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Math Anxiety Differentially Affects Boys' and Girls' Arithmetic, Reading and Fluid Intelligence Skills in Fifth Graders

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Abstract

Previous research has shown that math anxiety negatively affected cognitive performance in adults and adolescents beyond arithmetic. In children, math anxiety has been reported to impair arithmetic performance mainly in girls, but the effect of math anxiety on other cognitive skills has not been investigated in children so far. To fill this gap, the present study examined the effects of math anxiety on arithmetic, reading and fluid intelligence in 5th-grade children, studying possible gender differences and controlling for the effects of test anxiety. The results indicated marked gender differences in the relation between math anxiety and cognitive abilities, showing that only in girls' math anxiety was negatively correlated with arithmetic, reading and fluid intelligence. In boys, no significant correlations were found between math anxiety and the three cognitive abilities. Theoretical and practical implications of these results will be discussed.

Keywords

Mathematics Anxiety, Gender Differences, Mental Arithmetic, Reading, Fluid Intelligence

1. Introduction

Approximately 20% of the population suffers from a more or less severe type of math anxiety (Ashcraft & Kirk, 2001). Math anxiety refers to physiological arousal and negative thoughts and ruminations in situations involving numbers or math related activities (Richardson & Suinn, 1972) and often leads to avoidance of situations related to mathematical problem solving and reasoning (Ashcraft & Ridley, 2005). These situations include ordinary life and academic settings, such as paying a restaurant bill or

solving an arithmetic problem at school. Math anxiety can have serious consequences for an individual's life, since high levels of math anxiety often lead to avoidance of math (related) classes, which may limit future career paths (e.g. Hembree, 1990; Ma, 1999). In many cases, math anxiety develops already during primary school years (Newstead, 1998), but most research so far has focused on math anxiety in adults and adolescents. An important question addressed in these studies is whether math anxiety affects cognitive abilities, mostly arithmetic. Given the long-lasting negative effects of math anxiety, it is important to examine the consequences math anxiety can have on cognitive abilities in children, which is the aim of the current study.

Numerous studies with adults have consistently shown that math anxiety significantly and negatively influences performance on arithmetic tasks (see Hembree, 1990 for a review, Ashcraft & Ridley, 2005). Although relatively limited, studies including children have also reported negative links between math anxiety and arithmetic (Chiu & Henry, 1990; Suinn, Taylor & Edwards, 1988; Young, Wu & Menon, 2012; Wu, Barth, Amin, Malcarne & Menon, 2012).While gender differences in the relation between math anxiety and arithmetic have not always been taken into account in these studies, recently it has been shown that in 12 - 15-year old and 7 -15-year old children, respectively, only girls (but not boys) with higher levels of math anxiety showed performance decrements on a general arithmetic ability test (Devine, Fawcett, Szűcs, & Dowker, 2012; Erturan & Jansen, study 1, 2015). This effect was observed after controlling for the effects of test anxiety, a factor related to math anxiety (Richardson & Woolfolk, 1980) which has been shown to be important to take into account when studying relations between math anxiety and arithmetic (Devine et al., 2012).

Besides the impact of math anxiety on arithmetic, there is evidence that at least in adults and adolescents, also other cognitive abilities are negatively affected by math anxiety. For example, math anxiety has been shown to negatively influence reading speed and comprehension (Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998) and WAIS performance IQ (Hopko, Crittendon, Grant, & Wilson, 2005) in adults and overall academic performance in adolescents (Venkatesh Kumar & Karimi, 2010). So far, in children, only little is known about the effects of math anxiety on cognitive skills beyond arithmetic. In a study by Wu et al. (2012) including 2nd and 3rd grade children, scores on math anxiety were not significantly correlated with reading achievement as measured by a word reading and reading comprehension task. Recently, Passolunghi, Caviola, De Agostini, Perin and Mammarella (2016) found that 6th to 8th grade children who were high and low in math anxiety did not differ in reading and writing performance. However, in these studies the effects of gender were not examined. Given recent findings that math anxiety differentially affects arithmetic performance in boys and girls (Devine, et al., 2012; Erturan & Jansen, study 1, 2015) it is likely that any possible negative relations between math anxiety and cognitive abilities differ between genders. To address this, the present study investigated the relationship between 5th-graders' math anxiety, math performance and two cognitive skills (i.e. reading and fluid intelligence, the latter referring to an individual's reasoning and problem solving abilities

(Carpenter, Just, & Shell, 1990)), while examining effects of gender and controlling for test anxiety.

