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Development of Math Anxiety and Its Longitudinal Relationships with Arithmetic Achievement among Primary School Children

Abstract

The aim of this study is to examine the development of two separable aspects of math anxiety, anxiety about math-related situations and anxiety about failure in math, and their cross-lagged relationship with arithmetic achievement. The mean level of anxiety about math-related situations decreased among second, third, and fourth graders, and the level of anxiety about failure in math declined among third, fourth, and fifth graders. The rank-order of individuals was more stable in arithmetic achievement than in either aspect of math anxiety. Arithmetic achievement predicted later anxiety about failure in math, but neither aspect of math anxiety predicted later achievement. The results underline the importance of paying attention to math anxiety because anxiety about math-related situations seems to be as stable in primary school as it is in secondary school students. It is important to provide sufficient educational support and take into account affective factors related to learning from the beginning of schooling.

Keywords: Math anxiety; mathematical skills; primary school; longitudinal study

1. Introduction

1.1 Math anxiety

Math anxiety is most commonly defined as feelings of nervousness and tension interfering with manipulating numbers and solving mathematical problems "in a wide variety of ordinary life and academic situations" (Richardson & Suinn, 1972). Even in childhood, math anxiety has been found to be a unique construct, separate from both test anxiety and general anxiety (Carey, Hill, Devine, & Szücs, 2017). Knowledge of the development of math anxiety during school is limited: whether the average level of math anxiety varies in different grade levels, how stable math anxiety is during school years, and whether stability is affected by age. Moreover, there is a lack of research about the causal relations between math anxiety and math achievement—which one influences the other and whether the relation is reciprocal. Among adolescents and adults, math anxiety has been found to be related to achievement (Hembree, 1990; Richardson & Suinn, 1972), but among primary school students, previous findings about the relationships have been contradictory (Authors, 2017). Longitudinal studies on math anxiety are scarce, and knowledge of the developmental aspects of math anxiety is needed for effective targeting of early interventions.

In our previous, cross-sectional study we investigated the prevalence of math anxiety and its relation with arithmetic skills among primary school children (Authors, 2017). Literacy review revealed that some studies have operationalized math anxiety as being *unable to do something* in mathematics (Dowker, Bennet, & Smith, 2012; Haase et al., 2012; Krinzinger, Kaufmann, & Wilmess, 2009; Thomas & Dowker, 2000). In our study, this aspect of math anxiety is defined as *anxiety about failure in mathematics* (Authors, 2017). On the contrary, other studies have stressed operationalization anxiety in various math-related situations without emphasizing the expected outcomes, successes, or failures (Vucovic, Kieffer, Bailey, & Harari, 2013; Wu, Barth, Amin, Malcarne, & Menon, 2012). This aspect has been defined as *anxiety about math-related situations* (Authors, 2017). Interestingly, contradictory findings seem to be related to the aspect of math anxiety measured. The results of our study confirmed the hypotheses raised from previous literature and showed that these two ways of operationalizing shed light on two separable but related (correlation .40) aspects of math anxiety, and these aspects were differently related to mathematical achievement (Authors, 2017). However, because our first study was cross-sectional, we couldn't examine development or longitudinal relationships. The aim of the present study is to shed light on the development of these two aspects of math anxiety among primary school children over the course of a school year as well as the longitudinal relationship between aspects of math anxiety and math achievement.

1.2 The development of math anxiety

The limited understanding of the development of math anxiety among primary school students results, at least partly, from the paucity of studies focusing on this age group and from the incoherency of the findings. There are a few studies investigating the development of the level of math anxiety longitudinally (Krinzinger et al., 2009; Ma & Xu, 2004) and some investigating differences between several age groups cross-sectionally (Gierl & Bisanz, 1995; Gunderson, Park, Maloney, Beilock, & Levine, 2018; Authors, 2017). Use of different methodological approaches might explain some of the incoherency in the earlier findings and hinder the formation of a lucid understanding of the development of math anxiety. The methodological diversity concerns not only the above-mentioned operationalization of math anxiety but also the approach chosen in examining stability and change in anxiety over time. The approaches to investigate stability and change in math anxiety have varied from the stability of, or change in, the average level of math anxiety (i.e., *mean level change*; Krinzinger et al., 2009) to the stability of, or change in, the relative position of the individuals within a group over time (i.e., *rank-order stability*; Krinzinger et al., 2009; Ma & Xu, 2004) by analyzing stability coefficients of math anxiety between different time points.

The results of the previous studies concerning the development of math anxiety during primary school years are somewhat contradictory. One reason for this might be that they have measured different aspects of math anxiety. Krinzinger et al. (2009) assessed the mean level of *anxiety about failure* longitudinally from first to third grade and found that the level increased over time. Thus far, to our knowledge, the development of *anxiety about math-related situations* has not been studied longitudinally in primary school, but the knowledge about the mean level change is based on cross-sectional studies comparing students in different grade levels. Gierl and Bisanz (1995) found no differences between third and sixth graders in the level of math anxiety in problem-solving situations, but the mean level of math anxiety concerning test situations was higher among older children than younger. Authors (2017) compared the prevalence of anxiety about failure and anxiety about math-related situations in grade levels 2 to 5. There were no differences in the prevalence of anxiety about failure between children at different grade levels, but anxiety about math-related situations was more common among younger students compared with older students. The latter result was in line with the results of Gunderson et al. (2018) who found that the level of anxiety about math-related situations was lower among second than among first graders.

