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General academic anxiety and math anxiety in primary school. The impact of math anxiety on calculation skills

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ABSTRACT

Some academic subjects, such as math, produce negative feelings, influencing achievement. Math anxiety interferes with processing math-related or number-related information and tasks in ordinary life and academic situations. It differs from general academic anxiety that involves all the academic situations, independently by the specificity of the study subject. Further, it is possible to identify two correlated dimensions of math anxiety which may considerably interfere with math performance: anxiety related to learning mathematics and that experienced during tests. This study investigated the relationship between general academic anxiety, math anxiety, and calculation skill in schoolchildren ($N = 204$). Results showed that math anxiety was negatively associated with calculation performance in schoolchildren. More specifically, anxiety for math tests correlated negatively with numerical knowledge, calculation accuracy, and calculation speed, while anxiety for learning math correlated negatively with written calculation scores. These findings have a great educational interest. Indeed, calculation skills are central in school and daily life so teachers should recognize math anxiety precociously and promote educational interventions to control it.

1. Introduction

It is generally assumed that mathematics can elicit stronger emotional reactions, especially anxiety, than most other academic subjects (Dowker et al., 2016). Indeed, many students have little interest in mathematics, are unaware of their mathematical skills, and experience mathematics as a complex and challenging subject that generates anxiety (Justicia-Galiano et al., 2017). Given the increasing importance of mathematical reasoning in a variety of educational and professional situations, the construct of math anxiety has received increasing attention in recent years, in order to remove barriers to learning this discipline which is central to everyday tasks (Dowker et al., 2016).

1.1. Definition of math anxiety

Math anxiety is a widespread problem all over the world and affects all age groups. In this regard, according to the data reported in an Information Capsule on the strategies for reducing math anxiety (Blazer, 2011), approximately 93% of adults in the USA refer to have experienced math anxiety. Similarly, the Program for International Student Assessment (PISA), in the 2019 assessments, found that a high percentage of secondary school students worry about math and are in tension when they do math homework.

Math anxiety is defined as a feeling of tension, helplessness, mental disorganization, and increased physiological reactivity when individuals deal with math (Hunsley, 1987; Luttenberger et al., 2018). Devine et al. (2012) described math anxiety as a state of unrest caused by performing math tasks, characterized by feelings of apprehension, worry, aversion, and frustration. This condition depends on several factors such as math self-concept (Dowker et al., 2016), pedagogical factors (Rayner et al., 2009), and gender (Szczygiel, 2020; Van Mier et al., 2018). In this regard, it has been shown that males report better performances in math tasks than females (Ehrtmann & Wolter, 2018; Szczygiel, 2020; Van Mier et al., 2018) and that females show higher levels of math anxiety than males (Devine et al., 2012).

Math anxiety is a multidimensional construct (Lukowski et al., 2019). The literature on this topic identified at least two correlated dimensions of math anxiety: anxiety related to learning mathematics and that experienced during tests (Hopko et al., 2016; Lukowski et al., 2019). Math learning anxiety involves undertaking math operations, manipulating numbers, or acquiring math concepts in the classroom, while math test anxiety is specifically related to test situations (Hopko et al.,

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2016; Luttenberger et al., 2018). Both dimensions of math anxiety significantly interfere with math performance (Passolunghi et al., 2020). The multidimensional nature of math anxiety is also expressed in the various questionnaires for the assessment of math anxiety, such as the Mathematics Anxiety Scale (MAS) (Fennema & Sherman, 1976), the Mathematics Anxiety Rating Scale (MARS) (Richardson & Suinn, 1972), the Mathematics Anxiety Questionnaire (MAQ) (Wigfield & Meece, 1988), and the Anxiety Toward Mathematics Scale (ATMS) (Sandman, 1980). The MAS and the MAQ assess negative affects related to mathematics. The MARS is a multidimensional measure strongly emphasizing mathematics test and numerical anxiety, while the ATMS assesses general uneasiness in mathematics situations.

Math anxiety has to be distinguished from other types of anxiety, such as general academic anxiety. General academic anxiety determines negative feelings that involve all the academic situations, independently by the subject's specificity. It can also be linked to specific situations that are perceived as potentially threatening to one's self-esteem, such as essential exams (general academic test anxiety) (Krispenz et al., 2019). General academic anxiety influences lifelong academic and vocational development and can cause academic procrastination (van Eerde, 2003), the voluntary delay of important and intended actions or decisions related to the academic context (Krispenz et al., 2019). The main physiological symptoms are sweaty palms, cold, nervousness, panic, fast breathing, racing heartbeat, and stomach pain (Ruffins, 2007). Psychological symptoms include nervousness before tutorial classes, panicking, going blank during tests, feeling helpless while doing academic tasks or homework, or lack of interest in academic subjects (Vitasari et al., 2010). Unlike general academic anxiety, math anxiety is related to specific impairments in processing math-related or number-related tasks. Students suffering from math anxiety have low perceptions of their math skills and perform poorly in math reasoning tasks, processing numeric information, and evaluative situations connected to math (Ashcraft & Moore, 2009; Paechter et al., 2017; Shi & Liu, 2016). As highlighted above, the two different math anxiety components (math learning anxiety and math test anxiety) can affect calculation skills differently and need to be further explored.

