015). However, it has been shown that among gifted students, concern over mistakes is also positively correlated with math anxiety (Tsui & Mazzocco, 2006).

Regarding the age group of primary school children, only a few studies (Harari et al., 2013; Jameson, 2013) have simultaneously assessed both anxiety about math-related situations and anxiety about failure in mathematics. Usually, either one or the other of these two ways of operationalizing has been used (Dowker et al., 2012; Haase et al., 2012; Krinzinger et al., 2007; Krinzinger et al., 2009; Vucovic et al., 2013; Wood et al., 2012; Wu et al., 2012; Wu et al., 2014). Since they seem to tap into different kinds of anxiety, at least from the second grade onward, this should be taken into consideration in measuring math anxiety.

Some limitations of the study should be noted. Our study supports the stance that more attention should be paid to understanding the structure and dimensions of math anxiety. As we focused on only two aspects of anxiety, future research is needed to better understand how different constructs introduced in the math anxiety literature are related to each other and to math performance as well as what the effect of contextual factors is (e.g. test or social situation). Different kinds of math anxiety dimensions have been found in previous studies, for example "test anxiety", "calculation anxiety" and "social anxiety" (e.g. Richardson & Suinn, 1972; Gierl & Bisanz, 1995) and, on the other hand, affective and cognitive dimensions of math anxiety, specifically "negative affective reactions" and "worry about performance" (e.g. Wigfield & Meece, 1988). Anxiety about failure and anxiety about math-related situations are, to some extent, overlapping with these different dimensions. Anxiety about failure is somewhat similar to "worry about performance"; however, they are not necessarily equal constructs. In the items relating to anxiety about failure, children were not asked whether they were worried about or afraid of failure. Instead, they were asked to imagine how anxious they would be if they noticed they were unable to do something.

Becoming anxious *when a failure occurs* does not necessarily mean being worried or afraid of it *beforehand*.

We assessed only basic arithmetic skills, and it is worth considering that mathematics is not a single entity but rather consists of many components (see, e.g., Dowker, 2005). In future studies, the relationships between math anxiety and achievement in a wider range of mathematical skills should be explored. Moreover, we used only timed measures. To understand the effects of math anxiety on mathematical performance more comprehensively, math anxiety should be assessed using both timed and untimed measures (Ashcraft & Moore, 2009). There are some limitations of group tests that should also be considered with regard to the present findings. For example, compared to individual assessments, in group tests it is more difficult to monitor and control for a correct understanding of the tasks or problems in maintaining attention. Further, our math anxiety measure consisted of a rather limited number of items. Nevertheless, among adolescents and young adults, short scales with three items and even single-item measures have been found to be reliable in assessing domain-specific academic anxieties and math anxiety (Gogol et al., 2014; Núñez-Peña, Guilera, & Suárez-Pellicioni, 2014).

In future studies, the effect of operationalizing math anxiety on the relationship between math anxiety and achievement, as well as the development of math anxiety, should be explored longitudinally and cross-culturally. The present study, consistent with previous research, shows that anxiety about math-related situations is related to arithmetic fluency. However, the causal connection between anxiety and achievement among children remains unexplored. Further knowledge about the development of math anxiety is needed to determine whether it is linear or whether there are some points during the educational career that propel an increase in the risk of math anxiety. We lack an understanding of the early development of negative math-related feelings and math anxiety. However, since math anxiety is reported as early as the second grade, it is possible that some children become anxious about mathematics during their first year at school or even earlier.

Conclusion

Consistent with previous research (Ma, 1999; Ramirez et al., 2013), the current study suggests that even in a country in which math anxiety has been reported to be low compared to many other countries (Lee, 2009), it is present in children as early as in the second grade. Thus, it is important to investigate mathematics anxiety even in young children and to gain a better understanding of its origins. In particular, a key focus should be on anxiety about math-related situations, because it seems to be directly related to arithmetic fluency. Negative math-related emotions should be identified and addressed at school at an early stage so as to prevent negative outcomes in skills development. Math anxiety should also assume great significance when planning mathematics education in primary school.

