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Math anxiety and math performance in children: The mediating roles of working memory and math self-concept

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Background. Numerous studies, most of them involving adolescents and adults, have evidenced a moderate negative relationship between math anxiety and math performance. There are, however, a limited number of studies that have addressed the mechanisms underlying this relation.

Aims. This study aimed to investigate the role of two possible mediational mechanisms between math anxiety and math performance. Specifically, we sought to test the simultaneous mediating role of working memory and math self-concept.

Sample. A total of 167 children aged 8–12 years participated in this study.

Methods. Children completed a set of questionnaires used to assess math and trait anxiety, math self-concept as well as measures of math fluency and math problem-solving. Teachers were asked to rate each student's math achievement. As measures of working memory, two backward span tasks were administered to the children.

Results. A series of multiple mediation analyses were conducted. Results indicated that both mediators (working memory and math self-concept) contributed to explaining the relationship between math anxiety and math achievement.

Conclusions. Results suggest that working memory and self-concept could be worth considering when designing interventions aimed at helping students with math anxiety. Longitudinal designs could also be used to better understand the mediational mechanisms that may explain the relationship between math anxiety and math performance.

Many students show little interest in mathematics, have lower perceptions of their math skills, and consider mathematics a difficult subject that generates anxiety (Organization for Economic Cooperation and Development [OECD], 2014). Math anxiety has been 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). Thus, this type of anxiety emerges in specific math-related situations (for recent reviews, see Dowker, Sarkar, & Looi, 2016; Suárez-Pellicioni, Núñez-Peña, & Colomé, 2015).

Numerous studies, most of them involving adolescents and adults, have evidenced a moderate negative relationship between math anxiety and math performance (Ashcraft & Kirk, 2001; Hembree, 1990; Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998; Richardson

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& Suinn, 1972). This relation has been observed in complex tasks, including problem-solving, and even in basic math such as counting and simple addition (Ashcraft & Faust, 1994; Maloney, Risko, Ansari, & Fugelsang, 2010). A comparatively small but growing number of studies conducted on young children have revealed that math anxiety may be detected when children are in the early stages of math learning (Gierl & Bisanz, 1995; Harari, Vukovic, & Bailey, 2013; Krinzinger, Kaufmann, & Willmes, 2009; Ramirez, Gunderson, Levine, & Beilock, 2013; Vukovic, Kieffer, Bailey, & Harari, 2013; Young, Wu, & Menon, 2012). Although the detrimental effects of math anxiety on math performance may be present from the earliest years of schooling, this relationship seems less consistent than that observed in adults, perhaps due to the relatively limited body of research on children.

Even though the influence of anxiety on math performance has been consistently demonstrated, particularly among adolescents and adults (Hembree, 1990; Ma, 1999), the mechanisms underlying this relationship remain to be clarified. The attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007) and its precedent, the processing efficiency theory (Eysenck & Calvo, 1992), are two approaches to anxiety and cognition that account for how anxiety may influence performance. From these theories, worry generates distracting thoughts that reduce working memory (WM) capacity. Therefore, WM would likely mediate the relationship between math anxiety and math performance. In addition, these theories posit that anxious individuals may be motivated to compensate for the negative effects of anxiety on performance. They often put more effort into maintaining task performance provided they are motivated to overcome the effects of anxiety. Therefore, cognitive-motivational mechanisms may also mediate the relationship between anxiety and performance. This study aimed to investigate the role of two such possible mediational mechanisms. Specifically, we sought to test the simultaneous mediating effects of WM and self-concept on math ability. Given their different natures, they may, to some extent, operate independently.

Mediational mechanisms

Working memory

To date, WM has been the most studied mediator to account for the relationship between math anxiety and math performance. WM is a limited capacity system that holds information for a brief period of time while simultaneously manipulating it (Baddeley & Hitch, 1974). Numerous studies have shown that WM plays an important role in math performance (for a review, see Peng, Namkung, Barnes, & Sun, 2015). This is not surprising given that many math tasks require storage and simultaneous information processing.