The notion that math anxiety affects performance on domains other than arithmetic might be explained in relation to the attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007). One main assumption of this theory is that (math) anxiety evokes worrisome thoughts, which limit working memory resources by depleting limited attention resources. This in turn reduces the amount of available working memory capacity when performing concurrent tasks. Thus, based on this theory, it may be argued that especially working memory demanding tasks are negatively influenced by math anxiety. In fact, both reading and fluid intelligence are highly dependent on the availability of sufficient working memory (attentional) resources, particularly in children (e.g. Brady, 1991; Engle, Tuholski, Laughlin, & Conway, 1999).

In sum, math anxiety has been shown to negatively impact cognitive skills beyond mathematics in adults and adolescents, as well as arithmetic performance in children, with the latter mainly in girls. It is unknown so far if math anxiety also impairs performance in other domains of cognitive functioning in children (such as reading and fluid intelligence), and if this differs between genders. To address this, girls and boys attending 5th grade were administered a math anxiety questionnaire, a general arithmetic ability test, a reading test and a fluid intelligence test. The general arithmetic ability test was administered to replicate findings of two recent studies (Devin et al., 2012; Erturan & Jansen, 2015) demonstrating that math anxiety only impaired arithmetic performance in girls. Because math anxiety is at least partially influenced by environmental factors such as the teacher's attitude towards mathematics (Beilock, Gunderson, Ramirez, & Levine, 2010) and because levels of math anxiety might change across development (Wigfield & Meece, 1988), the current study included children that attended the same grade level in primary school. All children were also administered a test anxiety questionnaire to check if test anxiety accounted for any relations between the measures of interest.

2. Method

2.1. Participants

Participants were 39 children aged 9 to 11 years from the 5th grade of an international primary school located in the South of the Netherlands. This age group was selected since from ages 9 - 11 years onwards children begin to develop emotional reactions and attitudes toward mathematics (McLeod, 1993). Five children were excluded from data analyses due to incomplete data. Of the final sample of 34 children, 17 were boys (mean age = 10.3 years, SD = 0.60) and 17 were girls (mean age = 10.4 years, SD = 0.61). None of the children had a history of neurological disorders or learning disabilities. The parents of all participating children had provided written informed consent before the start of the study. After completing the experiment, children received a small toy present. The study was approved by the ethical committee and was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki.

2.2. Measures

The revised *Child Math Anxiety Questionnaire* (CMAQ-R; Ramirez, Chang, Maloney, Levine, & Beilock, 2016) was included to index children's math anxiety levels. This 16-item scale was adapted from the Mathematics Anxiety Rating Scale for Elementary school students (MARS-E; Suinn, Taylor, & Edwards, 1988). The items in the questionnaire assess how nervous children would feel in certain situations that contain math-related content (e.g. how do you feel when your teacher explains to you how to do a math problem?). Children had to respond to each item by pointing to one of five smiley faces depicting how nervous they would feel about each item, with the 1 displayed on the left side of the scale (i.e. not nervous at all), and the 5 displayed on the right side of the scale (i.e. very, very nervous). A child's math anxiety level was determined by adding up the scores for all items, with a higher score indicating higher math anxiety levels (maximum score = 80).

The *Tempo Test Arithmetic* (TTA; De Vos, 1992) was used to index general arithmetic ability. This paper and pencil test contains five columns of 40 problems each. Every column covers a different arithmetical operation: addition, subtraction, division, multiplication and a mixed column including all operations. Per column, children were instructed to solve as many problems as possible within 1 minute. One point was assigned for each correctly solved problem. To get an index of a child's general arithmetic ability, the number of correctly solved problems per column was counted and added up over columns to arrive at a total score (maximum score = 200).

The *Multi Lit 1-minute reading test* was used to measure a child's reading ability (http://www.multilit.com). This test consists of 200 nonrelated words and children were asked to read the words as quickly and accurately as possible within 1 minute. The number of words read correctly within this period was used as an indication of a child's reading ability (maximum score = 200).

Raven's standard progressive matrices (RPM; Raven, 1992). This paper and pencil test was included as a measure of fluid intelligence. It comprises 60 items, which are divided over 5 sets (A, B, C, D and E) with 12 items per set. Each item consisted of a visual pattern from which a piece was missing. Children had to select the missing piece out of 6 (sets A and B) or 8 alternatives (sets C, D and E) that were shown below the pattern. One point per correctly solved item was assigned. In the current study raw scores were used to index a child's fluid intelligence (maximum score = 60).