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Table 1.
Previous Research Examining the Relationship between Math Anxiety and Achievement in Children below Grade 6

Study/studies	Measure	The type of math anxiety measured	Relation to achievement?
Dowker *et al*., 2012; Haase *et al*., 2012; Krinzinger *et al*., 2007; Krinzinger *et al*., 2009; Wood *et al*., 2012	MAQ (Thomas & Dowker, 2000); Two components (Krinzinger *et al*., 2007): evalution of mathematics and math anxiety. The first component consists of items relating to self-rating and liking math. The math anxiety component consists of questions "*How worried/unhappy would you be if you did badly in. . .*" targeted at different types of math tasks (*math in general, written sums, mental sums, easy and difficult maths, math tests, understanding the teacher*).	Anxiety about failure	No
Wu *et al*., 2012; Wu *et al*., 2014	Scale for Early Mathematics Anxiety – created based on MARS (Richardson & Suinn, 1972) and MARS -E, X items measuring nervousness when answering math-related questions (e.g., *"Is this right? 9 + 7 = 18")* or being in math-related situations (e.g., "*You are in math class and your teacher is about to teach something new*").	Anxiety in math-related situations	Yes
Harari *et al*., 2013	The Mathematics Anxiety Scale for Young Children – questions derived from MARS-E (Suinn *et al*., 1988); the Mathematics Anxiety Questionnaire (Wigfield & Meece, 1988) consists of 12 items measuring numerical confidence (e.g., "*Figuring out if I have enough money to buy cookies and a drink is fun*"), worry (e.g., "*I get nervous about making a mistake in math*") and negative reactions (e.g., "*Math gives me a stomachache*").	Anxiety about failure and anxiety in math-related situations	Numerical confidence and negative reactions were related to achievement; worry was not.
Jameson, 2013	The Children's Anxiety in Math Scale consists of 16 items measuring general math anxiety (e.g., "*Thinking about working on math in class makes me feel. . .*"), math performance anxiety (e.g., "*If I have to add up numbers on the blackboard in front of the class, I feel. . .*") and math error anxiety (e.g., "*When the teacher gives the class a math problem I don't understand, I feel. . .*").	Anxiety about failure and anxiety in math-related situations	Yes, but the relationship between the the two types of anxiety is not examined separately.
Ramirez *et al*., 2013	The Child Math Anxiety Questionnaire (CMAQ; Ramirez *et al*., 2013), adapted from MARS-E., asked children how they feel when they have to solve a math task or problem (e.g., "*There are 13 ducks in the water, there are 6 ducks on land, how many ducks are there in all?*") or when they are in math-related situations ("*being called by teacher to explain a math problem on the board*").	Anxiety in math-related situations	Only for children with high working memory
Vucovic *et al*., 2013	Items adapted from MARS-E (Suinn *et al*., 1988) and the Mathematics Anxiety Questionnaire (Wigfield & Meece, 1988): 12 items assessing negative reactions and worry, items with positive valence (e.g., "*I like being called on in math*") and negative valence ("*I get nervous about making a mistake in math").*	Anxiety about failure and anxiety in math-related situations	Yes, but the relationship between the dimensions is not examined separately.