Although most of the research has focused on math anxiety, assuming that math-related worries are more intense than those experienced about other academic subjects (Dowker et al., 2016), several studies indicated that anxiety related to other specific subjects might also exist (Hill et al., 2016). In this regard, an interesting study by Punaro and Reeve (2012) showed that literacy anxiety can arise in children with age-appropriate reading skills but is less frequent than math anxiety. Other studies underlined that children and adolescents with poor literacy show more language anxiety than their literate peers (Carroll et al., 2005) and that there is an association between reading difficulties and anxiety symptomatology (Carroll & Iles, 2006).

1.2. The relation between math anxiety and math performance

Math performance is the result of several competencies and knowledge related to the use of numbers to notice, compare, predict, quantify, and verify relationships (Dowker, 1998; Gersten et al., 2005).

The main competence that children acquire at the start of primary school is calculation. McCloskey et al. (1985) hypothesized two different systems implicated in the calculation. The first, “number-processing system,” includes different components that make possible number comprehension and number production. The second, “calculation system,” concerns the mechanisms specifically involved in the calculation. It comprises three components: processing operational symbols or words, storing basic arithmetic facts, and executing calculation procedures. Any calculation task requires adequate functioning of both systems. Moreover, mental and written calculations need different procedures and processes (Cornoldi et al., 2002). Based on the McCloskey et al. (1985), Cornoldi and Lucangeli (2004) identified four components of calculation skills: numerical knowledge, calculation accuracy, calculation speed, and written calculation. Numerical knowledge is the set of abilities and knowledge that allows a child to comprehend numerical measures and their transformations (Dehaene et al., 1990; Lucangeli, 1999). Calculation accuracy and speed concern the capacities to execute arithmetic calculations accurately and promptly (Cornoldi & Lucangeli, 2004; Jordan & Montani, 1997). Written calculation concerns the use of the correct procedures while performing the written calculation. Poor performance in mental and written calculation tasks depend on difficulties in one or more of these components that compose calculation skills (Cornoldi & Lucangeli, 2004).

According to the literature, children usually report positive attitudes toward mathematics but may begin to form attitudes that may be negative (Dowker et al., 2012; Petronzi et al., 2018). In this regard, it has been demonstrated that children report math anxiety as early as the first grade and then in the following years of elementary school (Ganley & McGraw, 2016; Jameson, 2013; Krinzinger et al., 2009; Sorvo et al., 2017). Math anxiety in children makes the acquisition of mathematical skills more difficult as negative attitudes lead to avoidance and poor performance, further escalating negative feelings (Gierl & Bisanz, 1995; Szczygiel, 2020; Vukovic et al., 2013). Furthermore, it has been shown that children with developmental dyscalculia are twice as likely to suffer from math anxiety than their peers with typical mathematics performance (Devine et al., 2018).

Several studies showed a moderate negative relationship between math anxiety and math performance (Justicia-Galiano et al., 2017; Passolunghi et al., 2020). Although moderate levels of anxiety can motivate a student to understand the mathematical concepts better, high levels of math anxiety have been associated with negative performance, avoiding behavior, and negative beliefs on the own skills (Ashcraft, 2016). A recent meta-analysis by Zhang et al. (2019) indicated a strong negative math anxiety-performance link that was stronger in high school students than in elementary ones. Nevertheless, the mechanisms underlying this relationship are still unclear. In this regard, it has been shown that working memory is a significant mediator of the relationship between math anxiety and math performance in children (Justicia-Galiano et al., 2017). According to Ashcraft and Kirk (2001, Jun), math anxiety selectively affects calculation with high working memory demand. Conversely, according to Maloney et al. (2012), math anxiety affects all mathematical activities, including the most basic ones such as magnitude comparison. A recent study by Lee and Cho (2018) showed a negative relationship between math anxiety and math performance related to magnitude processing and complex calculation with high working memory demand. On the contrary, the retrieval-based simple calculation, which requires a low working memory load, is not significantly compromised by math anxiety. Beilock and Willingham (2014) showed a strong relationship between math anxiety and math performance, especially in mathematical reasoning, with particular reference to advanced problem-solving skills. In contrast, Harari et al. (2013) reported a weak link between math anxiety and digital calculation, which assessed basic computational skills.

In the light of this evidence, math anxiety significantly decreases students’ math performance (Van Mier et al., 2018; Wu et al., 2012; Zhang et al., 2019). However, according to a recent meta-analysis by Zhang et al. (2019), the studies that analyzed the relationship between math anxiety and math performance evaluated calculation and problem solving without investigating the impact of math anxiety on the different math performance components. Moreover, the literature on the topic focused on math anxiety and did not distinguish the different aspects of math anxiety from general academic anxiety. Therefore, it is important to clarify the nature of the relationship between math anxiety and math performance and to identify, in particular, the specific math skills most strongly affected by math anxiety.

1.3. Research aims

The present study will investigate the correlation between math anxiety and calculation skills in a sample of children that attend primary school. In particular, the study aims to investigate the relationship between math anxiety and the different calculation skills (i.e., numerical knowledge, calculation accuracy, calculation speed, and written calculation). General academic anxiety, learning math anxiety, and math test anxiety will be analyzed. Furthermore, we will investigate the relationship between gender, general academic anxiety, math anxiety, and math performance. Specifically, we expect to find better math performance in males than in females and higher levels of anxiety in females than in males.