According to the processing efficiency theory (Eysenck & Calvo, 1992) and its extension, the attentional control theory (Eysenck *et al.*, 2007), anxiety, and the associated worrying thoughts would reduce the storage and information processing capacity of WM. Thus, math-anxious students would have fewer resources available to correctly accomplish the tasks and, as a consequence, their performance would be negatively affected (Ashcraft & Krause, 2007; Eysenck & Calvo, 1992; Hopko *et al.*, 1998).

There are only a handful of studies that have tested the role of WM in the relationship between anxiety and math performance using a mediation approach (Ganley & Vasilyeva, 2014; Ng & Lee, 2015; Owens, Stevenson, Hadwin, & Norgate, 2012; Owens, Stevenson, Norgate, & Hadwin, 2008). Interestingly, these studies have considered trait anxiety rather than math anxiety, the former understood as a relatively stable characteristic in individuals reflecting a general proneness to anxiety experience. Thus, Owens *et al.* (2008) evidenced that verbal WM acted as a partial mediator between anxiety and scores in math and quantitative reasoning (Owens *et al.*, 2012). Ganley and Vasilyeva (2014) conducted two studies with college students and found that visuospatial WM mediated the relationship between the worry component of state anxiety and math performance. More recently, Ng and Lee (2015) observed that, in a sample of 11-year-olds, the effect of trait test anxiety on mental arithmetic accuracy was mediated by recall accuracy, although only under a high memory load condition. To summarize, the limited amount of evidence available concerning the mediating role of WM has been obtained using trait anxiety measures.

Self-concept

In addition to the cognitive factors, it is conceivable that math anxiety also influences performance through motivational mechanisms. Students with math anxiety tend to avoid math tasks, show less persistence when it comes to math-related tasks, and continue to have lower expectations about their own math performance (Ashcraft & Faust, 1994; Ma & Xu, 2004). Expectancy-value theory holds that individuals' choice, persistence, and performance can be explained in part by their own beliefs about how well they will do on the activity (Wigfield & Eccles, 2000). Hence, it could be argued that math anxiety may impair performance because individuals with negative self-concept about their math abilities are less likely to engage in math tasks. Conversely, anxious students with comparatively more positive self-concept may compensate for their impaired efficiency by making an extra effort. The idea that negative effects of anxiety on performance may be counteracted through increased effort is also taken into account by the attentional control theory (Eysenck & Derakshan, 2011; Eysenck *et al.*, 2007). As such, the second mediational mechanism considered in this study is math self-concept.

Although the relationship between anxiety and self-concept may be reciprocal, recent findings have shown that trait anxiety (Sowislo & Orth, 2013) and specifically math anxiety (Ahmed, Minnaert, Kuyper, & van der Werf, 2012) are antecedents of self-concept and self-esteem. Thus, math anxiety may promote negative self-concepts regarding math abilities (Ashcraft & Kirk, 2001; Wu, Barth, Amin, Malcarne, & Menon, 2012).

Self-concept in turn has been identified as an important antecedent for academic performance (Huang, 2011; Marsh, 1990; Marsh & Martin, 2011). Indeed, math self-concept has proven to influence academic achievement after controlling for previous math performance (Seaton, Parker, Marsh, Craven, & Yeung, 2014). Students with a poor self-image in the math domain may become less motived to perform, less willing to make subsequent efforts and carry the task through, and more prone to avoid math situations. The mediating role of self-concept between math anxiety and math performance may be inferred by combining findings from previous studies; however, to our knowledge, this has not been explicitly assessed.

The current study

This study aimed to determine whether WM together with math self-concept mediate the relationship between math anxiety and math performance. Models encompassing multiple mediators might better explain the link between variables than those considering a single mediator (Hayes, 2013; MacKinnon, Fairchild, & Fritz, 2007). To our knowledge, this study is the first to analyse the simultaneous role of both possible mediators.

Different outcomes of math performance were included in this study given that previous research has shown different patterns of relationship between math anxiety and math performance depending on the math domain assessed. For example, Krinzinger *et al.* (2009) did not find relations between calculation ability and math anxiety using a longitudinal design where first- to third-grade children were tested four times. Similarly, Hill *et al.* (2016) failed to observe a relationship between math anxiety and arithmetical ability in children from third to fifth grade. Other researchers have found math anxiety to mainly be related to tasks that involve comprehension and numerical processing (Wu *et al.*, 2012). Nonetheless, some studies have reported consistent relationships between math anxiety and performance on both simple and complex math tasks (Harari *et al.*, 2013; Vukovic *et al.*, 2013). Given the variability of results across studies, we used different outcomes of math performance. Thus, we assessed math fluency that involves the automatic recall of basic math facts and math problem-solving that requires a more controlled processing and the ability to reason mathematically. We also obtained an overall teacher assessment on students' math achievement.