Table 2.
Descriptive Statistics of Observed Variables

	Gender		Grade			
	Girls	Boys	2	3	4	5
Study variables	*M* (*sd*)	*M* (*sd*)	*M* (*sd*)	*M* (*sd*)	*M* (*sd*)	*M* (*sd*)
Math anxiety						
How anxious or calm would you be if you were unable to do something in mathematics? (MA1)[1]	2.95 (1.09)	2.94 (1.17)	2.83 (1.23)	2.97 (1.14)	3.05 (1.15)	2.84 (1.01)
How anxious or calm would you be if you were unable to do a mental calculation task? (MA2) [1]	3.09 (1.10)	3.03 (1.19)	3.14 (1.33)	3.05 (1.18)	3.13 (1.16)	2.93 (0.98)
How anxious or calm would you be if you were unable to do mathematics homework? (MA3)[1]	3.08 (1.17)	3.01 (1.26)	3.08 (1.39)	3.00 (1.22)	3.09 (1.21)	3.02 (1.10)
I get anxious when I have to answer the teacher's questions in math class. (MA4) [2]	2.72 (2.05)	2.39 (1.98)	2.71 (2.27)	2.71 (2.13)	2.46 (1.89)	2.32 (1.79)
I get anxious when I start doing math. (MA5)[2]	1.98 (1.73)	1.75 (1.52)	2.16 (2.00)	1.99 (1.78)	1.82 (1.54)	1.53 (1.13)
I feel tension when I have to do math. (MA6) [2]	1.94 (1.60)	1.82 (1.60)	2.18 (1.99)	2.00 (1.70)	1.79 (1.47)	1.63 (1.25)
Basic arithmetic skills						
Addition Fluency Test score (ARI1) (observed min 0; max 101)	32.73 (13.15)	35.27 (15.47)	22.55 (9.00)	28.82 (9.90)	36.74 (13.18)	46.00 (15.24)
Subtraction Fluency Test score (ARI2) (observed min 2; max 87)	27.92 (11.57)	29.46 (13.69)	17.88 (8.41)	25.79 (9.49)	30.89 (11.85)	37.24 (14.01)
The three-minute Basic Arithmetic Test score (ARI3) (observed min 0; max 27)	14.74 (4.84)	15.16 (5.31)	9.88 (4.27)	14.00 (4.54)	15.86 (4.36)	18.49 (4.13)

Note. [1]scale from 1 to 5. [2]scale from 1 to 7.

Table 3.
Spearman Correlations between the Observed Variables at All Grade Levels

Variable	MA1	MA2	MA3	MA4	MA5	MA6	ARI1	ARI2
Grade 2								
MA1	1							
MA2	.62**	1						
MA3	.57**	.64**	1					
MA4	.23**	.27**	.25**	1				
MA5	.18*	.26*	.27**	.43**	1			
MA6	.10	.17*	.22**	.41**	.58**	1		
ARI1	−.09	−.10	−.07	−.10	−.16*	−.15	1	
ARI2	−.09	–.11	−.14	−.16*	−.25**	−.23**	.77**	1
ARI3	−.05	.01	−.06	−.18*	−.25**	−.24**	.66**	.71**
Grade 3								
MA1	1							
MA2	.52**	1						
MA3	.56**	.62**	1					
MA4	.20**	.20**	.18**	1				
MA5	.20**	.16**	.13**	.50**	1			
MA6	.12*	.13**	.10**	.45**	.49**	1		
ARI1	–.10*	-.03	-.06	-.08	−.11**	−.06	1	
ARI2	−.20**	−.10*	−.17**	−.15**	−.16**	−.07	.73**	1
ARI3	−.15**	−.11*	−.15**	−.15**	−.20**	−.14**	.64**	.74**
Grade 4								
MA1	1							
MA2	.62**	1						
MA3	.62**	.62**	1					
MA4	.20**	.27**	.24**	1				
MA5	.17**	.18**	.23**	.49**	1			
MA6	.17**	.19**	.20**	.44**	.53**	1		
ARI1	−.12*	−.14**	−.14*	−.24**	−.19**	−.16**	1	
ARI2	−.16**	−.21**	−.16**	−.23**	−.22**	−.17**	.82**	1
ARI3	−.16**	−.19**	−.16**	−.25**	−.20**	−.12*	.70**	.73**
Grade 5								
MA1	1							
MA2	.65**	1						
MA3	.57**	.57**	1					
MA4	.27**	.24**	.21**	1				
MA5	.26**	.19**	.23**	.38**	1			
MA6	.24**	.11*	.14*	.42**	.52**	1		
ARI1	−.05	−.14**	−.11	−.25**	−.09	−.05	1	
ARI2	−.14*	−.18**	−.15*	−.23**	−.11	−.13	.80**	1
ARI3	−.18**	−.22**	−.21**	−.20**	−.14*	−.08	.68**	.76**

Note. MA1, MA2, MA3, MA4, MA5, MA6 = math anxiety items; ARI1, ARI2, ARI3 = scores of arithmetic measures .
**p* < .05, ***p* < .01, ****p* < .001.

