



Math anxiety, intelligence, and performance in mathematics: Insights from the German adaptation of the Abbreviated Math Anxiety Scale (AMAS-G)

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ABSTRACT

Math anxiety (MA) affects students in various countries and across educational levels. Here, we first evaluated a German adaptation of Abbreviated Math Anxiety Scale (AMAS-G). The AMAS-G was administered to 341 university students as part of a larger test battery, including the assessment of intelligence facets (numerical, figural, verbal) and indicators of math performance (arithmetic fact retrieval, arithmetic procedures, higher-order mathematics). The AMAS-G turned out to be a reliable and valid tool to assess MA. We then further aimed to elucidate the link between MA and math performance by controlling for intelligence differences. Numerical intelligence mediated the relationship between MA and all three indicators of math performance. However, while the relationship between MA and arithmetic fact retrieval was fully mediated by numerical intelligence, MA remained directly related to arithmetic procedures and higher-order mathematics. Results suggest that students with MA show both lower numerical intelligence and specific deficits in mathematics.

1. Introduction

1.1. Definition and prevalence of MA

Math anxiety (MA) is commonly defined as “feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations” (Richardson & Suinn, 1972, p. 551).

MA has been shown to affect students in various countries and across all educational levels (Dowker, Sarkar, & Looi, 2016; Foley et al., 2017). For instance, in the *Programme for International Student Assessment* (PISA) report in 2012, 59% of the interviewed ninth graders stated that they are afraid that it will be difficult for them in mathematics (OECD, 2013). Similarly, more than half of the college students enrolled in math classes have been reported to experience feelings of anxiety towards mathematics (Betz, 1978), and Ashcraft and Moore (2009) have estimated that about 17% of the overall population display heightened levels of MA. Importantly, MA has been repeatedly demonstrated to be associated with poor performance in mathematics (for a recent review, see Foley et al., 2017). In the PISA 2012 report, MA explained a total of 14.2% of the variance in students mathematics performance across all 64 participating countries (OECD, 2013). Being asked about their attitudes towards mathematics, math-anxious students often report lower levels of enjoyment, motivation, and self-

confidence as compared to their less math-anxious classmates. At the same time, these students tend to avoid the subject, for instance, by taking fewer high school mathematics courses (Hembree, 1990). Negative attitudes towards mathematics and avoidance of the subject have been suggested as important factors contributing to the lower math achievements of math-anxious students (Carey, Hill, Devine, & Szűcs, 2016). In light of these findings, there is an urgent need to improve existing tools that assess MA and to further our understanding of the relationship between MA and math performance.

1.2. MA and other forms of anxiety

MA has been discussed as being related to other forms of anxiety, especially to trait anxiety (i.e., general anxiety that is not specific to a situation or content) and test anxiety (i.e., anxiety that occur before or during tests and examinations) (for a review, see Dowker et al., 2016). Indeed, math-anxious students show on average higher levels of both trait anxiety and test anxiety than their less math-anxious peers (for a meta-analysis, see Hembree, 1990). However, correlations between measures of MA and other forms of anxiety have been reported to range from small to medium (Dew, Galassi, & Galassi, 1983; Hembree, 1990), suggesting that the underlying constructs are sufficiently independent. Therefore, MA is widely considered in the literature as a psychological construct that is related but distinct from trait anxiety and test anxiety

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(see Dowker et al., 2016).

1.3. The Abbreviated Math Anxiety Scale (AMAS)

A popular questionnaire to assess MA is the Abbreviated Math Anxiety Scale (AMAS; Hopko, Mahadevan, Bare, & Hunt, 2003). This scale was first developed within an US-American sample of college students based on the items of the Math Anxiety Rating Scale (MARS; Richardson & Suinn, 1972). The AMAS consists of nine items, which are rated on a 5-point Likert scale and are assigned to one of two subscales, namely, learning math anxiety (LMA) and math evaluation anxiety (MEA). While LMA refers to feelings of anxiety when mathematical content has to be learned (e.g., “Listening to another student explain a math formula”), MEA refers to situations in which performance in mathematics is being evaluated (e.g., “Thinking about an upcoming math test 1 day before”). The psychometric properties of the AMAS have been shown to be excellent as indicated by a high reliability as well as good convergent and discriminant validity of the scale (Hopko et al., 2003). Because of these qualities, the AMAS has become one of the most widely used questionnaires to assess MA in various populations, including university students (Hopko et al., 2003), high school students (Primi, Busdraghi, Tomasello, Morsanyi, & Chiesi, 2014), and with modified items in primary (Carey, Hill, Devine, & Szűcs, 2017; Caviola, Primi, Chiesi, & Mammarella, 2017) and secondary school students (Carey et al., 2017). Moreover, while most previous MA questionnaires have been tested only for English-speaking students, the AMAS has been evaluated in different language, including Iranian (Vahedi & Farrokhi, 2011), Italian (Primi et al., 2014), and Polish (Cipora, Szczygiel, Willmes, & Nuerk, 2015). While this development is positive, there is currently—to the best of our knowledge—no questionnaire available in German to assess MA in high school and college students. This is surprising given the high prevalence rate of MA among these groups of students (Betz, 1978) and the potentially detrimental consequences of MA for their performance in mathematics (Ashcraft & Moore, 2009). Given the excellent psychometric properties of the AMAS (Hopko et al., 2003) and its development towards becoming an international standard for assessing MA (Campbell, 2004), adapting the AMAS into German appeared to be the best choice in order to fill this gap. The first aim of the present study was therefore to assess the psychometric properties of a German adaptation of the AMAS (Abbreviated Math Anxiety Scale-German; AMAS-G).