Besides the mean-level of math anxiety, Krinzinger et al. (2009) investigated the anxiety about failure in mathematics also from the perspective of rank order stability. They found lower stability for anxiety (one-year stability coefficients from .49 to .60) than for achievement (one-year stability coefficients from .79 to .91). To our knowledge, anxiety about math-related situations has not been investigated from the perspective of *rank-order stability* among primary school children. Ma and Xu (2004) examined the development of anxiety about math-related situations from seventh to twelfth grade using this approach. They found that math anxiety remained relatively stable from grade 8 onward (one-year stability coefficients were slightly below .60), although not as stable as achievement in mathematics (one-year stability coefficients were over .90). Although the mean-level change approach provides information about the development of math anxiety at *the group level*, by investigating the rank-order stability we get knowledge of the stability of math anxiety at *the individual level* within the group—in other words, whether the same students report anxiety over time.

These two approaches are complementary, and both approaches are needed in order to get a clearer picture of the development of anxiety. It is possible to find decreasing or increasing average levels of anxiety over time, but stable rank-order would reveal that individuals maintain their relative position within a group with respect to their anxiety level. Similarly, it is possible to find low stability in rank-order, indicating individual changes in math anxiety while the anxiety at the group level remains constant. However, these two approaches are rarely used in the same study. More research with a repeated-measures design, taking into account both perspectives as well as different ways of operationalizing math anxiety, is needed in order to better understand the development of math anxiety during primary school.

1.3 Association between math anxiety and achievement

Recent studies on math anxiety suggest that it is related to performance in the primary school years (Cargnelutti, Tomasetto, & Passolunghi, 2017; Carey, Devine, Hill, & Szucs, 2017; Devine, Fawcett, Szücs, & Dowker, 2012; Ramirez, Gunderson, Levine, & Beilock, 2013; Ramirez, Chang, Maloney, Levine, & Beilock, 2016; Authors, 2017; Wu et al., 2012). However, there are also studies questioning this relationship (Devine, Hill, Carey, & Szücs, 2018; Dowker, Bennett, & Smith, 2012; Haase et al., 2012; Hill et al., 2016; Krinzinger et al., 2007; Krinzinger et al., 2009; Thomas & Dowker, 2000; Wood et al., 2012). The inconclusive results of previous studies may be understood considering the varying operationalizations of math anxiety (Authors, 2017). Most of the studies that did not find a relationship between math anxiety and math performance among primary school children operationalized math anxiety as anxiety about failure in mathematics (Dowker et al., 2012; Haase et al., 2012; Krinzinger et al., 2007; Krinzinger et al., 2009; Thomas & Dowker, 2000; Wood et al., 2012). However, studies that operationalized math anxiety as anxiety in math-related situations in general have usually revealed the relationship (Cargnelutti et al., 2017; Harari, Vukovic, & Bailey, 2013; Jameson, 2013; Vucovic et al., 2013; Wu et al., 2012; Wu, Willcutt, Escovar, & Menon, 2014). When the two operationalizations were examined together, it was found that anxiety about failure in math is more common among primary school children, but anxiety about math-related situations in general is directly and more strongly related to performance in mathematics (Authors, 2017). However, the existence of the relationship between math anxiety and achievement cannot be fully explained by the operationalization of math anxiety. Hill et al. (2017), who investigated anxiety about math-related situations, did not find the relationship between anxiety and achievement among primary school students, but they found it among secondary students. Also, Devine et al. (2018) assessed anxiety about math-related situations of primary and secondary school students and found that nearly 80% of highly math-anxious students had typical or high performance in math, questioning the link between math anxiety and achievement.

Even if anxiety about math-related situations has been found to be more strongly related to achievement than anxiety about failure among primary school children (Authors, 2017), the causal relationships between the aspects of math anxiety and math achievement remain unclear. To shed light on the contradictory findings of the relationship between math anxiety and achievement, three competing models have been suggested (Carey, Hill, Devine, & Szücs, 2016). First, the model with the causal direction from high math anxiety to poor math performance is called the *debilitating anxiety model* (Carey et al., 2016). Based on a metaanalysis, Hembree (1990) claimed that math anxiety would weaken math performance, but he did not find any evidence suggesting that poor performance would increase anxiety. This model is supported by the finding that math anxiety seems to cause an "affective drop" in performance: math-anxious individuals are likely to underperform every time they have to do math in a timed setting (Ashcraft & Moore, 2009). There are also some studies among first and second graders with results supporting the debilitating anxiety model. Cargnelutti et al. (2017) found an indirect effect of math anxiety in grade 2 on achievement in grade 3. In a study by Vucovic et al. (2013), anxiety about math-related situations in second grade was found to predict skill development in math, but because anxiety was not assessed longitudinally, strong conclusions about the causal relations could not be made. Besides, Ramirez et al. (2016) studied math anxiety of first and second graders and found that especially children with high working memory are likely to underperform when they experience high math anxiety.

The second model, *deficit theory* (i.e. poor math performance elicits math anxiety; Carey et al., 2016), is supported by a study among junior and senior high school students by Ma and Xu (2004) indicating that prior low math performance predicts later high math anxiety, but prior high mathematics anxiety hardly predicts later low achievement. Furthermore, studies have shown that primary school children with math learning disabilities report more anxiety than their typically achieving peers (Passolunghi, 2011; Rubinsten & Tannock, 2010; Wu et al., 2014), giving support to this model.