Table 4.

Spearman Correlations between the Observed Variables in Girls and Boys. Correlations for girls are presented above the diagonal, and correlations for boys are presented below the diagonal.

Girls Boys	MA1	MA2	MA3	MA4	MA5	MA6	ARI1	ARI2	MA1
MA1	–	.62**	.59**	.21**	.21**	.20**	-.14**	-.14**	-.16**
MA2	.57**	–	.61**	.24**	.21**	.20**	-.15**	-.17**	-.18**
MA3	.57**	.61**	–	.22**	.23**	.22**	-.16**	-.17**	-.20**
MA4	.24**	.23**	.20**	–	.44**	.41**	-.09*	-.12**	-.13**
MA5	.18**	.17**	.18**	.48**	–	.53**	-.20**	-.22**	-.23**
MA6	.12**	.11**	.10*	.45**	.52**	–	-.13**	-.13**	-.13**
ARI1	-.04	-.05	-.02	-.18**	-.11**	-.11**	–	.84**	.78**
ARI2	-.12**	-.11**	-.10*	-.19**	-.15**	-.13**	.83**	–	.81**
ARI3	-.10*	-.10*	-.08*	-.18**	-.17**	-.14**	.75**	.81**	–

Note. MA1, MA2, MA3, MA4, MA5, MA6 = math anxiety items; ARI1, ARI2, ARI3 = scores of arithmetic measures.

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 5.
The Proportions of Participants Reporting Anxiety among Girls and Boys and Different Grade Levels: χ^2 Test with Adjusted Standardized Residuals

		Gender			Grade				
Math anxiety item	All %	Girls %	Boys %	χ^2 (*df*)	2 %	3 %	4 %	5 %	χ^2 (*df*)
How anxious or calm would you be if you were unable to do something in mathematics? (MA1)[1]	27.44	28.40	26.48	0.60 (1)	24.27 n.s	26.16 n.s.	33.78 3.2	23.16 n.s.	11.34* (3)
How anxious or calm would you be if you were unable to do a mental calculation task? (MA2)[1]	33.51	34.58	32.63	0.55 (1)	39.53 n.s.	33.26 n.s.	37.90 2.1	24.47 -3.6	16.38** (3)
How anxious or calm would you be if you were unable to do mathematics homework? (MA3)[1]	33.85	34.96	32.78	0.68 (1)	35.26 n.s.	32.52 n.s.	36.39 n.s.	31.80 n.s.	2.11 (3)
I get anxious when I have to answer the teacher's questions in math class. (MA4)[2]	18.99	21.04	17.18	3.04* (1)	25.44 2.3	22.05 2.0	16.16 n.s.	14.08 -2.4	13.60** (3)
I get anxious when I start doing math. (MA5) [2]	9.23	10.66	8.04	2.55 (1)	17.16 3.8	11.41 n.s.	7.54 n.s.	3.51 -3.8	27.40*** (3)
I feel tension when I have to do math. (MA6)[2]	8.81	8.82	8.78	0.00 (1)	15.38 3.3	10.44 n.s.	7.20 n.s.	4.24 -3.1	19.15*** (3)

Note. Statistically significant adjusted standardized residuals (absolute value > 1.96) reported below the percentages of the participants on each grade level. **p* < .05, ***p* < .01, ****p* < .001. Reporting anxiety = [1]responding with an anxious or very anxious pictorial face; [2]responding by "mostly true" or "true".

