Social Psychology of Education
https://doi.org/10.1007/s11218-023-09854-3

Mathematics self-concept moderates the relation between cognitive functions and mathematical skills in primary school children

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Received: 4 January 2023 / Accepted: 6 October 2023

Abstract

In this paper, we investigated the contribution of both cognitive and affective factors to mathematical skills. In particular, we looked at the protective role of self-concept for mathematical learning and performance. In a field study, we tested the relation of math self-concept and short-term visuo-spatial working memory to the mathematical abilities of second- grade primary school children in Italy ($N = 105$). Measures included the "Test for the evaluation of calculating and problem-solving abilities" (AC-MT 6–11), the backward Corsi blocks test (Battery for Visuo-Spatial Memory), and the mathematics self-concept sub-scale of the Self-Description Questionnaire-I (SDQ-I, Italian version). As expected, correlation and moderated regression analyses showed that mathematics self-concept and working memory both positively predict mathematical operations and numeracy, but not accuracy. Simple slope analysis confirmed our moderation hypothesis, with working memory predicting mathematical abilities at low levels of math self-concept, but not at medium and high levels. The theoretical and practical implications are discussed.

Keywords Mathematical skills · Self-concept · Working memory · Primary school students

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Published online: 26 October 2023

1 Introduction

Mathematics is a key competence acquired at school that helps students access relevant scientific knowledge and academic and professional skills (Gravemeijer et al., 2017). A large literature shows how cognitive abilities are related to academic achievement in mathematics and the important role of executive functions in mathematic performances. In particular, working memory plays a role in a series of mathematical skills (Peng et al., 2016). Furthermore, studies that focused on the variables involved in dyscalculia and other specific learning disorders showed that emotional and affective factors are important features of the disorder (Devine et al., 2017). This contributes to a vicious circle of avoiding academic activities implying mathematical reasoning to avoid negative feelings of incompetence and inefficacy, and therefore reducing the opportunities to learn and improve.

Also, we argue here that motivational variables and their social correlates such as the development of the self-concept, can be used to explain correlations between cognitive factors, such as working memory and academic performance. Some arguments in support of this idea could be found, for example, in important theories like Cognitive Load Theory (Sweller & Chandler, 1991) as motivational factors may modify the cognitive structure of the learner in the interaction with learning activities and content (Schnotz et al., 2009). Indeed, the process through which people define themselves and their identity, both at the individual and collective level, can also be mentioned as a fundamental aspect in human adaptation to the social context and human social behavior. As such, self-definition processes have often been related to human motivation and performances in a variety of daily life domains, including academic and school achievement, as well as widely known psychological concepts such as Bandura's (1997) self-efficacy, or Ajzen's (1991) perceived behavioral control can also be mentioned in this process.

Thus, in this paper, we aim to investigate the contribution of both cognitive and affective factors on mathematical skills, looking at the protective role of self-concept for mathematical learning and performance. In the following sections, we discuss the relation between mathematical skills and working memory and between self-concept and academic performance.

2 Working memory and mathematics

Working memory (WM) is referred to as the ability to process and store relevant information to perform a task (Baddeley, 1992). According to a multicomponent model, WM implicates different components related to the processing of visuospatial and phonological stimuli (Baddeley & Hitch, 1974). The involvement of the subcomponents of the WM in mathematical tasks is required by the demand of simultaneous information processing and storage (Peng et al., 2016; Van de Weijer-Bergsma et al., 2015; Van Der Ven et al., 2013). In particular, consistent with a domain specific theory of WM, earlier studies found that the numerical and visuospatial domains of WM specifically may be associated with the performance on numeracy and calculation mathematical tasks (Andersson & Lyxell, 2007; Nosworthy et al., 2013). However, a meta-analysis by Peng et al. (2016) found different results, showing that WM also is linked to mathematical performance, in addition to specific domains of WM (visuo-spatial, verbal, numerical). This association is moderated by the type of mathematical skills examined, because of the differentiated cognitive load demanded, and by the sample investigated.