1.4. MA and individual differences in intelligence

From the beginning of empirical investigations into MA, researchers have been interested in the question of how MA is related to intelligence (Dreger & Aiken, 1957). In a seminal study, Dreger and Aiken (1957) predicted that MA would be negatively correlated with numerical intelligence but not with overall intelligence. This prediction was indirectly confirmed in a meta-analysis by Hembree (1990): while MA was inversely related with overall intelligence (mean $r = -0.17$), the relationship with verbal aptitude tests was considerably smaller (mean $r = -0.06$). In fact, Hembree (1990) proposed that the latter correlation would be too small to be of any practical importance. Consequently, the relationship between overall intelligence and MA has been assumed to be based on performance differences in the numerical or quantitative items of intelligence tests, and that MA is specifically related to lower numerical intelligence (Ashcraft, 2002; Ashcraft & Moore, 2009). However—to the best of our knowledge—no empirical study has tested this assumption directly by using a multi-facet intelligence test differentiating between numerical and verbal intelligence.

In addition to numerical and verbal intelligence, intelligence tests often include tasks to assess the figural facet of intelligence (McGrew, 2009; McGrew & Wendling, 2010). Figural (or figural-spatial) intelligence has been largely neglected when studying individual

differences in intelligence and its association with MA (see Hembree, 1990). This is surprising given that a large number of studies suggests that the processing of numerical and spatial information are essentially intertwined (for a review, see Hubbard, Piazza, Pinel, & Dehaene, 2005). Moreover, visual-spatial processes have been shown to be important for mathematical problem solving, especially in the domain of geometry (Tartre, 1990). To date, only one study appears to have investigated how MA is related to figural-spatial abilities (Ferguson, Maloney, Fugelsang, & Risko, 2015). Results of the study indicate that individuals with higher MA exhibit both lower small-scale (i.e., mental rotation) and large-scale (i.e., sense of direction) spatial abilities as compared to less math-anxious individuals. In light of this evidence, MA is likely to be not only related to lower numerical intelligence but also to lower figural intelligence.

1.5. MA and performance in mathematics

It is well-documented that MA is accompanied by lower performance in mathematics (for meta-analyses, see Hembree, 1990 and Ma, 1999). For instance, MA has been shown to be inversely related to measures of mathematical achievement and math-anxious students have been reported to obtain lower grades in mathematics than their less math-anxious classmates. However, it is a question of ongoing research which specific aspects of mathematical performance are affected most by MA. Most empirical studies have aimed to elucidate this question by comparing the performance of highly math-anxious students with a control group of less math-anxious students in a task tapping into one aspect of math performance.

Using the AMAS to assess MA, Maloney, Risko, Ansari, and Fugelsang (2010) could demonstrate that math-anxious undergraduate students were slower to count the number of items in a dot set as compared to their less math-anxious classmates. In a similar vein, math-anxious students exhibited delayed response times in a symbolic magnitude comparison task, in which participants are asked to decide whether a given number is larger or smaller compared to a reference number (Maloney, Ansari, & Fugelsang, 2011). Finally, Wang et al. (2015) showed that MA is inversely related to the accuracy with which both adolescents and adult students estimate the position of a given number on a number line. These results suggest that MA is related to individual differences in basic numerical skills in university students.

In a seminal study, Ashcraft and Faust (1994) addressed the question of how MA is related to arithmetic problem solving. For this, students were asked to verify small (e.g., $3 + 8 = 11$) and large (e.g., $9 \times 16 = 144$) arithmetic problems. While small problems can be solved by fact retrieval (i.e., the solution is stored in memory and just “pops up in one’s mind”), large problems require the application of some sort of transformation or procedure to be solved (Siegler, Adolph, & Lemaire, 1996). For example, the problem 9×16 can be solved by decomposing the problem into 9×10 and 9×6 , and then summing up the solutions of the two intermediate calculations (i.e., $90 + 54 = 144$). Math-anxious students showed overall a lower performance in arithmetic (i.e., slower response times and higher error rates) than their less math-anxious classmates. However, performance differences were only marginal for small arithmetic problems but more pronounced for large problems, indicating that procedural strategies are especially affected by MA. This evidence was corroborated by another study in which math-anxious students demonstrated particular difficulties when arithmetic problems required a carry-over operation (Faust, Ashcraft, & Fleck, 1996). Most recently, Lee and Cho (2017) have reported that MA is associated with a lower solution rate of large arithmetic problems but not with the retrieval of arithmetic facts. Interestingly, Ramirez, Chang, Maloney, Levine, and Beilock (2016) could show that the usage of advanced problem solving strategies partially mediated the relationship between MA and arithmetic performance in elementary school children. More specifically, math-anxious children relied less often on more advanced strategies, such as decomposition, to

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