Carey et al. (2016) as well as Foley et al. (2017), in their reviews based on previous studies, suggest that one reason for the conflicting results of previous research supporting either deficit theory or debilitating anxiety model might be that the studies actually shed light on different aspects of a bidirectional relationship. In this third model, *reciprocal theory*, math anxiety and achievement influence one another in a vicious circle (Carey et al., 2016). Carey, Devine et al. (2017) investigated math anxiety with latent profile analysis. Based on their results, it seems that some individuals might develop math anxiety as a result of poor performance and some only because of their predisposition to anxiety generally. However, math anxiety also seemed to lower performance, to some degree, regardless of why it had developed. Therefore the researchers suggest that math anxiety and achievement affect each other reciprocally. Also Gunderson et al. (2018) found reciprocal cross-lagged relations between math anxiety and achievement of first and second graders. Even though the relations were reciprocal, the impact of initial achievement on later anxiety was stronger than the effect of anxiety predicting later achievement. They state that children who achieve lower in math and lack some of the math concepts foundational for later development when they start school are more likely to develop math anxiety but also that a higher level of math anxiety is more likely to lead to poorer achievement over time.

Previous longitudinal studies among primary school children have usually focused on relatively young students from first to third grade and have not taken into account different aspects of math anxiety. Longitudinal research taking into account both anxiety about math-related situations and anxiety about failure in math is needed before conclusions concerning the causal directions of the relationship between math anxiety and achievement can be made. More research about the causal relations is needed, especially in primary school when math anxiety and basic math skills are just developing.

2. The present study

The aim of the present study is to examine the development of primary school students' math anxiety and its relationship with arithmetic achievement longitudinally during one school year. This study extends our previous work examining the two types of math anxiety: anxiety about failure in math and anxiety about math-related situations in general (Authors, 2017), by investigating the development of these two aspects of math anxiety and their longitudinal relationship with achievement.

The first aim was to study the development of these two aspects of math anxiety, during one school year, among primary school children from second to fifth grade. The development was studied from two perspectives, mean-level change and rank-order stability, in order to examine development on two levels, at the group level and at the level of individuals within the group. We examined whether there was any change in the mean levels of either anxiety about math-related situations or anxiety about failure in math during a school year at any grade level. Based on the previous, mostly cross-sectional research (Gierl & Bisanz, 1995; Gunderson, Park, Maloney, Beilock, & Levine, 2018; Authors, 2017), we hypothesized that the level of anxiety about math-related situations would decrease during a school year and that the level of anxiety about failure would stay the same or even increase. This could be due to children getting used to studying math during primary school, which would decrease the anxiety about math-related situations but would not affect the fear of failure (Authors, 2017). We also wanted to learn how stable the rank-order of the individuals was in these aspects of math anxiety. Based on the previous research (Ma & Xu, 2004), we hypothesized that the rank-order of the aspects of math anxiety would be less stable than the rank-order of arithmetic achievement. This might reflect the different nature of math anxiety and arithmetic skills: individual differences in arithmetic skills tend to be stable, whereas there seems to be more fluctuation in the level of math anxiety.

Second, we aimed to investigate the longitudinal relationships between the two aspects of math anxiety and arithmetic achievement. We hypothesized that anxiety about math related situations and anxiety about failure in math would predict each other. Further, we hypothesized that we would find a reciprocal relationship between math anxiety and achievement, in students with lower achievement are more likely to develop math anxiety and higher level of math anxiety is more likely to lead to poorer achievement over time. (Carey et al., 2016).

3. Method

3.1 Participants and procedure

This research is based on data from a longitudinal study on the development of self-beliefs and academic skills of primary school aged children. The participants were from 20 Finnish schools, situated in urban and semi-urban areas in central Finland. The participating schools were recruited via basic education municipality officials. The participating special education teachers recruited volunteering classroom teachers of grade levels 2 to 5 at their schools. Participation was voluntary, and written consent was obtained from the participants' guardians. The research procedure was evaluated by the ethical committee of the university. The participants of the present study were 1,321 children (47.84% girls). In the beginning of the follow-up, 178 of the children were second graders (13.47%; $M = 8.35$ years; $SD = 0.32$), 475 (35.96%) third graders ($M = 9.34$ years; SD = 0.31), 383 (29.00%) fourth graders ($M = 10.40$ years; $SD = 0.35$), and 285 (21.57%) fifth graders ($M = 11.39$ years; $SD = 0.36$).

The data for this study were collected at two time points: November 2013 (time point 1, or T1) and September 2014 (T2). The assessments were carried out and supervised by trained research assistants in group situations in the classroom during the school day. The items were read aloud for the students who then responded on answer sheets. The assessment was structured in a way so that none of the math anxiety questions were presented immediately after the basic arithmetic skills tasks.

Complete data for the measures of math anxiety and basic arithmetic skills in both time points were available for 73.9% of the sample. The highest percentage of missing data (13%

of the participants) was obtained for items of arithmetic achievement and items of anxiety in math-related situations in T2, mainly due to school absences.