Two measures of anxiety were used: trait and math anxiety. It can be assumed that they are different yet related constructs (Artemenko, Daroczy, & Nuerk, 2015). The meta-analysis performed by Hembree (1990) showed that the mean correlation between both types of anxiety was .35. Indeed, it is possible that dispositional forms of anxiety may influence or even be a predisposing genetic factor of other more specific types of anxiety such as math anxiety (Wang *et al.*, 2014). As with math anxiety, some studies have found trait anxiety to be negatively related to math performance (Owens *et al.*, 2008, 2012). Nevertheless, there is evidence to indicate that trait and math anxiety may relate differently to math performance. Thus, some recent studies have reported the absence of a relationship between trait anxiety informed by parents and children's math performance (Wu *et al.*, 2012), and it has also been found that math anxiety is related to math performance after controlling for more dispositional forms of anxiety such as general or trait anxiety (Hill *et al.*, 2016; Mammarella, Hill, Devine, Caviola, & Szűcs, 2015; Wu *et al.*, 2012). Hence, not all studies reveal the same pattern of relationship between the different types of anxiety and math performance.

An initial goal was to assess both types of anxiety (math and trait) in order to compare their possible relationship with different measures of math performance. As a second goal, it was deemed relevant to determine whether WM and self-concept mediate the possible relationship between both types of anxiety and math performance. It is worth noting that the limited body of research available on the mediating role of WM has assessed trait anxiety rather than math anxiety (Owens *et al.*, 2008, 2012). Therefore, regarding the role of WM, it was important to replicate previous results obtained for trait anxiety and to extend them to the case of math anxiety.

Method

Participants

A total of 167 third and fifth graders aged 8–12 years (81 boys and 86 girls) participated in this study. The children's mean age was 9.44 (SD = 1.10). Written informed consent was obtained from their parents. The children assented to complete the tasks once they had been explained. Three children were not tested during the second session because they were absent the day the tasks were administered. Two children were not rated on their math achievement by their teacher.

Materials

The following tasks and questionnaires were administered to all participants:

Math performance

Math fluency. Arithmetical ability was assessed using a subtest of the Woodcock–Muñoz III Tests of Achievement (Muñoz-Sandoval, Woodcock, McGrew, & Mather, 2005). The subtest Math Fluency measures the ability to solve simple addition, subtraction, and multiplication problems quickly. The subtest takes three minutes to complete. The reliability coefficients reported in the manual range from .94 to .97 for the ages included in this study.

Math problem-solving. To assess problem-solving abilities, the Differential and General Aptitude Test Battery (BADyG; Yuste, 2006) was used. This subtest measures the ability to solve math problems requiring single or multiple steps. A series of 24 problems are verbally presented to the child. Subtest completion time is 10 min. The reliability coefficient reported in the manual for this subtest is .88.

Math teacher assessment. Teachers were asked to rate each student's math achievement on a scale of 0–10.

Anxiety

Math anxiety. The Abbreviated Math Anxiety Scale (AMAS; Hopko, Mahadevan, Bare, & Hunt, 2003) was used. This is a short scale comprising nine items that assess anxiety in math-related academic situations (e.g., Being given an assignment of many difficult math exercises due the next class meeting). Responses are given on a 5-point Likert scale (1 = *low anxiety*; 5 = *high anxiety*). Scores on the AMAS range from 9 to 45, with a higher score being indicative of greater math anxiety. The AMAS has shown psychometric qualities comparable to the longer original scale (MARS; Hopko, 2003). The Cronbach's alpha for this study was $\alpha = .680$.