2. Material and methods

2.1. Participants

Participants were 204 primary schoolchildren (120 males, 84 females), who attended grade three (age range: 8-9 years; $M = 8.63$, $SD = 0.48$). Children attended four public schools in a town in Italy. The academic curricula were the same for each school. In Italy, primary school comprises five grades. All the third-grade students, who attended the schools involved in the study, participated. The students with certifications of physical or cognitive disabilities by the Italian Public Health System were not included in the sample. None of the children presented developmental disorders or had a previous history of learning difficulties. In Italy, schoolchildren with learning or intellectual disabilities or other physical or psychological disturbances receive a certification by the health system and scholastic office. The choice to recruit students who attend the third grade depended on the Italian Scholastic System's characteristics and legislation on math learning disorders. Indeed, in Italy, children begin to study math in the first grade, and they can execute the four arithmetic operations correctly and use the decimal number system in the third grade.

One hundred ninety-five children were native Italian speakers; the remaining were of immigrant families. However, they lived in Italy for almost five years and spoke the Italian language correctly. The vision was normal or corrected-to-normal.

Parental and school approval and the child's oral consent were obtained before test administration. The study was performed following the ethical standards of the 1964 Declaration of Helsinki and followed the Ethical Code for Italian psychologists (L. 18.02.1989, n. 56), Italian law for data privacy (DLGS 196/2003), and Ethical Code for Psychological Research (March 27, 2015) approved by Italian Psychologists Association.

2.2. Procedures

A trained psychologist administered the tests in individual and group settings during school time. Anxiety and math tests were administered on different days to avoid interference effects. Tests order was counterbalanced between participants to control the order effect (Breakwell, 2006).

2.3. Measures

The Italian standardized test battery "Test for the evaluation of calculating and problem-solving abilities" (AC-MT 6–11) was used to assess the mathematical performance (Cornoldi et al., 2002). It consists of 10 paper-and-pencil tests that evaluate the numerical and calculation skills of children aged 6-11. The battery includes a section that can be administered collectively for a general assessment of the child's calculation skills and an individually administered section to evaluate further the specific components involved in calculation skills. The collective battery includes the following five subtests: Written calculation, Size comparison, Word–number transcoding, Number ordering. The Written calculation subtest assesses the child's ability to use the procedures to solve basic written operations. The Size comparison subtest evaluates the child's semantic numerical knowledge: specifically, the child must decide which of the six pairs of numbers (e.g. 1024 and 1402) he/she is presented with is the largest number. The Word–number transcoding subtest evaluates the child's lexical and syntactic numerical knowledge: specifically, the child must write the numbers corresponding to six sets of lexical strings which report in random order the numbers of units, tens, hundreds and thousands. Finally, the Number ordering subtest assessed the child's semantic and syntactic knowledge:the child must order, according to an increase or decrease in size, 10 series of four complex numbers (Cornoldi & Lucangeli, 2004).

Individual subtests include "mental calculation," "written calculation," "enumeration" (forward from 1 to 20, forward from 1 to 50, backward from 100 to 50), "number dictation" and "numerical facts". This last task measures basic knowledge of addition and subtraction with one-digit numbers, multiplication tables, and other facts (Cornoldi et al., 2002).

AC-MT 6-11 test provides four global scores relating to the numerical skills of children: written calculation, referring to the ability to perform written calculations; numerical knowledge, referring to the aspects of basic numerical cognition; accuracy, referring to the number of errors in the individual tests; calculation speed, referring to the automatization of numerical processing skills. These scores supply information about the different components of arithmetic skills (numerical knowledge, written calculation, calculation accuracy, and calculation skills). For each test, raw scores concerning the age are converted into z points and/or percentile, and a standardized score is assigned to assess the child's performance and illustrate it graphically (good, fair, attention request, request for immediate intervention). The AC-MT 6-11 has a good test retest reliability ($r = 0.83$). Furthermore, the authors correlated the test scores with teachers' opinions to evaluate the concurrent test validity. The correlations outcomes are significant at the 0.01 level, and the correlation average is 0.51 (Cornoldi et al., 2002). The correlations between the reading tests showed high values for accuracy and speed ($r = 0.90$).

The MeMa Mathematical Anxiety Scale was used to assess general academic anxiety and math anxiety (Caponi et al., 2012). It consists of 30 items, and children must indicate their emotional response to the described situations using a 4-point Likert scale, ranging from 1 (little fear/anxiety) to 4 (fear/high anxiety). High scores indicate high levels of math anxiety.

The MeMa test allows to assess two different dimensions of math anxiety: math learning anxiety and math test anxiety. The items related to the dimension of math learning anxiety concern situations and activities related to learning mathematics (e.g., "Observing a teacher explaining an equation on the blackboard", "Starting a new chapter in a math book", "Listening to a classmate explain a math rule"). The items related to the dimension of math text anxiety concern contexts and situations in which the student is assessed in mathematics (e.g., "Thinking about the math test you have to take tomorrow", "Solving a square root or other complex mathematical operation", "Preparing to be tested in math"). In addition to these two dimensions, the MeMa test evaluates a third dimension of control related to generalized school anxiety. The items related to this dimension concern anxiety in other school subjects (e.g., "Answering some questions about a text you have read", "Being tested in history", "Reading a musical score") (Caponi et al., 2012).

The MeMa test is an adapted version of the MARS test that is one of the more famous measures of math anxiety. The original version includes 24 items (Saccani & Cornoldi, 2005) and shows good psychometric properties. The Cronbach alpha of 0.96 indicated high internal consistency, while the test-retest reliability was 0.90 (Suinn & Winston, 2016). Similar psychometric values were found in our sample with the Italian adjustment of this scale.