3.2 Measures

3.2.1 Math anxiety

Math anxiety was assessed at the two time points with a questionnaire comprised of six items. Three of the items were from the Finnish adaptation (Authors, 2017) of the Math Anxiety Questionnaire (MAQ; Thomas & Dowker, 2000). The format of the MAQ questions was "How anxious or calm would you be if you were unable to do…," and students were to respond regarding "something in mathematics" (MA1), "a mental calculation task" (MA2), and "math homework" (MA3). The two first questions were from the original MAQ, and the third was included for the Finnish version (Authors, 2017). As in the original MAQ, these three items were to be rated on a 5-point scale with pictures of faces depicting various emotions, from *very anxious* (rated as 5) to *very calm* (rated as 1).

The last three math anxiety items (Authors, 2017) were adopted from a subscale that had been initially designed for assessing sources of self-efficacy, based closely on the ideas of Usher and Pajares (2008). These items, "I get anxious when I have to answer the teacher's questions in math class" (MA4), "I get anxious when I start doing math" (MA5), and "I feel tension when I have to do math" (MA6), were rated on a 7-point scale (1 = *false*, 2–3 = *mostly false*, 4 = *neither true nor false*, 5–6 = *mostly true*, 7 = *true*). The anxiety questionnaire items loaded on two factors (for details, see Authors, 2017): the items MA1 through MA3 loaded on one factor, named Anxiety about Failure in Mathematics, and the items MA4 through MA6 on another factor, named Anxiety about Math-Related Situations. The model with two factors was significantly better than the model in which all the math anxiety items were loaded on one factor. Cronbach's alpha for items of the Anxiety about

Math-Related Situations factor was .71 and for the items of the Anxiety about Failure in Math was .82.

3.2.2 Basic arithmetic skills

Basic arithmetic skills were assessed at two time points with three time-limited paper-and-pencil group tests. The first two tests, the two-minute addition fluency test (Author, 2010a) and the two-minute subtraction fluency test (Author, 2010b), consisted of 120 items. All the addends in the addition test and all the results in the subtraction test were smaller than 10. The third test, the three-minute basic arithmetic test (Aunola & Räsänen, 2007), consisted of 30 items assessing addition, subtraction, division, and multiplication skills. The scores for the basic arithmetic skills tests were standardized at both time points within each grade level. Cronbach's alpha for the basic arithmetic skills items was .92.

3.3 Statistical analysis

The analyses were conducted using Mplus software, version 7.3 (Muthén & Muthén, 1998–2017). The full information maximum likelihood (FIML) with robust standard errors and scale-corrected chi-square test values were estimated. The FIML uses all information in the data without imputing missing values. First, a measurement model with latent factors for anxiety in math-related situations, anxiety about failure in math, and arithmetic achievement at both time points was constructed. For interpreting the latent means and correlations across grade levels at different time points, strong invariance was required, i.e. the factor loadings and intercepts of observed variables should be invariant over time and in different grade levels (Van de Schoot, Lugtig, & Hox, 2012). The invariance of the factor loadings and intercepts of observed variables of arithmetic and math anxiety across time and grade levels was tested by comparing the root mean square error of approximation (RMSEA; Steiger, 1990) values of the nested models (parameters freely estimated versus parameters constrained to be equal in all grade levels/time points). A small difference between the RMSEA values of the nested models indicates that the models fit the data as well; therefore, the tested parameters can be set equal between grade levels and time points (MacCallum, Browne, & Vai; 2006). The invariance was tested using the procedure of MacCallum et al. (2006) by comparing the RMSEA values of the most freely estimated and the most constrained models. According to MacCallum et al. (2006), the non-central value is calculated, and the test value of nested models is compared to correspondent non-central chi-square distribution to get a *p*-value to reject the null hypotheses of small difference. The chi-square difference test (Satorra & Bentler, 2001) was not used for testing measurement invariance because this test is overly sensitive to small differences in the loadings and intercepts in the data with a large number of participants. The goodness-of-fit of the final measurement model was evaluated using a chi-square 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 chi-square test should be greater than .05, the RMSEA less than .06, the CFI and the TLI greater than .95, and the standardized root mean residual (SRMR) less than .08 (Hu & Bentler, 1999).

Second, the change in, or stability of, the mean levels of the math anxiety factors from T1 to T2 was examined in each grade level. The mean of the intercepts of the observed variables of each factor was constrained to be zero, and then the equality of the factor means in the two time points was tested using the Wald Test of Parameter Constraints (Muthén & Muthén, 1998–2017).

Next, a model with stability effects of the math anxiety factors and the arithmetic achievement factor, as well as concurrent associations and cross-lagged relationships between the three factors in T1 and T2, was constructed. In the final model, only statistically significant paths were presented (see Figure 3). The goodness-of-fit of the model was evaluated using the chi-square test, RMSEA, CFI, TLI, and SRMR.

Finally, the longitudinal relationships between math anxiety factors and achievement were examined. To investigate if there was any difference in the cross-lagged effects across the grade levels, the cross-lagged relationships were compared using a multi-group approach and the Wald Test of Parameter Constraints.

4. Results

4.1 Invariance of math anxiety measure over time and across grade levels

The invariance test (p = .32) indicated small differences between the RMSEA values of the freely estimated model (RMSEA = .05) and the model with most constraints (the factor loadings and intercepts over time and across the grade levels; RMSEA = .06; see Table 1). Thus, the measures of math anxiety and achievement were assumed to be invariant across time. The fit indices for the measurement model with factor loadings and intercepts constrained to be equal over time and across all grade levels were $\chi^2(564) = 1320.27$, $p <$ .001, RMSEA = .06, CFI = .92, TLI = .91, and SRMR =.06.