Verbal and spatial components of WM may have a differential impact on different mathematical skills: tasks requiring the articulation of numerical words (e.g. counting) are solved with an important contribution of verbal WM, while tasks requiring use of the number line and mathematical equations need the spatial WM component (Geary, 2011). Therefore, it is important to measure the relationship between WM and mathematics by taking in consideration the specific types of mathematical abilities.

For example, age plays an important role in the relationship between WM and mathematics (Soltanlou et al., 2015; Van de Weijer-Bergsma et al., 2015). Although WM is linked with mathematical skills at any age from preschool onwards (Friso-Van Den Bos et al., 2013), the type of WM involved varies as the specific mathematical tasks change, and these in turn, vary across age (Friso-Van Den Bos et al., 2013; Schneider, 2008). Also, different WM components may be linked to different mathematical task achievement (Pina et al., 2014). Age has been found to moderate this relation as well: visuospatial working memory plays a greater role in mathematics in younger ages (Caviola et al., 2014; Clearman et al., 2017) and coherently contributes greatly to dyscalculia (Mammarella et al., 2018), while verbal working memory is more important in older children. An exception to these findings is the study by Allen et al. (2020), who found a greater contribution of verbal WM to mathematical (written) tasks in younger students in primary school (years 2 to 4) and of visuospatial WM for older students (year 5). The cognitive load required by tasks relevant to assessing mathematical skills in students with increasing mathematical learning experience may assign a different role to these components of WM to perform the tasks. Moreover, there is evidence that WM becomes a solid predictor of mathematics achievement during formal mathematics education, while in earlier years more specific indicators (e.g. approximate number system acuity) may better predict children's mathematical achievement (Fanari et al., 2019; Gimbert et al., 2019).

Furthermore, it has been found that the effect of WM on academic achievement may be mediated by other cognitive factors (e.g., intelligence) and non-cognitive factors (e.g., student–teacher relationship or self-concept; Giofrè et al., 2017) as well. However, despite considerable evidence that WM influences academic achievement along with other factors (e.g., self-concept), there is still a literature gap regarding the study of how these variables (cognitive and non-cognitive) operate together in students' mathematical abilities. To our knowledge, only one study tested the joint impact of working memory and self-concept (e.g. self-esteem) on mathematics performance (Semeraro et al., 2020), showing that students' self-concepts play a role in the mathematical achievement, regardless of their cognitive abilities.

3 Self-concept and mathematics achievement

We can define academic self-concept as a *"mental representations of one's abilities in academic domains and school subjects"* (Brunner et al., 2010, p. 964). Self-concept is an extremely important construct, affecting psychological and behavioral outcomes and overall wellbeing of students. Several studies have shown that academic self-concept is related positively to students' academic achievement (Dresel et al., 2010; Lauermann et al., 2019; Lotz et al., 2018). A recent meta-analysis by Möller et al. (2020) shows a positive relationship between self-concept and academic achievement. Self-concept positively correlates with achievement only within the same school subject, highlighting the importance of investigating its specific domains. For mathematics in particular, self-concept is a strong predictor of students' grades (Lotz et al., 2018; Vicente et al., 2019). This relationship is not unidirectional, but rather mutual (Arens et al., 2017): in fact, self-concept can be both an outcome of prior, and a predictor of later, academic achievement (Huang, 2011). Furthermore, self-concept also is linked to learning attitudes and academic performance (Chamorro-Premuzic et al., 2010). For example, the influence of ability self-concept on performance could be explained by its impact on mathematics achievement-related attitudes (Hall & Suurtamm, 2020; Möller et al., 2020; Turgut & Turgut, 2020), which are affected by other cognitive processes (e.g., intelligence; Lotz et al., 2018). Therefore, it is plausible that other factors may intervene in this relationship and that, specifically, self-concept might influence other cognitive processes—such as working memory—while pursuing academic mathematical tasks.