Table 6.
Invariance Comparison for the Math Anxiety Model

Model	Model $\chi^2(df)$	χ^2 difference test	
		$\chi^2(df)$	p
Invariance comparison between genders			
Unconstrained model	26.12 (16)	–	–
Tresholds of observed variables set to be equal	39.84 (26)	13.68 (4)	.19
Factor loadings and tresholds of observed variables set to be equal	40.84 (30)	1.82 (4)	.77
Mean of anxiety about failure factor, factor loadings and tresholds set to be equal	36.51 (31)	.71 (1)	.40
Means of both anxiety factors, factor loadings and tresholds set to be equal	46.87 (32)	8.42 (1)	.00
Factor variances, means, loadings and tresholds of observed varibles set to be equal	52.12 (34)	4.49 (2)	.11
Factor covariance, variances, means, loadings and tresholds of observed variables set to be equal	50.70 (35)	.64 (1)	.42
Invariance comparison between grade levels			
Unconstrained model	46.54 (32)	–	–
Tresholds of observed variables set to be equal	91.01 (68)	47.93 (36)	.09
Factor loadings and tresholds of observed variables set to be equal	106.44 (74)	13.45 (12)	.34
Mean of anxiety about failure factor, factor loadings and tresholds set to be equal	101.65 (77)	4.36 (3)	.22
Means of both anxiety factors, factor loadings and tresholds set to be equal	104.99 (80)	3.77 (3)	.29
Variance of anxiety about failure factor, means of both anxiety factors, factor loadings and tresholds set to be equal	139.84 (83)	17.02 (3)	.00
Factor variances, means, loadings and tresholds of observed varibles set to be equal	175.64 (86)	23.17 (3)	.00
Factor covariance, variances, means, loadings and tresholds of observed variables set to be equal	167.63 (89)	1.51 (3)	.68

Note. χ^2 difference test = model compared to previous, less constrained model.

Table 7.
Invariance Comparison for the Basic Arithmetic Skills Model

Model	Model fit indices		χ² difference test		
	χ²(df)	*sc*	*χ²(df)*	*sc*	*p*
Invariance comparison between genders					
Unconstrained model	0.00 (0)	1.00	–	–	–
Factor loadings set to be equal	1.86 (2)	1.16	1.86 (2)	1.16	.39
Factor loadings and intercepts of observed variables set to be equal	7.19 (4)	1.06	5.69 (2)	.96	.06
Invariance comparison between grade levels					
Unconstrained model	0.00 (0)	1.00	–	–	–
Factor loadings set to be equal	8.11 (6)	1.14	8.11 (6)	1.14	.23

Note. *sc* = scaling correction; χ² difference test = model compared to previous, less constrained model.