The *Children's Test Anxiety Scale* (CTAS; Wren & Benson, 2004) is a self-report questionnaire that was included to measure a child's test anxiety levels. This questionnaire contains 30 items that describe the feelings a child can experience during a test situation using a 4-point Likert scale (1 = almost never; 4 = almost always). A child's test anxiety level was determined by adding up the scores of all items; a higher score indicated a higher level of test anxiety (maximum score = 120). The reliability of the CTAS is 0.92 (Wren & Benson, 2004).

2.3. Procedure

Children participated in two sessions: one individual session and one group-based ses-

sion. In the individual session, the MultiLit 1-minute reading test, the CTAS and the CMAQ were administered in consecutive order in a quiet room at school. In the group-based session, children were presented with the TTA and the Raven's standard progressive matrices.

3. Results

3.1. Descriptive Analyses

The means and standard deviations of all administered measures are presented in Table 1. A significance level of $p < 0.05$ was adopted for all statistical analyses. We first performed several descriptive analyses and tested whether there were gender differences in math anxiety, test anxiety and the three cognitive skills, i.e. general arithmetic ability, reading and fluid intelligence. Independent t-tests showed that boys and girls did not significantly differ in math anxiety ($t(32) = -1.47$, $p = 0.15$), test anxiety ($t(32) = -0.97$, $p = 0.34$), general arithmetic ability ($t(32) = 0.27$, $p = 0.79$) or reading ability ($t(32) = -0.05$, $p = 0.96$). Fluid intelligence was trend-significantly higher in boys than in girls ($t(32) = 1.9$, $p = 0.08$).

3.2. Gender Differences in the Relation between Math Anxiety and Arithmetic, Reading, and Fluid Intelligence

To address our main research question, i.e. if math anxiety negatively and differentially influences arithmetic, reading and fluid intelligence in boys and girls, partial Pearson correlation analyses were performed per gender. The influence of test anxiety was controlled in all correlational analyses by adding the scores on the test anxiety questionnaire as a covariate. The results of the correlational analyses are presented in Table 2.

Table 1. Descriptive statistics for the study variables.

Measure	Boys			Girls		
	M	*range*	*SD*	*M*	*range*	*SD*
Math anxiety score	34.2	18 - 56	12.6	40.6	22 - 65	12.8
Arithmetic ability score	104.2	61 - 151	23.8	101.4	53 - 200	36.8
Reading performance	123.7	62 - 200	37.3	124.3	50 - 188	35.9
Fluid intelligence	48.4	42 - 55	3.6	44.9	35 - 52	6.7
Test anxiety score	62.6	34 - 114	18.7	69.0	40 - 111	20.0

Table 2. Pearson correlations between arithmetic ability, reading, fluid intelligence and math anxiety in boys and girls.

measure	math anxiety	
	boys	girls
arithmetic ability	−0.06	−0.60*
reading	−0.31	−0.51*
fluid intelligence	−0.16	−0.52*

*$p < 0.05$.

For boys, no significant correlations were found between math anxiety and arithmetic, between math anxiety and reading or between math anxiety and fluid intelligence. These data indicate that in boys, the level of math anxiety was not related to arithmetic ability, reading ability or fluid intelligence. A different pattern of results was obtained for girls, where moderate to strong correlations were found. Here, math anxiety significantly and negatively correlated with arithmetic performance, reading performance and fluid intelligence. These data indicate that only in girls math anxiety was significantly related to cognitive performance, with higher levels of math anxiety resulting in lower performance in arithmetic, reading and fluid intelligence. Importantly, these relations could not be accounted for by the influence of test anxiety, which was controlled in all analyses.

4. Discussion

The current study was set up to replicate gender specific findings regarding the association between math anxiety and arithmetic performance in children and to investigate if math anxiety also negatively affected children's performance in cognitive domains beyond arithmetic (i.e. reading and fluid intelligence), studying possible gender differences and controlling for the effects of test anxiety.

First of all, the current data demonstrated that only in girls, math anxiety negatively influenced arithmetic performance in children attending 5th grade (while controlling for test anxiety), there by replicating and confirming recent work (Devin et al., 2012; Erturan & Jansen, 2015). In contrast to the studies by Devin et al., (2012) and Erturan and Jansen (2015) who focused on children of larger and partly different age ranges, the present study included children attending the same grade level in primary school. It thus seems that irrespective of the specific age range under study and whether wide or narrow age groups are investigated, the finding of gender-specific influences of math anxiety on arithmetic performance seems to be quite robust so far. It should be noted that the current study as well as those of Devin et al., (2012) and Erturan and Jansen (2015) assessed arithmetical competency by deriving (total) scores on more general arithmetic ability tests. An interesting question that arises is whether similar gender differences would be observed when focusing on other arithmetical competencies, such as arithmetic reasoning or the type of strategies used when solving arithmetic problems.