Math self-concept refers to students' perceptions or beliefs about how they see themselves in the specific academic domain of mathematics (Bong & Skaalvik, 2003). It is often argued that math self-concept may be intertwined to students' mathematical achievement (Arens et al., 2017; Marsh & Martin, 2011; Möller et al., 2011; Pinxten et al., 2014). Poor achievement in math may lower the students' math self-concept. In turn, students with low math self-concept may be less motivated to perform, less willing to make efforts and accomplish tasks, and will tend to avoid mathematical situations. However, in addition to this circular relationship, math self-concept also can be a mediator in the relationships between math-related emotions (e.g., anxiety) and performance (e.g., Justicia-Galiano et al., 2017). For example, Pinxten et al. (2014) found that competence beliefs mediated the relationship between math enjoyment and achievement. Goetz et al. (2008) also found a mediating role of self-concept in the relationship between mathematics' achievement and consequent enjoyment: achievement in mathematics had positive effects on math self-concept and, subsequently, math self-concept was positively associated with enjoyment of mathematics. Van der Beek et al. (2017) found that math self-concept had significant indirect effects on both enjoyment and anxiety in mathematics, showing that higher mathematics self-concept contributed to more enjoyment and less anxiety in mathematics.

4 The relations between cognitive abilities, performance and motivational factors

Although research found direct relationships between cognitive skills and mathematical achievement and between self-concept and learning achievement, theories and empirical evidence also suggest that motivational factors and self-concept, may moderate the relationship between cognitive abilities and students' performance (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000).

Motivational aspects developed by individuals in cognitively demanding activities, such as performance expectation, have been shown to influence cognitive performance by older adults facing cognitive decline (Vallet et al., 2020). These motivational factors influence cognitive performance by increasing cognitive reserve, the possibility of optimizing the use of cognitive abilities and adopt better cognitive strategies, to achieve better performance. For example, studies of older adults showed that the motivational factor of perceived capacity mediates the relation between cognitive reserve and cognitive performance (Vallet et al., 2020). Evidence supporting a multiplicative model of the relations between motivational factors and cognitive performance has been accumulated in several studies considering mid-level specificity measures, corresponding to context-specific achievement motivation (in contrast with general trait and with task-specific factors). This approach could help confirm the hypothesis that the relationship between cognitive abilities and cognitive performance is stronger for higher levels of motivation (Hirschfeld et al., 2004; Van Iddekinge et al., 2018). Such hypotheses have been tested on a variety of cognitive abilities and with several motivational factors (e.g. self-efficacy, performance expectations, intrinsic motivations) with mixed results. An ability-motivation interaction could be found in several studies of adults and provides the bases for well-established theories, even if other studies indicate that the ability-motivation interaction provides a very small contribution to the prediction of performance compared to additive effects of ability and motivation. Also, differences in the results may depend on the choice of measuring trait *vs.* state motivation and about how ability and performance were measured (Van Iddekinge et al., 2018).

Few studies investigated the different factors that explain the effect of self-concept on academic achievement and even fewer considered the role of working memory in this link in children. Previous studies indeed found that beliefs in one's ability may counterbalance the effects of low WM in scientific domains (Hoffman & Schraw, 2009). However, a deeper understanding of the interrelation between these two variables and their effect on academic achievement still is missing. The present study aims to investigate the relationship between ability motivation and performance using a direct measure of performance and selecting specific-domain self-concept as motivational factor.

5 Aims and hypothesis

Given the relationship between WM and mathematical achievement, and the relationship between math self-concept and achievement, the purpose of this study is to investigate whether the relationship between WM (i.e., visuo-spatial short-term memory) and mathematical abilities (operations, numeracy, accuracy) can be moderated by math self-concept.

We expect a positive relationship between working memory and mathematical abilities and between mathematical abilities and math self-concept. Furthermore, we expect that a higher math self-concept buffers the effect of lower memory skills on mathematics abilities.

6 Method

6.1 Procedure

Three primary schools in the Latina province (central Italy) were contacted for the study as part of a screening and teachers' training intervention project. A preliminary briefing with school-heads and teachers was organized to explain the purposes of the study, prior to the data collection; periodic meetings were held to inform the stakeholder during the course of the study. Before testing children, informed consent of the parents was obtained with the help of the teachers. All procedures and ethical implications of the study were examined and ethically approved by the institutional bodies of the schools involved and by the school principal offices.