2.4. Statistical analyses

The Statistical Package for the Social Sciences (SPSS) version 25.0 (IBM Corporation, Armonk, NY) was used for the statistical analyses. Missing data and outliers were checked to ensure accurate data entry and no outliers were detected. As the first step, descriptive statistics and *t*-test examined differences in calculation skills and anxiety by gender. Secondly, based on correlation analysis, several multiple regression analyses evaluated the impact of general academic anxiety and the different aspects of math anxiety on arithmetic skills components. Multiple regression analyses were calculated using the anxiety scores as the independent variables. Each arithmetic scale score was added as a dependent variable in separate analyses. All the correlations values, which were calculated preliminarily to the regression analysis, were lower than 0.70, which is the value that causes problems in the interpretation of regression results. Moreover, there was no evidence for multicollinearity between the predictors in any regression analyses ($VIF < 2$; $rs < 0.60$). Results were considered significant if $p < .05$.

3. Results

Table 1 reports the results of the *t*-test comparisons between males and females for anxiety and arithmetic performance. Males reported significantly better written calculation scores than females ($p = .002$), while there were no significant differences in the other components of calculation skills ($p > .05$). Moreover, females experienced higher levels of math anxiety than males, both concerning anxiety for math learning ($p = .029$) and anxiety for math tests ($p < .001$). There were no significant differences in general academic anxiety ($p > .05$).

Based on the correlation matrix reported in Table 2, a series of multiple regression analyses was run using the "forced entry" method. The regressions evaluated whether math anxiety and general academic anxiety were predictive of the different calculation skills aspects. Numerical knowledge, written calculation, calculation accuracy, and calculation speed were regressed on all the anxiety scores with control for gender also included in the regression. Table 3 reports the regression analysis results and shows that math anxiety scores, but not general academic anxiety scores, were useful predictors of the different aspects of calculation skills.

More specifically, anxiety for math test scores was a significant predictor of numerical knowledge, calculation accuracy, and calculation speed scores. Furthermore, gender and anxiety for learning math scores were significant predictors of the written calculation scores. Fig. 1 provides a graphic summary of the results of the regression models.

Table 1
Means, standard deviations and *t*-test statistics of the math tasks and anxiety tests scores.

	Gender	*M*	*SD*	*t*	*p*
Anxiety for math learning	Male	51.51	11.64	-2.20	0.02
	Female	55.30	12.67		
Anxiety for math tests	Male	50.05	8.77	-3.55	0.000
	Female	54.53	9.03		
General academic anxiety	Male	48.07	8.84	-0.54	0.58
	Female	48.75	8.86		
Written calculation	Male	2.02	1.01	3.08	0.002
	Female	1.60	0.88		
Numerical knowledge	Male	20.18	2.49	-0.27	0.78
	Female	20.29	2.70		
Calculation accuracy	Male	7.48	7.00	-0.55	0.55
	Female	7.98	4.92		
Calculation speed (in seconds)	Male	149.12	91.93	1.09	0.22
	Female	137.02	49.77		

M: mean; SD: standard deviation.

4. Discussion

This study analyzed the relationship between math anxiety and the different components of arithmetic performance (i.e., numerical knowledge, calculation accuracy, calculation speed, and written calculation) in a sample of children attending primary school. More specifically, the study evaluated how anxiety for learning math, anxiety for math tests, and general academic anxiety were correlated with math performance. Multiple regression analyses showed that math anxiety was a significant predictor of all the aspects of calculation skills. In contrast, general academic anxiety did not prove to be a valid predictor of arithmetic performance, confirming that math anxiety is a specific construct different from academic anxiety (Ashcraft, 2016; Ashcraft & Moore, 2009).

In particular, learning math anxiety was significantly associated with written calculation, while math test anxiety was significantly associated with the other aspects of calculation skills, i.e., numerical knowledge, calculation accuracy, and calculation speed. These results are worthy of attention and show that fear of math examinations contributed to determining the quality of calculation performance, influencing the correctness of calculations, speed of execution, and also the abilities implicated in the comprehension of numerical measures and their transformations, as measured through the "numerical knowledge" task. Learning math anxiety was associated with the use of procedures involved in the written calculation that require more complex skills and knowledge than those involved in the numerical knowledge. These findings would suggest that math test anxiety mainly affects the ability to correctly and automatically process the information during a calculation, which is central to success in math testing situations. On the other hand, learning math anxiety affects above all the ability in written calculation, which requires the possession of procedures that are acquired in the learning process in the classroom. However, further studies are needed to better clarify the relationship between the dimensions of math anxiety and different math skills.

Furthermore, these data can be interpreted in the light of the most recent theories on the role of anxiety in mathematical performance. The literature confirmed that that working memory plays an important role in the performance of arithmetic operations and other mathematical tasks (Commodari & Di Blasi, 2014). Also, numerical knowledge is supported by underlying cognitive systems, specifically working memory (Daubert & Ramani, 2019). In particular, it has been underlined that anxiety produces worry and impairs performance related to tasks with high attentional or short-term memory demands (Ashcraft & Kirk, 2001, Jun; Ashcraft & Krause, 2007; Shi & Liu, 2016). According to Eysenck and Calvo's (1992) processing efficiency theory, worry causes a reduction in the working memory system's storage and processing capacity for a concurrent task and an increment in on-task effort activities designed to improve performance. Anxiety characteristically impairs processing efficiency more than performance effectiveness (Artemenko et al., 2015; Hadwin et al., 2005; Owens et al., 2008). The studies by Ashcraft and colleagues (Ashcraft & Kirk, 2001, Jun; Ashcraft & Krause, 2007) also confirmed that math anxiety selectively affects calculation with high working memory demand. This study confirmed the significant relationship between math anxiety and math performance, particularly in tasks requiring a more significant commitment of attentional resources and working memory, such as calculation accuracy and speed. However, future studies will have to further investigate the relationship between math anxiety, working memory, and math performance and clarify which processes are involved in this relationship.