Trait anxiety. Trait anxiety was assessed using the State-Trait Anxiety Inventory for Children (STAIC; Spielberger, Edwards, Lushene, Montuori, & Platzek, 1973). The scale consists of two 20-item scales, the first measuring the current level of anxiety (state) and the other assessing the typical level of anxiety (trait). For the purpose of this study, the second scale was used. The trait anxiety scale uses a 3-point Likert scale (1 = *almost never*; 2 = *sometimes*; 3 = *often*), where higher scores indicate greater anxiety (e.g., I worry about making mistakes). The Cronbach's alpha for this study was $\alpha = .833$.

Math self-concept
Math self-concept was measured using the Self Description Questionnaire (SDQ I; Marsh, 1992). This assesses self-perceptions relative to four non-academic and three academic areas, as well as the overall perception of self. For the purpose of this study, students rated their skill, ability, enjoyment, and interest in the math domain (e.g., I get good marks in mathematics; I learn things quickly in mathematics; I like mathematics; I am interested in mathematics). The Cronbach's alpha for this study was $\alpha = .980$.

Working memory
Digit span. In the digit span backward task, the children heard digit sequences of increasing span size through headphones and they had to recall these sequences in the reverse order of presentation. Digits were presented at a rate of one digit per second. The length of the sequence started with two digits and went up to a maximum of nine digits. Each span level included two lists. The task was discontinued when the child failed in two consecutive lists. The dependent measure was the span of the largest sequence in the reverse order of presentation for each trial. The maximum score for each task was 14 points.

Word span. In this task, sequences comprising two-syllable high frequency words were presented auditorily at a rate of one word per second. Children had to recall the words in reverse order. Sequence length increased from two to eight words. Two trials were presented for each span. The task was discontinued when the child failed in two consecutive lists. The dependent measure was the highest span of words correctly recalled. The word span task was identical to the digit span task in terms of procedure and scoring.

A composite of scores obtained in the two span tasks served as the WM measure.

Procedure
The tasks were administered across two sessions. In the first session, which lasted approximately 50 min, math anxiety, trait anxiety, self-concept, and math achievement measures were group administered in this order. In the second session, the digit span and word span tasks, following this order, were administered individually in a quiet room. This session lasted around 15 min.

Results
Preliminary analyses
Prior to conducting the main analysis of interest, a one-way analysis of variance was performed to determine whether grade level would lead to differences in math outcomes (math fluency, problem-solving, and math teacher assessment). A grade effect was observed for math fluency, $F(1, 165) = 107.43, p < .001, \eta_p^2 = .39$. Third graders showed lower performance (48.18) than their fifth-grade peers (73.23). A similar grade effect was also found for problem-solving, $F(1, 165) = 55.66$, $p < .001$, $\eta_p^2 = .25$. Fifth graders (17.27) outperformed third-grade children (11.70). There were no differences in math teacher assessment across each grade level ($p > .14$). Given the grade-related differences

in math outcomes, scores on the different variables were standardized by grade level in the subsequent analyses.

Pearson correlation coefficients were calculated to assess the relationships among the variables considered in this study. These results, including means and standard deviations, are shown in Table 1. Math anxiety was moderately related to trait anxiety and negatively associated with math performance. Trait anxiety was also negatively associated with math performance variables. The different measures of anxiety were moderately correlated with WM scores and math self-concept in the expected directions. Math self-concept was specifically related to math performance.

Hierarchical regression analyses

A first aim of this study was to determine the relationship of each measure of anxiety with the different math outcomes. In order to identify the relative contribution of each type of anxiety to the different math outcomes, two-step hierarchical multiple regression analyses were performed in which both anxiety measures were entered as predictors. In the first set, math anxiety was entered first followed by trait anxiety. In the second set, the predictors were entered in reverse order (Table 2).

As can be observed in Table 2, there was no increase in the amount of explained variance when math anxiety was entered first and trait anxiety second (models 1a, 2a, 3a). In contrast, the amount of explained variance for each dependent variable increased significantly when the order was reversed (models 1b, 2b, 3b). Thus, math anxiety accounted for an additional 3–5% of explained variance in math fluency, problem-solving, and math teacher assessment. In other words, math anxiety predicted math outcomes above and beyond trait anxiety.