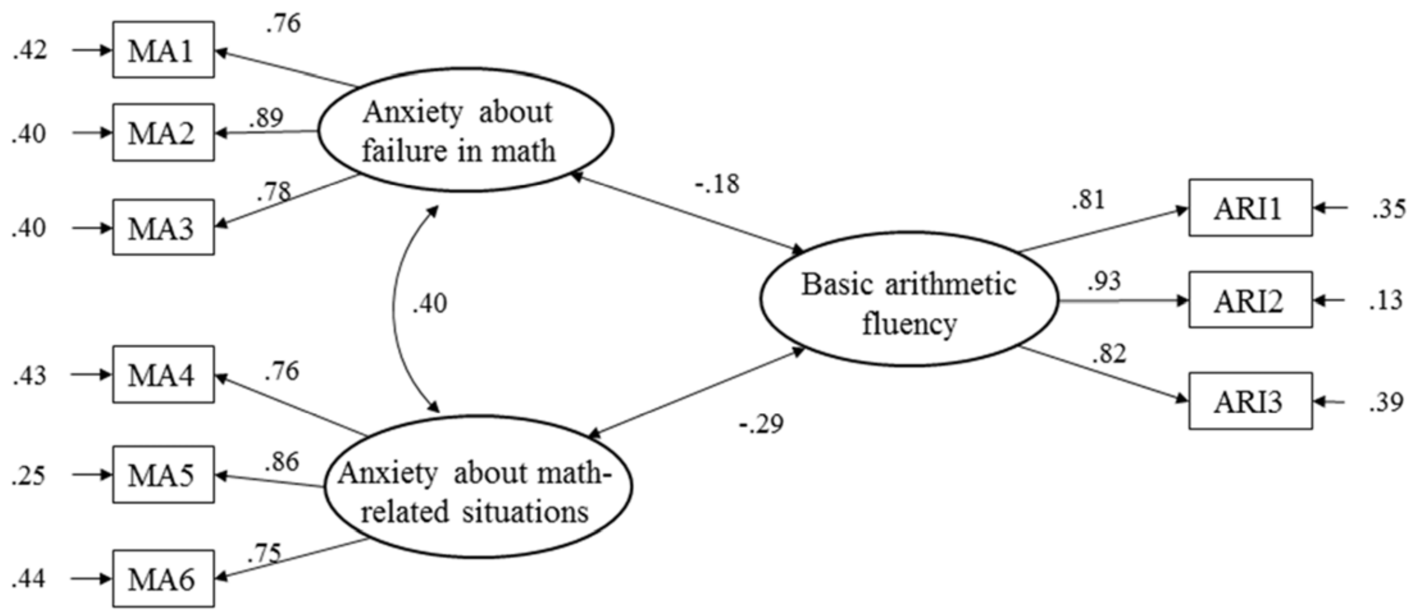

Figure 1. Model linking the two dimensions of math anxiety and achievement. All estimates are standardized. All paths $p < .05$; fit statistics: χ^2 (24) = 51.71, $p = .001$; RMSEA = .03 CFI = .99; TLI = .99