The results also showed that males and females differed in the use of procedures involved in the written calculation, in which males outperform females. This finding was not surprising. Many studies showed differences by gender in math skills and found better performance in males than females (Ehrtmann & Wolter, 2018; Szczygiel, 2020; Van Mier et al., 2018). Males and females also differed in math anxiety. Females reported a higher level of math anxiety, both anxiety for

Table 2
Correlation matrix for all measures.

	1	2	3	4	5	6	7
1. Anxiety for learning math							
2. Anxiety for math tests	0.60**						
3. General academic anxiety	0.28**	0.37*					
4. Written calculation	-0.23*	-0.13	-0.05				
5. Calculation accuracy	0.21*	0.24*	0.07	-0.59**			
6. Calculation speed	0.16	0.29**	0.02	-0.54**	0.60**		
7. Numerical knowledge	-0.23*	-0.27**	0.007	0.51**	-0.59**	-0.49**	

* Correlation is significant at 0.01.
** Correlation is significant at 0.001.

Table 3
Multiple regressions analyses using "gender" and anxiety scores as the independent variables and calculation skill scores as the dependent variables (n for each regression = 204).

Dependent variables	Numerical knowledge			Calculation accuracy			Calculation speed			Written calculation		
Independent variables	$R^2 = 1.09$, $F = 2.96$ $p = .023$			$R^2 = 0.17$, $F = 4.96$ $p = .001$			$R^2 = 0.11$, $F = 3.23$ $p = .01$			$R^2 = 0.13$, $F = 3.83$ $p = .006$		
	B	*t*	*p*	*B*	*t*	*p*	*B*	*t*	*p*	*B*	*t*	*p*
Gender	0.10	1.01	0.31	-0.05	-0.61	0.53	-0.16	-1.65	0.10	0.29	3.04	0.003
Anxiety for math tests	-0.27	-2.15	0.03	0.28	2.29	0.02	0.37	2.93	0.004	-0.07	-0.56	0.57
Anxiety for learning math	-0.12	1.01	0.31	0.20	1.79	0.07	-0.001	-0.01	0.99	-0.24	-2.04	0.04
General academic anxiety	0.14	1.37	0.17	-0.05	-0.58	0.55	-0.10	-1.03	0.30	‘0.03	0.30	0.76

Note: sig: $p < .05$.

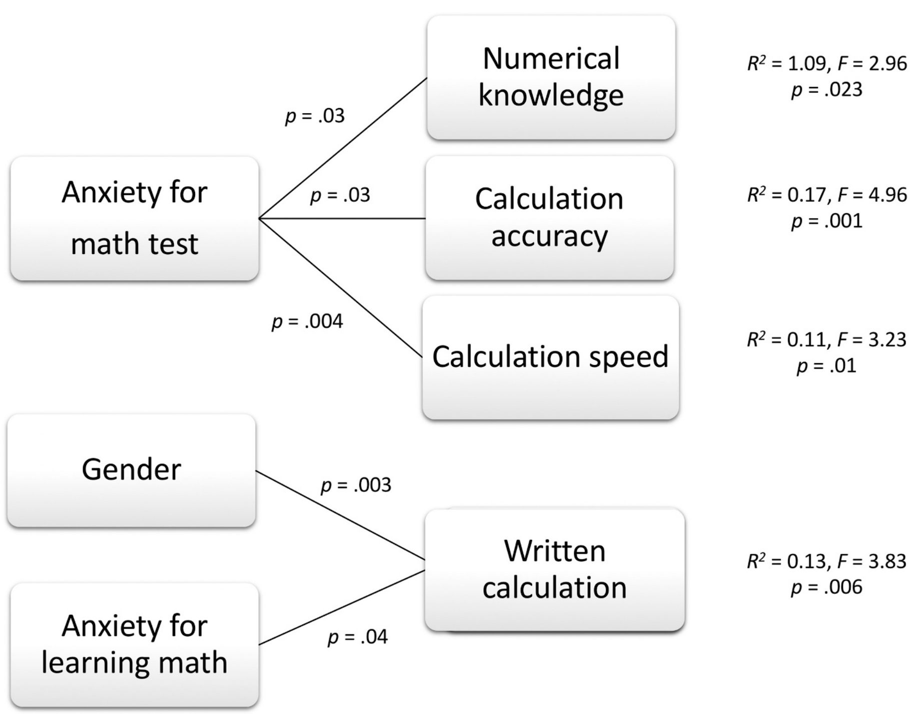

Fig. 1. Graphical representation of the results of the regression models.

learning math and anxiety for math tests, than males. There were no significant differences by gender in general academic anxiety. These results are consistent with the literature data according to which females might have more substantial math anxiety than males when dealing with tasks that involve mathematical skills and numerical skills (Maloney et al., 2012; Zhang et al., 2019).

Finally, no significant relationship was found between general academic anxiety and math performance. Having assessed anxiety related to other school subjects, this finding confirms the specificity of math anxiety which differs from generalized school anxiety and has a direct impact on math skills, as other studies on the topic have already shown (Dowker et al., 2016; Sorvo et al., 2017).