Mediation analyses

Given the pattern of correlations observed and the results of the hierarchical regression analyses, a set of multiple mediation analyses was conducted to test the hypothesis that the association between anxiety and math performance is mediated by both WM and math self-concept simultaneously. Mediators were not expected to be related, and, in fact, the correlation between WM and math self-concept was not significant. Therefore, we considered six parallel multiple mediation models (see Figure 1, for the general model).

Table 1. Means, standard deviations, and Pearson correlations between study variables

Measures	*M*	*SD*	1	2	3	4	5	6
1. Math fluency	60.18	19.99	–					
2. Problem-solving	14.37	5.56	.60**	–				
3. Math teacher assessment	7.06	1.89	.36**	.45**	–			
4. Working memory	3.19	1.11	.38**	.40**	.33**	–		
5. Math self-concept	38.77	10.10	.13	.24**	.48**	.03	–	
6. Math anxiety	17.77	5.30	−.26**	−.27**	−.27**	−.23**	−.27**	–
7. Trait anxiety	34.25	7.18	−.16*	−.14	−.19*	−.24**	−.21**	.46**

Notes. $N = 167$ (Teacher assessment, $N = 165$; Working memory, $N = 164$).
Correlations were calculated using z-scores for each grade level.
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

Table 2. Regression analyses predicting math performance by math anxiety and trait anxiety

	R^2	*SE*	$\triangle R^2$	*F*	*gl*	*p*
Model 1a: Math Fluency						
Step 1: Math anxiety	.05	.97	.05	9.42	1, 165	.003
Step 2: Trait anxiety	.05	.97	.00	0.10	1, 164	.744
Model 1b: Math fluency						
Step 1: Trait anxiety	.01	.99	.01	2.75	1, 165	.099
Step 2: Math anxiety	.05	.97	.03	6.63	1, 164	.011
Model 2a: Problem-solving						
Step 1: Math anxiety	.05	.97	.05	9.00	1, 165	.003
Step 2: Trait anxiety	.05	.97	.00	0.01	1, 164	.928
Model 2b: Problem-solving						
Step 1: Trait anxiety	.01	.99	.01	2.01	1, 165	.158
Step 2: Math anxiety	.05	.97	.04	6.86	1, 164	.010
Model 3a: Teacher assessment						
Step 1: Math anxiety	.08	.95	.08	15.87	1, 163	.000
Step 2: Trait anxiety	.09	.95	.01	0.93	1, 162	.336
Model 3b: Teacher assessment						
Step 1: Trait anxiety	.04	.97	.04	7.31	1, 163	.008
Step 2: Math anxiety	.09	.95	.05	9.12	1, 162	.003

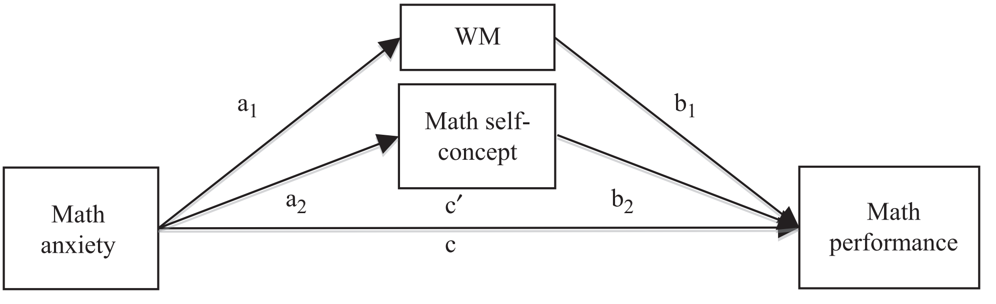

Figure 1. Hypothesized mediation model for the relationship between math anxiety and math performance.

These different models derived from the combination of two types of anxiety (math anxiety and trait anxiety) and three math outcomes (math fluency, problem-solving, and math teacher assessment).

Each of the six models required three regression equations to estimate the effect of anxiety on math performance. These general equations were:

$$\text{WM} = \beta_1 + a_1(\text{Anxiety}) + e_1, \tag{1}$$

$$\text{Math Self-Concept} = \beta_2 + a_2(\text{Anxiety}) + e_2, \tag{2}$$

$$\text{Math Performance} = \beta_3 + c'(\text{Anxiety}) + b_1(\text{WM}) + b_2(\text{Math Self-Concept}) + e_3. \tag{3}$$

It should be noted that the first two regression equations estimated the effect of anxiety on both mediators. The third regression equation estimated the direct effect of anxiety and the mediators on math performance.