4.2 The mean-level change in math anxiety

The means of the Anxiety about Math-Related Situations factor are presented in Figure 1. The Wald Test of Parameter Constraints (Table 2) revealed that, during a school year, the level of anxiety about math-related situations declined significantly among second to fourth graders, and the level of anxiety about failure in math declined significantly among third to fifth graders.

4.3 Rank-order stability

The rank-order stabilities (standardized regression coefficients) of the math anxiety and achievement factors, from T1 to T2, are presented in Figure 3. There were no differences between the grade levels in the regression coefficients ($\chi^2(9) = 15.65$, p = .07).

4.4 Cross-lagged relationships between math anxiety and achievement

The cross-lagged model for anxiety about math-related situations, anxiety about failure in mathematics, and arithmetic achievement is presented in Figure 3. The results showed that high anxiety about math-related situations at T1 predicted high anxiety about failure at T2, and low arithmetic achievement at T1 predicted high anxiety about failure in math at T2. Neither arithmetic achievement nor anxiety about failure predicted anxiety about math-related situations, and neither of the two math anxiety factors at T1 predicted arithmetic achievement at T2 when controlling for T1. There were no grade-level differences in the cross-lagged ($\chi^2(18) = 26.07$, $p = .10$) relationships between the math anxiety factors and achievement.

5. Discussion

5.1 General discussion

This study investigated change in math anxiety among primary school children and examined relations between math anxiety and math fluency measured at the beginning and the end of the school year using a cross-lagged design. The development of math anxiety during one school year was examined from two perspectives of stability or change: the mean level of anxiety and the rank-order of individuals. Two aspects of math anxiety—anxiety about math-related situations in general and anxiety about failure in math—were assessed to shed light on the controversies of previous findings.

When the development of math anxiety during a school year was examined, the results showed that, as hypothesized, the average level of anxiety about math-related situations decreased among second, third, and fourth graders but stayed virtually the same among fifth graders. In anxiety about failure in math, we expected that there would be no change or that the level of anxiety would even increase. However, there was no change among second graders, but among third, fourth, and fifth graders the level of this aspect of math anxiety declined as well. The rank-order of the individuals was a bit more stable in anxiety in math-related situations in general (.51) than in anxiety about failure in math (.33). As we hypothesized, the rank-order of participants remained more stable in the arithmetic achievement (.91) than in the two aspects of math anxiety.

We hypothesized that we would find reciprocal relationships between the two aspects of math anxiety and arithmetic achievement. However, the results for the cross-lagged relationships between math anxiety and arithmetic achievement suggest that prior low arithmetic achievement predicts later high anxiety of failure in math, giving support to the deficit theory (Carey et al., 2016). The cross-lagged relationships were similar across grade levels, indicating a similar longitudinal effect from achievement to anxiety in all grade levels from second to fifth.

5.2 The development of math anxiety

In the present study, we used complementary approaches to get a better picture of the development of math anxiety. First, we examined the average level of math anxiety of the whole group of participants (mean-level change/stability) and, second, whether the same students tend to report anxiety over time (the rank-order stability/change). The mean-level results suggest that, on average, primary school students feel less anxious about math during the follow up, including a transition to the next grade level, which opposes the findings of several previous studies (Gierl & Bisanz, 1995; Krinzinger et al., 2009). The mean-level of anxiety about math-related situations decreased among second, third, and fourth graders, and anxiety about failure decreased among third, fourth, and fifth graders during the follow-up. Because the present study was the first longitudinal study among primary school children examining the development of math anxiety and taking into account not only anxiety about failure but also anxiety about math-related situations in general, we do not know whether the decline in these aspects is characteristic of the specific educational context of Finnish schools or a more universal phenomenon.

However, the results for the rank-order stabilities of the two aspects of math anxiety are in line with the previous results. In the present study, the test-retest correlation of anxiety about math-related situations (.51) was close to what Ma and Xu (2004) found among secondary school students (.38 from seventh to eighth grade and .55–.59 from eighth to twelfth grade). It seems that feeling anxious about math-related situations is as stable a phenomenon already in second grade as it is by the end of secondary school. However, as has been previously found concerning anxiety about math-related situations among secondary school students (Ma & Xu, 2004) and anxiety about failure in math among primary school students (Krinzinger et al. 2009), the rank-order in math anxiety aspects was less stable than rank-order in arithmetic achievement.

5.3 Cross-lagged relationships between math anxiety and achievement

In the present study, those participants who were generally anxious about math-related situations were more likely to also be more anxious about failing in math, but prior anxiety about failure did not seem to lead to an increase in more general anxiety about math-related situations. Although arithmetic achievement seems to be cross-sectionally more strongly related to anxiety about math-related situations than to anxiety about failure (Authors, 2017), developmentally, arithmetic achievement has an effect especially on the latter: low achievement predicts higher anxiety about failure in math. The finding about achievement predicting math anxiety is in line with the results of previous research; children with mathematical learning difficulties have been found to be more anxious about mathematics than their typically performing peers (Passolunghi, 2011; Rubinsten & Tannock, 2010; Wu et al., 2014), and mathematical learning difficulties typically manifest as fundamental problems in the development of basic arithmetic skills (Geary, 1993).