The novel contribution of the current study to the existing literature was to examine, in children, the impact of math anxiety on cognitive skills besides arithmetic (specifically reading and fluid intelligence), looking at possible gender differences and controlling for test anxiety. The data showed that higher levels of math anxiety were linked to impaired reading performance and fluid intelligence scores, but only in girls. In boys, math anxiety did not significantly affect reading or fluid intelligence. Although previous studies in children did not show a significant correlation between math anxiety and reading or writing skills (Wu, et al., 2012; Passolunghi, et al., 2016), as stated before these studies did not take gender differences into account. Whereas prior research has demonstrated detrimental effects of math anxiety on a variety of cognitive abilities in

adults and adolescents (Hopko et al., 1998; Hopko et al., 2005; Venkatesh Kumar & Karimi, 2010) and on arithmetic abilities in girls (Devine et al., 2012; Erturan & Jansen, 2015), the present study contributes to this research by showing that also reading and fluid intelligence are negatively affected by math anxiety, but only in girls. Interestingly, although math anxiety differentially affected boys' and girls' cognitive abilities, they reported to experience comparable math anxiety levels. In addition, gender differences were absent in the cognitive abilities under study. This suggests that the gender-specific negative impact of math anxiety on arithmetic, reading and fluid intelligence cannot be explained by gender differences in math anxiety and/or the cognitive abilities tested.

The exact reason why math anxiety resulted in poorer performance in arithmetic, reading and fluid intelligence in girls only cannot be inferred from the current data, but some speculations can be made. Firstly, even though reported math anxiety levels were comparable between genders, it might be that when engaged in (working memory demanding) cognitive tasks such as those employed in the current study, girls suffer more from the ruminations associated with math anxiety than boys. This is suggested to lead to subsequent performance decrements in girls. Alternatively, it could be that girls and boys suffer equally from the math anxiety evoked ruminations, but boys might be better able to suppress these unwanted ruminations such that their cognitive abilities are not significantly affected. To test these hypotheses, future studies should measure the level of experienced ruminations associated with math anxiety during cognitive task performance. Secondly, the performance decrements seen in math anxious girls might stem from a phenomenon called stereotype threat. This refers to the observation that existing stereotypes about members of a disadvantageous group can lead to underperformance of these members regarding certain skills. Keller (2002) has shown that female high school students underperformed in math tasks in a condition of heightened salience of negative stereotypic expectations in comparison to a control group. Schmader (2002) found that the level of gender identification was related to math performance in female college students. Women with higher levels had lower math scores then men, while women with lower levels had scores that were equal to men. In relation to the current findings, it is suggested that girls with higher levels of math anxiety are particularly vulnerable to the stereotype threat that girls have inferior cognitive abilities compared to boys, resulting in girls' performance decrements in arithmetic, reading and fluid intelligence. In fact Schmader, Johns and Forbes (2008) state that anxiety is one of the mechanisms through which stereotype threat impacts performance. If this also applies to math anxiety in particular should be investigated in future studies.

There are several implications of the present results for the educational practice. Considering the fundamental role that cognitive abilities such as arithmetic, reading and fluid intelligence play in school, it is important that teachers become or are aware of the fact that the detrimental effects of math anxiety on these abilities differ between genders. This is also important in light of recent findings showing that among 1st and 2nd grade children, female teachers passed on their negative attitudes about mathematics to girls (but not boys), which negatively affected girls' math performance levels

(Beilock, Gunderson, Ramirez, & Levine, 2010). In combination with the findings of the current study this suggests that girls not only seem to be more sensitive to the negative influence of math anxiety on cognitive skills, but might also be more likely to adopt negative feelings about mathematics from female teachers. Where possible, (female) teachers should try to reinforce the positive attitudes of girls toward mathematics. Math anxiety levels might be systematically decreased by adopting an approach that has been successfully applied to college students, where visualizing, preparing early and replacing negative thoughts with confidence building was found to reduce math anxiety (Preis & Biggs, 2001).

5. Conclusion

In sum, the current study showed that the detrimental effects of math anxiety were not only restricted to the domain of mathematics, since math anxiety was found to also negatively affect girl's performance on a reading and fluid intelligence test. Nevertheless, several limitations of the current study should be considered. Firstly, the sample size in this study was relatively small. However, the observed correlations had moderate to large effect sizes (>0.50), making it unlikely that the reported data were due to chance or suffered from serious power issues. Secondly, because of the correlation design, no casual inferences can be made. Future research should employ longitudinal designs to investigate any casual relations between math anxiety and cognitive abilities.

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