The specific indirect effect of anxiety on math performance through WM was the product $a_1 \times b_1$, whereas the specific indirect effect of anxiety on math performance through math self-concept was $a_2 \times b_2$. Subsequently, the total indirect effect was the sum of the previous indirect effects ($a_1 \times b_1 + a_2 \times b_2$). The direct effect c' quantified the effect of anxiety on math performance that was independent of the indirect effects. Therefore, c' was equivalent to subtracting the total indirect effect from the total effect of anxiety on math performance (c). The total effect c was the relationship between anxiety and math performance without taking into account any indirect effect.

The method outlined by Baron and Kenny (1986) and Preacher and Hayes (2008) was followed to estimate the direct and indirect effects. Bootstrapping with 5,000 bootstrap samples was used to construct 95% confidence intervals for indirect effects. All analyses were run in SPSS version 19.0 using Model 4 of the PROCESS macro (Hayes, 2013).

Results for the three mediation models with math anxiety as the predictor variable are presented in Table 3. The results remained similar using 99% confidence intervals. The effects of math anxiety on math self-concept and WM (paths a) were significant across all models. Equally, the effects of WM and math self-concept on math scores were significant for each math outcome (paths b).[1] The total effects of math anxiety on each of the three math outcomes that were initially significant (path c) became non-significant when the mediator variables were considered (path c'), providing support for the proposed models.

A somewhat less consistent pattern of results to that described for math anxiety was obtained for mediation models including trait anxiety (Table 4). Only the total effect of trait anxiety on teacher assessment reached significance. This relationship was fully mediated by self-concept and WM. In contrast, the total effects of trait anxiety both on problem-solving and math fluency measures were not significant.[2]

Discussion

This study aimed to examine the possible mediating role of WM and math self-concept in the relationship between math anxiety and math performance among school-age children.

The first objective was to determine the relationship between trait and math anxiety with math performance in primary school children. As expected, children who showed higher levels of math anxiety tended to also show increased trait anxiety. Although both measures of anxiety were related to teacher assessment on students' math achievement, the hierarchical regression analyses showed that math anxiety explained a greater amount of variance in performance scores as opposed to trait anxiety. The mediation analyses are in line with the regression results. Most of the effects of math anxiety on math

[1] *The same set analyses were run for each WM measure (i.e., word span and digit span) separately. Results were similar to those reported with one exception: path b_1 from WM (word span) to math fluency turned out to be non-significant for both predictors (math and trait anxiety). All other WM indirect effects were largely similar to those presented with the composite WM measure. This suggests that the anxiety effects on WM are not due to the numerical features of the stimuli.*

[2] *It was deemed important to determine whether WM and self-concept mediate the relationship between math anxiety and math outcomes after controlling for trait anxiety. Therefore, an additional set of analyses were performed including math anxiety as a predictor and trait anxiety as covariate. A caveat with these analyses, however, is that when the covariate and the predictor are moderately correlated as in the present case, $r(165) = .46$, $p < .001$, both variables may cancel out each other's influence (cf., Hayes, 2013, p. 195). As a result, the significance of these effects may be underestimated. In any case, although the covariate effect of trait anxiety did not reach significance ($p = .238$), its inclusion in the model rendered path a_1 (math anxiety to WM) non-significant ($p < .088$). All other paths (a_2, b_1 and b_2) remained significant across all models ($p < .01$). On the other hand, the set of analyses with trait anxiety as predictor and math anxiety as covariate showed that none of the mediators (WM or self-concept) reached significance.*