The results of the present study about the longitudinal effect of arithmetic achievement on math anxiety provided support for the deficit theory of math anxiety (poor math performance elicits math anxiety; Carey et al., 2016). However, because math anxiety and math achievement were cross-sectionally related, the immediate effect of math anxiety on arithmetic achievement and, thus, the reciprocal relationship, with math anxiety and achievement influencing one another, cannot be ruled out either. If there is an immediate effect of anxiety on achievement, an "affective drop," as Ashcraft and Moore (2009) suggested, it may have been affecting the students' achievement before the age of the participants in the current follow-up. This might explain why the reciprocal relationship has been previously found with cross-lagged modeling among first and second graders (Gunderson et al., 2018), even though longitudinal studies usually give support to the deficit theory (Carey et al. 2016).

5.4 Limitations of the study

The present study has some notable limitations. First, the results suggest that primary school children get less anxious about general math-related situations and that anxiety about failure in math are based on the one year follow-up, including the transition to the next grade level. To compare the development between grade levels, a longer follow-up period is needed. Second, it cannot be assumed that the development of math anxiety would necessarily decline linearly throughout the school years. In Wigfield and Meece's (1988) study, the mean level of math anxiety did not show a consistent linear pattern of change. Among participants from sixth to twelfth grade, ninth graders reported the highest level of anxiety and sixth graders the lowest. In the present study, we focused on a period of time in which the learning environment usually remains relatively stable. In Finland, for example, students' own classroom teachers teach most of the school subjects, math included. Thus, we do not know what happens during transitional points from preschool to primary school or from primary to secondary school, when the structure of everyday school life changes and different school subjects are taught by subject teachers.

Based on the math anxiety measure used in the present study, we separated two aspects of math anxiety. The main difference between these two aspects was that one focused on failure in math, while the other more generally included different kinds of math-related situations without specifying the result (success or failure). Nevertheless, this is only one way to approach the varying operationalizations of math anxiety. Other, to some extent overlapping, operationalizations, for example, focus on the situations that arouse math anxiety (e.g. testing, problem-solving, or social situations; Carey, Hill, et al., 2017; Gierl & Bisanz, 1995; Richardson & Suinn, 1972), the affective and/or cognitive aspects of anxiety (Wigfield & Meece, 1988), or the habitual (trait) and momentary (state) aspects of math anxiety (Goetz, Bieg, Lüdtke, Pekrun, & Hall, 2013). Gierl and Bisanz (1995) found no grade-level differences in math anxiety in problem-solving tasks but a higher level of anxiety about math tests among older students compared with younger students. Correspondingly, the authors suggested that the situations most likely to arouse math anxiety possibly differ across grade levels. Since we did not measure anxiety about math tests, we cannot conclude whether declines occur in all aspects. Further, based on the measure of the present study, we were not able to separate the affective (negative affective reactions) and cognitive (worry about performance) components of math anxiety. Similar to most of the existing research, as Goetz et al. (2013) pointed out, we also focused on trait-like, habitual math anxiety; the assessments of math anxiety and achievement were carried out separately, and we did not measure anxiety in actual problem-solving situations.

The number of math anxiety items was limited on the questionnaire: both aspects of math anxiety were measured with three items only. However, scales with three or even just one item have been found to be adequate for measuring academic anxieties, including math anxiety (Gogol et al., 2014; Núñez-Peña, Guilera, & Suárez-Pellicioni, 2014). Besides, general or test anxiety was not assessed in this study. Even if math anxiety has been found to be a unique construct, even among children (Carey, Hill, et al. 2017), it is also highly correlated with test anxiety (Betz, 1978). It can also be considered a limitation that, of the many subskills of mathematics (see, e.g., Dowker 2005), we assessed only basic arithmetic skills. Further, tapping the actual skills of math-anxious children might be difficult, if the anxiety causes them to underperform. Especially the use of time-limited tests may magnify the effects of anxiety (Faust et al., 1996). However, in arithmetic skills, fluency of basic calculations is essential (Carr, Steiner, Kyser, & Biddlecomb, 2008), and when one aims to measure explicitly arithmetic fluency, time constraints in the assessment cannot be avoided.

5.5. Implications for future research

In future research, more attention should be paid to the complexity of the structure of math anxiety. Since the affective and cognitive dimensions of math anxiety seem to be differently related to achievement (Wigfield & Meece, 1988), the development and the significance of both at different stages of schooling should be studied. The measures of math anxiety should comprise diverse situations (e.g. testing, social, and general problem-solving) to find out whether the mean level change in math anxiety over time is similar in different situations. In addition, the association of math anxiety with a more diverse range of mathematical skills should be examined using tools with and without time limits as well as tasks adapted to the performance level.

The present study is one of the few longitudinal studies investigating math anxiety in primary school. In the future, a longer follow-up period and a focus on school transitions is recommended. In addition, it is possible that the decline in anxiety results from features related to the Finnish school system, such as the extensive part-time special education offered to support struggling learners relatively early without the need to wait for a formal diagnosis of learning disability. For answering this question, longitudinal and cross-cultural research is needed. The present results showing that low achievement predicts later higher math anxiety give support to the observation of Carey et al. (2016) in their review; usually longitudinal studies (Ma & Xu, 2004) provide support for the deficit theory, whereas studies manipulating anxiety levels (Park, Ramirez, & Beilock, 2014) support the debilitating anxiety model. As Carey et al. (2016) pointed out, more research combining these aspects is needed for better understanding of the causal relationships between math anxiety and math achievement.