In the Italian school system, compulsory education begins in primary school when children are about 6-years-old, the classes are homogeneous by age. The students attend a school primarily based on their area of residence, and for the five years of primary school, they are in the same group of students with a stable group of teachers. The school is completely inclusive, meaning that children with disabilities or other types of SEN are included the entire time and for all the activities in mainstreamed classes. When children with severe disabilities are included in a class, an extra teacher could be assigned to supplement the teachers and to support the teaching and learning process in that class.

6.2 Participants

A total of 105 children (61 males and 44 females), attending the second grade (age ranging from 7 to 8 years old) in four different primary schools, participated in the study. All the students attending the involved classes participated in the study, including children with SEN who did not refuse, since identification and diagnosis of learning difficulties (dyslexia, dyscalculia, and writing difficulties) are only possible after the end of the second grade of primary school. Children with certified disabilities were involved in the activities of data collection, but were excluded from the analyses. The administration of the tests was carried on during the school hours following a schedule agreed upon with the teachers. The tests were administered individually to the students in a quiet room of the school, except the subtests *Operations* and *Numbers judgment* of the AC-MT 6–11 test.

6.3 Instruments

6.3.1 Mathematical abilities

To assess the mathematical performance, the "Test for the evaluation of calculating and problem-solving abilities" was used (AC-MT 6–11; Cornoldi et al., 2012). It is an Italian normative paper-and-pencil test battery. The test was administered collectively in the classroom during school hours, following the test's administration instructions.

The battery consists of the following subtests that correspond to specific scores and are not combined in a composite score:

1. *Operations*: evaluates the ability to apply calculation procedures. The child must solve additions and subtractions.
2. *Numbers judgment*: evaluates the semantic comprehension of numerical quantities. For several pairs of Arabic digits, the child must identify the largest number.
3. *Accuracy*: evaluates the ability to process the syntactic structure of numbers, building digits from 0 to 99, from the number of 10s and ones. For example, the experimenter says, "Three 10s and four ones correspond to which number?" and, as a response, the child is expected to write the number 34. In addition, it evaluates the semantic representation of numbers. The child must write a random set of displayed numbers in decreasing order and then in an increasing order.

6.3.2 Visuo-spatial working memory

WM was assessed through the backward Corsi blocks test (Battery for Visuo-Spatial Memory; Mammarella et al., 2008). The test consists of a series of nine blocks arranged irregularly on a board. The examiner taps the blocks in a given order, and the child's task is to watch the examiner and repeat the tapping sequence backwards.

The participants are presented with trials of increasing levels of complexity until they are unable to solve at least two trials with the same number of blocks. The backward Corsi span score is determined by the maximum number of blocks correctly recalled in the reverse sequence.

6.3.3 Math self-concept

Math self-concept was measured using a sub-scale of the Self-Description Questionnaire-I (SDQ-I, Italian version; Camodeca et al., 2010). The selected sub-scale investigates children's perception of their confidence and abilities in mathematics. It consists of 10 items (e.g., "I am interested in mathematics") with response options limited to "false" (1) or "true" (2). The researcher administered the questionnaire individually to each child to assure their understanding of the items. Children were asked to indicate whether each statement was true or false based on their own perception. None of the children showed difficulties in understanding and answering the questionnaire, which is constructed and validated for children of this age.

The total sum score was calculated and scored in the “positive” direction (i.e., higher scores indicate higher math abilities, higher memory skills, higher self-concept). Cronbach’s alpha is 0.75. Descriptive statistics for each item are shown in “Appendix”.

6.4 Statistical analyses

Bivariate correlations and moderated regressions were conducted to test our hypotheses. To test for the moderation effect of math self-concept, we included the interaction term between the predictor and the moderator (WM x self-concept) in the regression equation, in addition to the main effects (Aiken et al., 1991). To suggest a moderation hypothesis, it is important that the interaction term has a significant effect on the criterion (Baron & Kenny, 1986). In line with Cohen et al. (2014), all variables included in the model were mean centered.