Table 3. Direct and indirect effects of math anxiety (AMAS) on math performance

Outcome	Mediator	Effects of MA on mediators (paths a_1 & a_2)	Effects of mediators on outcomes (paths b_1 & b_2)	Indirect effect ($a_1 \times b_1$ & $a_2 \times b_2$)	95% CI	Direct effect (path c')	Total effect (path c)	R^2
Math fluency	WM	−.21**	.24***	−.05	−0.11, −0.01	−.12 ns	−.26***	.18***
	Math self-concept	−.34***	.25***	−.08	−0.17, −0.03			
Problem-solving	WM	−.21**	.29***	−.06	−0.12, −0.02	−.07 ns	−.25**	.25***
	Math self-concept	−.34***	.34***	−.11	−0.20, −0.05			
Teacher assessment	WM	−.22**	.31***	−.07	−0.13, −0.02	−.11 ns	−.32***	.32***
	Math self-concept	−.36***	.39***	−.14	−0.23, −0.07			

Notes. This table summarizes three mediation analyses with different outcome measures (math fluency, problem-solving, and teacher assessment) but the same predictor (math anxiety) and mediators (self-concept and WM).
CI, confidence interval; MA, math anxiety; WM, working memory.
*$p < .05$; **$p < .01$; ***$p < .001$.

Table 4. Direct and indirect effects of trait anxiety (STAIC) on math performance

Outcome	Mediator	Effects of TA on mediators (paths a_1 & a_2)	Effects of mediators on outcomes (paths b_1 & b_2)	Indirect effect ($a_1 \times b_1$ & $a_2 \times b_2$)	95% CI	Direct effect (path c')	Total effect (path c)	R^2
Math fluency	WM	−.20**	.26***	−.05	−0.13, −0.01	.01 ns	−.12 ns	.17***
	Math self-concept	−.24**	.29***	−.07	−0.13, −0.02			
Problem-solving	WM	−.20**	.31***	−.06	−0.13, −0.02	.04 ns	−.10 ns	.25***
	Math self-concept	−.24**	.38***	−.09	−0.17, −0.04			
Teacher assessment	WM	−.20**	.32***	−.06	−0.13, −0.02	−.03 ns	−.20**	.32***
	Math self-concept	−.24**	.42***	−.09	−0.17, −0.04			

Notes. This table summarizes three mediation analyses with different outcome measures (math fluency, problem-solving, and teacher assessment) but the same predictor (trait anxiety) and mediators (self-concept and WM).
CI, confidence interval; TA, Trait anxiety; WM, working memory.
$*p < .05$; $**p < .01$; $***p < .001$.

performance remained significant when trait anxiety was included as covariate; however, no analyses were significant with trait anxiety as predictor and math anxiety as covariate.[2] Thus, math anxiety predicted math outcomes above and beyond trait anxiety.

It has been proposed that children's poor performance in math could be more related to an overall anxiety response pattern rather than to a specific type of anxiety such as math anxiety (Baloglu & Koçak, 2006; Hembree, 1990; Hill *et al.*, 2016; but see Wu *et al.*, 2012). This effect may become more specific, leading to math anxiety as children have experiences in the math domain. Thus, children with high levels of anxiety in general would be more likely to develop math anxiety. Once this type of anxiety appears, it could become a better predictor of math performance. Further research assessing younger children on different types of anxiety could investigate this possibility.

The main goal of this study was to determine the specific contribution of cognitive and cognitive-motivational factors to the relationship between math anxiety and math outcomes. To this end, the mediating role of WM and math self-concept was assessed. Results indicated that both variables mediated the relationship between anxiety and math performance.

Regarding the first mechanism, the current results show that WM mediated the relationship between math anxiety and different math outcomes such as math fluency, problem-solving, and teacher-graded math achievement. This pattern was evidenced in the case of trait anxiety for the teacher assessment measure, replicating previous findings (Ng & Lee, 2015; Owens *et al.*, 2008, 2012) and, most importantly, was extended to the case of math anxiety.

These results are consistent with the processing efficiency theory and its extension, the attentional control theory (Ashcraft & Kirk, 2001; Eysenck & Calvo, 1992; Hopko *et al.*, 1998). According to these approaches, children with higher levels of anxiety would display more worrying thoughts which, in turn, would detract some of the WM resources necessary to successfully perform the tasks. Consequently, performance might be negatively affected and anxious individuals would end up needing to increase their cognitive effort in order to compensate for their fewer resources (Artemenko *et al.*, 2015). Paradoxically, these students might not be willing to put in the extra effort required under certain circumstances (Ashcraft & Moore, 2009). For instance, depending on their expectations about the likely outcome, they may or may not strive to improve their performance (Wigfield & Eccles, 2000). Thus, motivational factors could also be involved in the relationship between math anxiety and math performance. Findings obtained with self-concept as a mediator are in line with this interpretation.