In the present study we focused on relationships on a group level. However, most of the students with math anxiety are not low-achieving (Devine et al., 2018). Even if low-achieving students seem to be more prone to math anxiety, not all low-achieving students become anxious about mathematics, and furthermore, nearly four of five students with math anxiety are typical or high-achieving. More research with a person-centered approach is needed to explain the relationship between math anxiety and achievement.

The results of the present study underline the importance of paying attention to math anxiety from the beginning of schooling, as anxiety about math-related situations seems to be as stable among second graders as it has been found to be in secondary school students. Integrative approaches in educational support focusing on both the skill development and feelings toward mathematics are needed, especially among children struggling in math. Nevertheless, as the students' rank-order in math anxiety is less stable than in achievement and, therefore, might be easier to affect, interventions targeted at reducing anxiety should be developed and implemented in basic education.

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Table 1

Invariance Comparison for the Measurement Model of Math Anxiety and Arithmetic Achievement in T1 and T2

Constraints over time	Constraints among grade levels	*χ²(df)*	*sc*	*RMSEA*
–	–	936.54 (480)	1.11	.054
Factor loadings	–	962.26 (504)	1.11	.052
Factor loadings, intercepts of observed variables	–	1017.130 (528)	1.10	.053
Factor loadings, intercepts of observed variables	Factor loadings	1160.00 (546)	1.12	.058
Factor loadings, intercepts of observed variables	Factor loadings, intercepts of observed variables	1320.27 (564)	1.12	.064

Note: χ^2 difference test = model compared to previous, less constrained model; sc = scaling correction factor; RMSEA = root mean square error of approximation.

Table 2

Wald Test Results Comparing Means of Math Anxiety Factors in T1 and T2

Grade	Anxiety about math-related situations	Anxiety about failure in math
2	10.25**	0.79
3	40.61***	16.38***
4	8.14**	41.99***
5	0.00	5.41*

Note. *$p < .05$, **$p < .01$, ***$p < .001$; df = 1 in all tests.

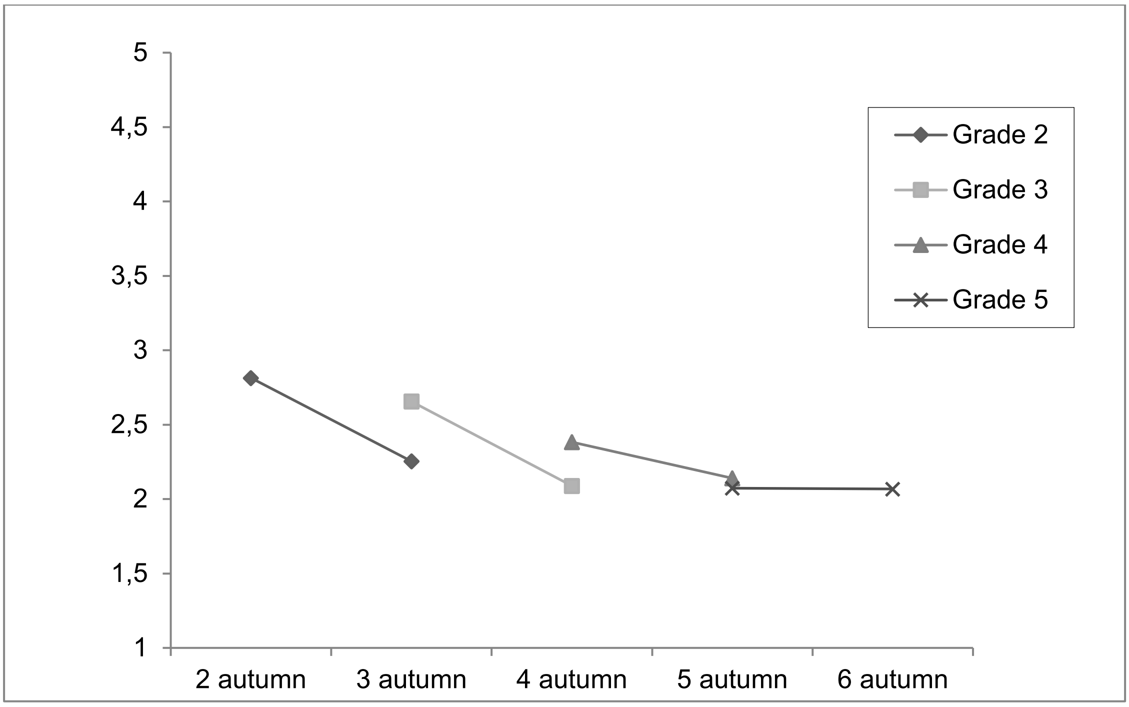

Figure 1. The means of the Anxiety about Math-Related Situations factor.