This study has several limitations. Firstly, the anxiety scales are self-report scales and do not measure the physical correlates of anxiety. Moreover, longitudinal data might permit evaluating the increasing of math skills and the age of establishing anxiety. Therefore, further studies will have to investigate further several mediators' involvement in the relationship between math anxiety and math performance, using longitudinal designs to evaluate each factor's influence on the investigated variables. Finally, we included a questionnaire assessing anxiety related to other school subjects but not one assessing general anxiety so future studies should investigate the relationship between general anxiety, math anxiety, and anxiety related to other school subjects.

However, despite these limitations, this study contributes to better understanding the relationships between math and anxiety and supplies useful indication for educational practice.

5. Conclusion

In conclusion, this study aimed to understand better the relationship between math anxiety and math performance in primary school children. These results underline the importance of planning adequate educational interventions to control math anxiety and improve math learning since the early years of schooling. Indeed, the evidence of the impact of math anxiety on academic performance should favor the development of math's teaching methodology. The evaluation moments should be limited or carried out in ways that do not pose students under pressure, especially during the first years of math acquisition. Reducing psychological stress and tension related to math achievement might produce positive effects on calculation accuracy and speed and increase the numerical system's functioning.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Artemenko, C., Daroczy, G., & Nuerk, H.-C. (2015). Neural correlates of math anxiety – An overview and implications. *Frontiers in Psychology, 6*. https://doi.org/10.3389/fpsyg.2015.01333

Ashcraft, M. H. (2016). Math anxiety: Personal, educational, and cognitive consequences. *Current Directions in Psychological Science, 11*(5), 181–185. https://doi.org/10.1111/1467-8721.00196

Ashcraft, M. H., & Kirk, E. P. (2001, Jun). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology. General, 130*(2), 224–237. https://doi.org/10.1037//0096-3445.130.2.224

Ashcraft, M. H., & Krause, J. A. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin & Review, 14*(2), 243–248. https://doi.org/10.3758/bf03194059

Ashcraft, M. H., & Moore, A. M. (2009). Mathematics anxiety and the affective drop in performance. *Journal of Psychoeducational Assessment, 27*(3), 197–205. https://doi.org/10.1177/0734282908330580

Beilock, S. L., & Willingham, D. T. (2014). Ask the cognitive scientist. math anxiety: Can teachers help students reduce it. *American Educator, 38*(2), 28–43.

Blazer, C. (2011). Strategies for reducing math anxiety [Information Capsule]. https://eric.ed.gov/?id=ED536509.

Breakwell, G. M. (2006). *Research methods in psychology* (3rd ed.). Sage Publications.

Caponi, B., Cornoldi, C., Falco, G., Focchiatti, R., & Lucangeli, D. (2012). *MeMa. Valutare la metacognizione, gli atteggiamenti negativi e l'ansia in matematica. Con CD-ROM. Edizioni Erickson*.

Carroll, J. M., & Iles, J. E. (2006). An assessment of anxiety levels in dyslexic students in higher education. *British Journal of Educational Psychology, 76*(3), 651–662. https://doi.org/10.1348/000709905x66233

Carroll, J. M., Maughan, B., Goodman, R., & Meltzer, H. (2005). Literacy difficulties and psychiatric disorders: Evidence for comorbidity. *Journal of Child Psychology and Psychiatry, 46*(5), 524–532. https://doi.org/10.1111/j.1469-7610.2004.00366.x

Commodari, E., & Di Blasi, M. (2014). The role of the different components of attention on calculation skill. *Learning and Individual Differences, 32*, 225–232. https://doi.org/10.1016/j.lindif.2014.03.005

Cornoldi, C., & Lucangeli, D. (2004). Arithmetic education and learning disabilities in Italy. *Journal of Learning Disabilities, 37*(1), 42–49. https://doi.org/10.1177/00222194040370010501

Cornoldi, C., Lucangeli, D., & Bellina, M. (2002). *AC-MT test: Test per la valutazione delle difficoltà di calcolo [The AC-MT arithmetic achievement test]*. Erickson Edizioni.

Daubert, E. N., & Ramani, G. B. (2019). Math and memory in bilingual preschoolers: The relations between bilingualism, working memory, and numerical knowledge. *Journal of Cognition and Development, 20*(3), 314–333. https://doi.org/10.1080/15248372.2019.1565536

Dehaene, S., Dupoux, E., & Mehler, J. (1990). Is numerical comparison digital? Analogical and symbolic effects in two-digit number comparison. *Journal of Experimental Psychology: Human Perception and Performance, 16*(3), 626–641. https://doi.org/10.1037/0096-1523.16.3.626

Devine, A., Fawcett, K., Szucs, D., & Dowker, A. (2012). Gender differences in mathematics anxiety and the relation to mathematics performance while controlling for test anxiety. *Behavioral and Brain Functions, 8*(1), 33. https://doi.org/10.1186/1744-9081-8-33

Devine, A., Hill, F., Carey, E., & Szűcs, D. (2018). Cognitive and emotional math problems largely dissociate: Prevalence of developmental dyscalculia and mathematics anxiety. *Journal of Educational Psychology, 110*(3), 431–444. https://doi.org/10.1037/edu0000222

Dowker, A. (1998). Individual differences in normal arithmetical development. In C. Donlan (Ed.), *The development of mathematical skills* (pp. 275–302). Psychology Press.