The current results provide evidence that math self-concept plays a role as a mediational mechanism in the relationship between both types of anxiety and children's math performance. This pattern was more evident for math anxiety than for trait anxiety. Whereas math self-concept mediated the relationship between math anxiety and all math performance measures, in the case of trait anxiety math self-concept only mediated the relationship between math fluency and math teacher assessment.

The results suggest that high-anxious children may believe that they lack the necessary skills to tackle math tasks. These low expectations for success may in turn lead to task avoidance or, in the case of trying, less effort and lower persistence. For example, students rush through the tasks to escape from the unpleasant situation as soon as possible. Therefore, in part as a self-fulfilling prophecy, their performance would be ultimately affected. This is in line with previous findings that reveal how competence beliefs have an influence on effort in mathematics (Chouinard, Karsenti, & Roy, 2007). Students who are less confident in their own abilities and have low self-efficacy may tend to engage less in the learning process and work less during tests (Zimmerman, 2000). To summarize, the relationship between math anxiety and self-concept appears to be consistent with the idea that math anxiety and worrying thoughts are likely to undermine self-concept. A lower self-concept would lead to less adaptive ways of performing math tasks which would be reflected in lower performance.

Cognitive and emotional mechanisms similar to those analysed in this study may not be exclusive to math anxiety; they may also play a role in other phenomena. For instance, Maloney, Schaeffer, and Beilock (2013) have argued that math anxiety and stereotype threat share the same underlying mechanisms. Research on stereotype threat has shown that the introduction of a negative stereotype in a particular domain impairs group members' performance, reduces effective WM capacity, and induces low self-concept and self-esteem (Steele, 1997; Beilock, Rydell, & McConnell, 2007; but see Flore & Wicherts, 2014; Ganley *et al.*, 2013, for recent concerns about the replicability of these studies).

This study's findings not only offer suggestions for future research, but may also have potential implications for educational practice. Results suggest that WM and self-concept are mediators worth considering when designing interventions aimed at helping students with math anxiety. A recent study has provided some preliminary evidence that WM training can induce positive changes in self-reported symptoms of trait and test anxiety (Hadwin & Richards, 2016). A more positive math self-concept may lead children to persist with the math task longer or help them better deal with negative feedback (Marsh & Craven, 2006). O'Mara, Marsh, Craven, and Debus (2006) performed a meta-analysis which revealed that relatively simple interventions based on an appropriate use of praise and feedback may be effective in enhancing students' self-concept. Recently, Núñez-Peña, Bono, and Suárez-Pellicioni (2015) developed a programme focused on giving feedback to university students about the mistakes they made in statistical exercises. One of the aims was to increase the students' self-confidence. Their results suggest that giving feedback reduces the negative impact of math anxiety. Although these findings are suggestive, interventions designed to change the mediating factors would provide unequivocal evidence about the causal relationships hypothesized (MacKinnon *et al.*, 2007).

Some limitations should be taken into account when interpreting the present results. Mediation analysis relies on correlational procedures and, as such, causal relations cannot be established. In fact, the relationships considered should, in all probability, be bidirectional. For instance, as regards the relation between math self-concept and math anxiety, Ahmed *et al.* (2012) found a reciprocal relationship between both constructs using a longitudinal design. This is consistent with previous findings and prevalent ideas about this relation (Cooper & Robinson, 1991; Meece, Wigfield, & Eccles, 1990). Experimental and longitudinal studies are needed to accurately determine the direction of the links between the different variables involved.

To summarize, this study aimed to better understand the relationship between math anxiety and math performance in primary school children. A novel contribution has been to analyse the simultaneous mediating role of both WM and self-concept. Recent research has also addressed the role of other significant variables such as metacognition (Lai, Zhu, Chen, & Li, 2015). Research in this field should investigate further the involvement of various mediators, using longitudinal designs which make it possible to identify the directions of the relationships between the various factors involved as well as their relative influence.

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