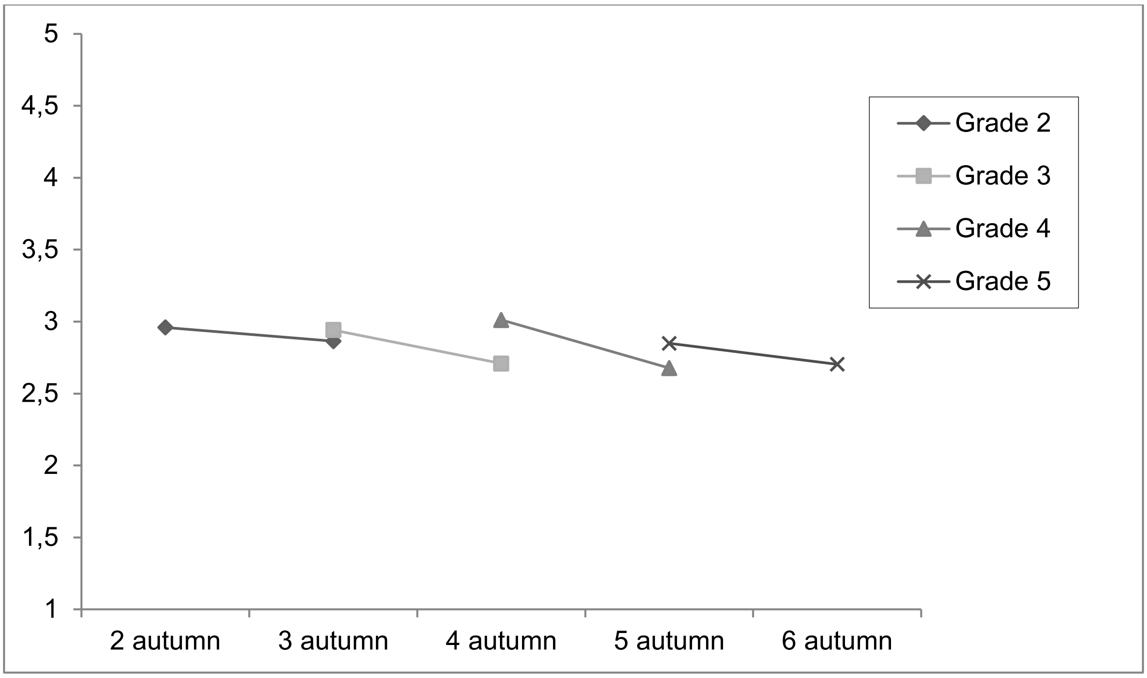

Figure 2. The means of the Anxiety about Failure in Math factor

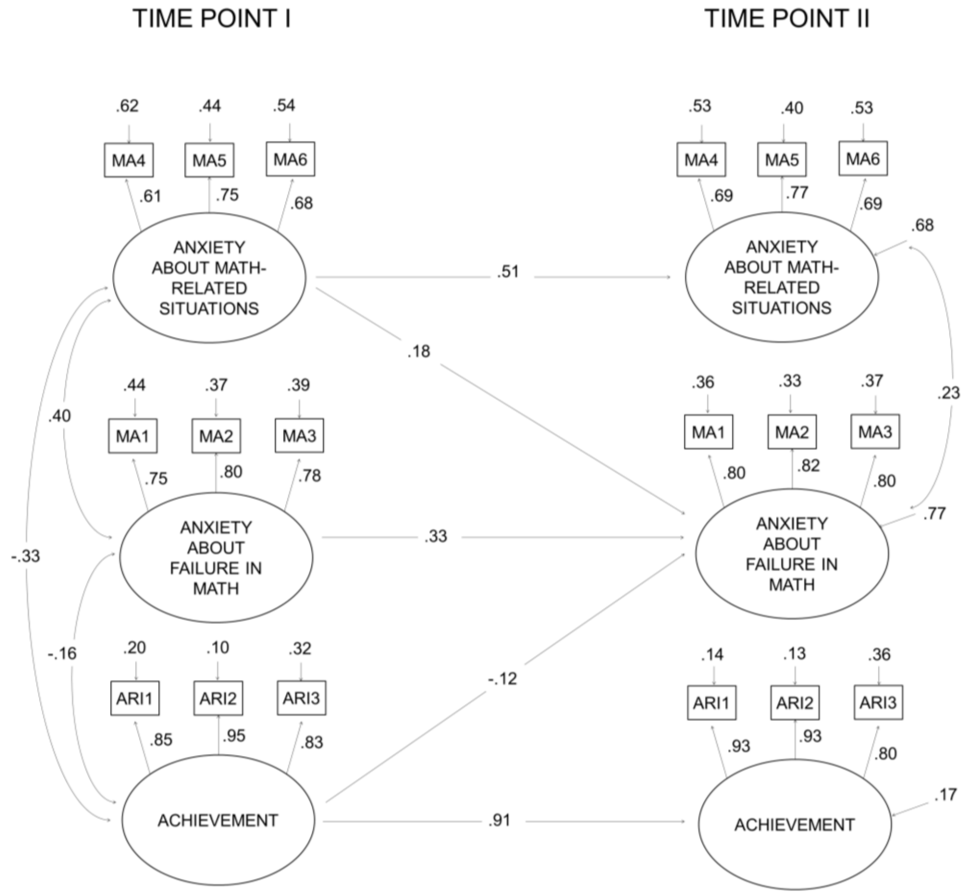

Figure 3. Stability effects of the math anxiety factors and the arithmetic achievement factor, as well as concurrent associations and cross-lagged relationships between anxiety about math-related situations, anxiety about failure, and arithmetic achievement for all participants. All estimates are standardized. All paths $p < .05$; fit statistics for full model: $\chi^2(120) = 493.20$; $p = .001$; RMSEA = .05; CFI = .96; TLI = .95; SRMR =.03.