Dowker, A., Bennett, K., & Smith, L. (2012). Attitudes to mathematics in primary school children. *Child Development Research, 2012*, 1–8. https://doi.org/10.1155/2012/124939

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics anxiety: What have we learned in 60 years? *Frontiers in Psychology, 7*.

Ehrtmann, L., & Wolter, I. (2018). The impact of students' gender-role orientation on competence development in mathematics and reading in secondary school. *Learning and Individual Differences, 61*, 256–264. https://doi.org/10.1016/j.lindif.2018.01.004

Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition & Emotion, 6*(6), 409–434. https://doi.org/10.1080/02699939208409696

Fennema, E., & Sherman, J. A. (1976). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *Journal for Research in Mathematics Education, 7*(5). https://doi.org/10.2307/748467

Ganley, C. M., & McGraw, A. L. (2016). The development and validation of a revised version of the math anxiety scale for young children. *Frontiers in Psychology, 7*. https://doi.org/10.3389/fpsyg.2016.01181

Gersten, R., Jordan, N. C., & Flojo, J. R. (2005). Early identification and interventions for students with mathematics difficulties. *Journal of Learning Disabilities, 38*(4), 293–304. https://doi.org/10.1177/00222194050380040301

Gierl, M. J., & Bisanz, J. (1995). Anxieties and attitudes related to mathematics in grades 3 and 6. *The Journal of Experimental Education, 63*(2), 139–158. https://doi.org/10.1080/00220973.1995.9943818

Hadwin, J. A., Brogan, J., & Stevenson, J. (2005). State anxiety and working memory in children: A test of processing efficiency theory. *Educational Psychology, 25*(4), 379–393. https://doi.org/10.1080/01443410500041607

Harari, R. R., Vukovic, R. K., & Bailey, S. P. (2013). Mathematics anxiety in young children: An exploratory study. *The Journal of Experimental Education, 81*(4), 538–555. https://doi.org/10.1080/00220973.2012.727888

Hill, F., Mammarella, I. C., Devine, A., Caviola, S., Passolunghi, M. C., & Szűcs, D. (2016). Maths anxiety in primary and secondary school students: Gender differences, developmental changes and anxiety specificity. *Learning and Individual Differences, 48*, 45–53. https://doi.org/10.1016/j.lindif.2016.02.006

Hopko, D. R., Mahadevan, R., Bare, R. L., & Hunt, M. K. (2016). The abbreviated math anxiety scale (AMAS). *Assessment, 10*(2), 178–182. https://doi.org/10.1177/1073191103010002008

Hunsley, J. (1987). Cognitive processes in mathematics anxiety and test anxiety: The role of appraisals, internal dialogue, and attributions. *Journal of Educational Psychology, 79*(4), 388–392. https://doi.org/10.1037/0022-0663.79.4.388

Jameson, M. M. (2013). Contextual factors related to math anxiety in second-grade children. *The Journal of Experimental Education, 82*(4), 518–536. https://doi.org/10.1080/00220973.2013.813367

Jordan, N. C., & Montani, T. O. (1997). Cognitive arithmetic and problem solving: A comparison of children with specific and general mathematics difficulties. *Journal of Learning Disabilities, 30*, 684. https://doi.org/10.1177/002221949703000606

Justicia-Galiano, M. J., Martín-Puga, M. E., Linares, R., & Pelegrina, S. (2017). Math anxiety and math performance in children: The mediating roles of working memory and math self-concept. *British Journal of Educational Psychology, 87*(4), 573–589. https://doi.org/10.1111/bjep.12165

Krinzinger, H., Kaufmann, L., & Willmes, K. (2009). Math anxiety and math ability in early primary school years. *Journal of Psychoeducational Assessment, 27*(3), 206–225. https://doi.org/10.1177/0734282908330583

Krispenz, A., Gort, C., Schültke, L., & Dickhäuser, O. (2019). How to reduce test anxiety and academic procrastination through inquiry of cognitive appraisals: A pilot study investigating the role of academic self-efficacy. *Frontiers in Psychology, 10*. https://doi.org/10.3389/fpsyg.2019.01917

Lee, K., & Cho, S. (2018). Magnitude processing and complex calculation is negatively impacted by mathematics anxiety while retrieval-based simple calculation is not. *International Journal of Psychology, 53*(4), 321–329. https://doi.org/10.1002/ijop.12412

Lucangeli, D. (1999). *Il farsi ed il disfarsi del numero: conoscenze, modelli e metodi a confronto. Borla*.

Lukowski, S. L., DiTrapani, J. B., Jeon, M., Wang, Z., Schenker, V. J., Doran, M. M., Hart, S. A., Mazzocco, M. M. M., Willcutt, E. G., Thompson, L. A., & Petrill, S. A. (2019). Multidimensionality in the measurement of math-specific anxiety and its