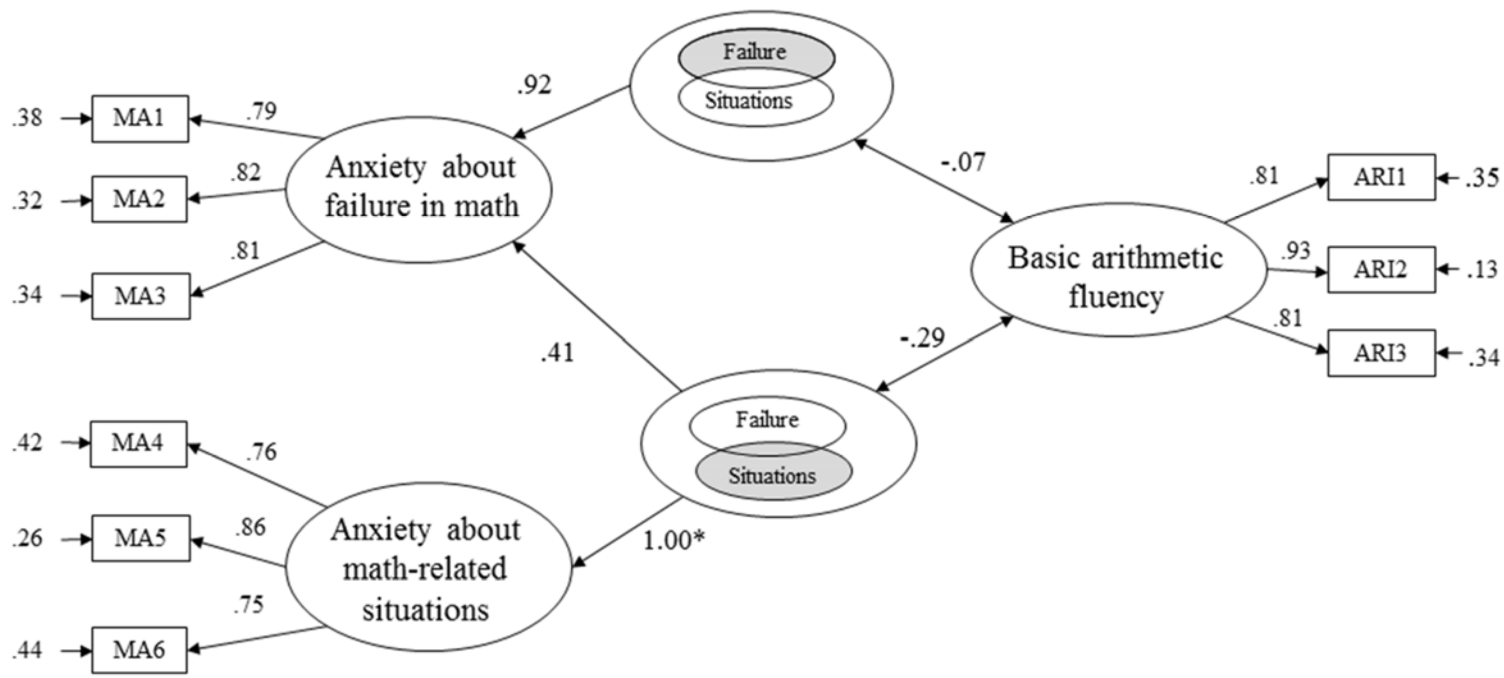

Figure 2. Model for unique variance of Worry. All estimates are standardized. Failure = Anxiety about failure in math; Situations = Anxiety about math-related situations. All paths $p < .05$; fit statistics: χ^2 (24) = 49.14, $p = .002$; RMSEA = .03 CFI = 1.00; TLI = .99

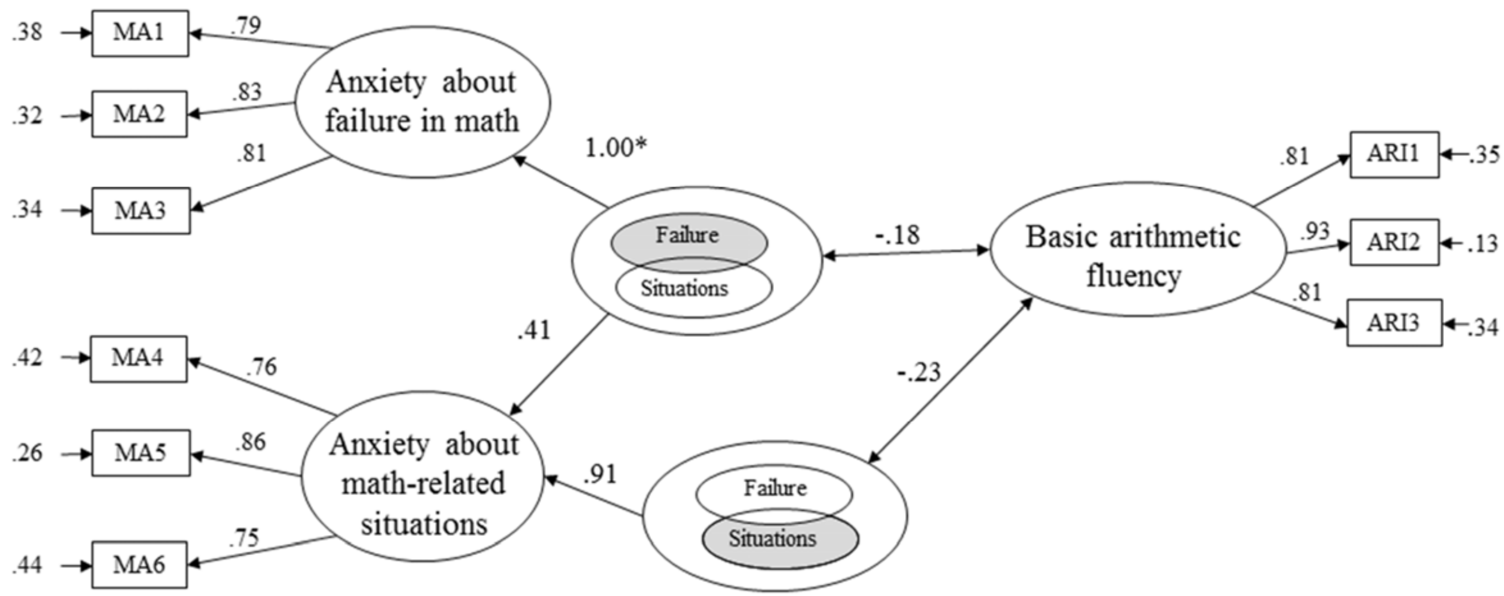

Figure 3. Model for unique variance of Negative affective reactions. Failure = Anxiety about failure in math; Situations = Anxiety about math-related situations. All estimates are standardized. All paths $p < .05$; fit statistics: χ^2 (24) = 49.14, $p = .002$; RMSEA =.30; CFI =1.00; TLI=.99