relationship with mathematical performance. *Learning and Individual Differences, 70*, 228–235. https://doi.org/10.1016/j.lindif.2016.07.007
Luttenberger, S., Wimmer, S., & Paechter, M. (2018). Spotlight on math anxiety. *Psychology Research and Behavior Management, 11*, 311–322. https://doi.org/10.2147/PRBM.S141421
Maloney, E. A., Waechter, S., Risko, E. F., & Fugelsang, J. A. (2012). Reducing the sex difference in math anxiety: The role of spatial processing ability. *Learning and Individual Differences, 22*(3), 380–384. https://doi.org/10.1016/j.lindif.2012.01.001
McCloskey, M., Caramazza, A., & Basili, A. (1985). Cognitive mechanisms in number processing and calculation: Evidence from dyscalculia. *Brain and Cognition, 4*(2), 171–196. https://doi.org/10.1016/0278-2626(85)90069-7
Owens, M., Stevenson, J., Norgate, R., & Hadwin, J. A. (2008). Processing efficiency theory in children: Working memory as a mediator between trait anxiety and academic performance. *Anxiety, Stress & Coping, 21*(4), 417–430. https://doi.org/10.1080/10615800701847823
Paechter, M., Macher, D., Martskvishvili, K., Wimmer, S., & Papousek, I. (2017). Mathematics anxiety and statistics anxiety. Shared but also unshared components and antagonistic contributions to performance in statistics. *Frontiers in Psychology, 8*, 1196. https://doi.org/10.3389/fpsyg.2017.01196
Passolunghi, M. C., De Vita, C., & Pellizzoni, S. (2020). Math anxiety and math achievement: The effects of emotional and math strategy training. *Developmental Science, 23*(6). https://doi.org/10.1111/desc.12964
Petronzi, D., Staples, P., Sheffield, D., Hunt, T. E., & Fitton-Wilde, S. (2018). Further development of the children's mathematics anxiety scale UK (CMAS-UK) for ages 4–7 years. *Educational Studies in Mathematics, 100*(3), 231–249. https://doi.org/10.1007/s10649-018-9860-1
Punaro, L., & Reeve, R. (2012). Relationships between 9-year-Olds' math and literacy worries and academic abilities. *Child Development Research, 2012*, 1–11. https://doi.org/10.1155/2012/359089
Rayner, V., Pitsolantis, N., & Osana, H. (2009). Mathematics anxiety in preservice teachers: Its relationship to their conceptual and procedural knowledge of fractions. *Mathematics Education Research Journal, 21*(3), 60–85. https://doi.org/10.1007/bf03217553
Richardson, F. C., & Suinn, R. M. (1972). The mathematics anxiety rating scale: Psychometric data. *Journal of Counseling Psychology, 19*(6), 551–554. https://doi.org/10.1037/h0033456
Ruffins, P. (2007). A real fear. *Diverse Issues in Higher Education, 24*(2), 17.
Saccani, M., & Cornoldi, C. (2005). Ansia per la matematica: la scala MARS-R per la valutazione e l'intervento metacognitivo. *Difficoltà in Matematica, 1*, 133–152.
Sandman, R. S. (1980). The mathematics attitude inventory: Instrument and user's manual. *Journal for Research in Mathematics Education, 11*(2). https://doi.org/10.2307/748906
Shi, Z., & Liu, P. (2016). Worrying thoughts limit working memory capacity in math anxiety. *PLoS One, 11*(10), Article e0165644. https://doi.org/10.1371/journal.pone.0165644
Sorvo, R., Koponen, T., Viholainen, H., Aro, T., Räikkönen, E., Peura, P., Dowker, A., & Aro, M. (2017). Math anxiety and its relationship with basic arithmetic skills among primary school children. *British Journal of Educational Psychology, 87*(3), 309–327. https://doi.org/10.1111/bjep.12151
Suinn, R. M., & Winston, E. H. (2016). The mathematics anxiety rating scale, a brief version: Psychometric data. *Psychological Reports, 92*(1), 167–173. https://doi.org/10.2466/pr0.2003.92.1.167
Szczygiel, M. (2020). Gender, general anxiety, math anxiety and math achievement in early school-age children. *Issues in Educational Research, 30*(3), 1126–1142.
van Eerde, W. (2003). A meta-analytically derived nomological network of procrastination. *Personality and Individual Differences, 35*(6), 1401–1418. https://doi.org/10.1016/s0191-8869(02)00358-6
Van Mier, H. I., Schleepen, T. M. J., & Van den Berg, F. C. G. (2018). Gender differences regarding the impact of math anxiety on arithmetic performance in second and fourth graders. *Frontiers in Psychology, 9*, 2690. https://doi.org/10.3389/fpsyg.2018.02690
Vitasari, P., Wahab, M. N. A., Othman, A., Herawan, T., & Sinnadurai, S. K. (2010). The relationship between study anxiety and academic performance among engineering students. *Procedia - Social and Behavioral Sciences, 8*, 490–497. https://doi.org/10.1016/j.sbspro.2010.12.067
Vukovic, R. K., Kieffer, M. J., Bailey, S. P., & Harari, R. R. (2013). Mathematics anxiety in young children: Concurrent and longitudinal associations with mathematical performance. *Contemporary Educational Psychology, 38*(1), 1–10. https://doi.org/10.1016/j.cedpsych.2012.09.001
Wigfield, A., & Meece, J. L. (1988). Math anxiety in elementary and secondary school students. *Journal of Educational Psychology, 80*(2), 210–216. https://doi.org/10.1037/0022-0663.80.2.210
Wu, S. S., Barth, M., Amin, H., Malcarne, V., & Menon, V. (2012). Math anxiety in second and third graders and its relation to mathematics achievement. *Frontiers in Psychology, 3*, 162. https://doi.org/10.3389/fpsyg.2012.00162
Zhang, J., Zhao, N., & Kong, Q. P. (2019). The relationship between math anxiety and math performance: A meta-analytic investigation. *Frontiers in Psychology, 10*, 1613. https://doi.org/10.3389/fpsyg.2019.01613