7 Results

Prior to the hypotheses test, we checked for possible gender differences. Independent *t*-test analyses showed no gender differences on mathematical abilities, except for mathematical operations, $t(104)=2.637$, $d=0.52$, $p=.010$, with boys ($M=61$, $SD=0.79$) showing higher abilities than girls ($M=45$, $SD=1.16$). No gender differences were detected for working-memory skills and math self-concept.

As data were collected in four different schools, for each variable a one-way ANOVA was conducted to check possible differences. The results showed a significant main effect of schools on accuracy, $F(2, 101)=241.1$, $\eta^2=0.88$, $p<.001$. Post-hoc analysis using Tukey’s contrasts revealed that school 4 showed a significant difference of $p<.001$ compared to all other schools. However, there were no significant differences between schools 2 and 3, and between schools 2 and 1. No differences were found for the other variables.

A correlation matrix is shown in Table 1. The Operations and Numeracy Judgment domains show a significant and positive correlation with visuo-spatial working memory and math self-concept. Accuracy domain does not show any significant correlation.

Two different moderation analyses were conducted to examine the interactive effects of visual-spatial working memory and math self-concept on operation abilities and numeric judgments (Table 2). Since no significant correlations with WM and self-concept emerged for the accuracy domain, no regression models were tested for this criterion.

For the criterion of mathematical operations, the regression model explained a significant proportion of variance ($R^2=0.26$, $p<.001$). Gender was inserted as a

Table 1 Descriptive Statistics and Correlations between the Variables

Variable	*M*	SD	1	2	3	4
1. Working Memory	4.23	0.95				
2. Self-concept	1.88	0.16	.22*			
3. Operations	3.09	1.09	.24*	.34**		
4. Numeracy Judgment	19.22	4.64	.23*	.27*	.47**	
5. Accuracy	7.78	13.12	.17	-.04	-.03	-.17

Note. M and *SD* are used to represent mean and standard deviation, respectively

*indicates $p < .05$. ** indicates $p < .01$

Table 2 Results of the two models of regression analysis with moderation interaction

Predictors	Estimate	SE	95% CI		*p*	R^2
			LL	UL		
Model 1 (*Operations*)						0.26**
Gender	-0.56**	0.18	-0.94	-0.19	.00**	
Visual-spatial Working Memory	2.80*	1.15	0.51	5.10	.017*	
Self-Concept	7.94**	2.67	2.63	13.25	.00**	
WM*Self-concept	-1.47*	0.62	-2.70	-0.24	.019*	
Model 2 *(Numeric Judgment)*						0.13**
Visual-Spatial Working Memory	10.9*	4.58	1.79	20.01	.019*	
Self-Concept	29.22**	10.6	8.16	50.27	.00**	
WM*Self-concept	-5.64*	2.46	-10.55	-0.74	.02*	

* indicates $p < 0.05$. ** indicates $p < 0.01$

covariate, based on the significant *t*-test. Both WM ($b = 2.81$, $SE = 1.15$, $p < .05$) and self-concept ($b = 7.94$, $SE = 2.67$, $p < .01$) were significant predictors of mathematical operations. Additionally, there was a significant interaction between WM and self-concept ($b = -1.47$, $SE = 0.62$, $p < .05$), indicating that the effect of WM on math operations depended on levels of math self-concept. The analysis of simple slopes showed that the relationship between visuo-spatial working memory and operations was significant when self-concept was low (16th percentile), $b = 0.30$, $SE = 0.13$, $p < 0.05$. The relationship was not significant when self-concept was medium ($b = 0.00$, $SE = 0.10$, $p = .96$) or high levels ($b = -0.14$, $SE = 0.13$, $p = .29$).

In sum, a poorer self-perception of mathematical abilities is associated with lower performance in operations, particularly among children with weaker visuo-spatial working memory. Specifically, our results indicate that children with both low levels of visuo-spatial working memory and low levels of math self-concept show the lowest ability in the domain of mathematical operations (Fig. 1).

A significant portion of variance in numeric judgment was accounted for by the regression model ($R^2 = 0.13$ $p < .01$). Visuo-spatial working memory ($b = 10.9$,

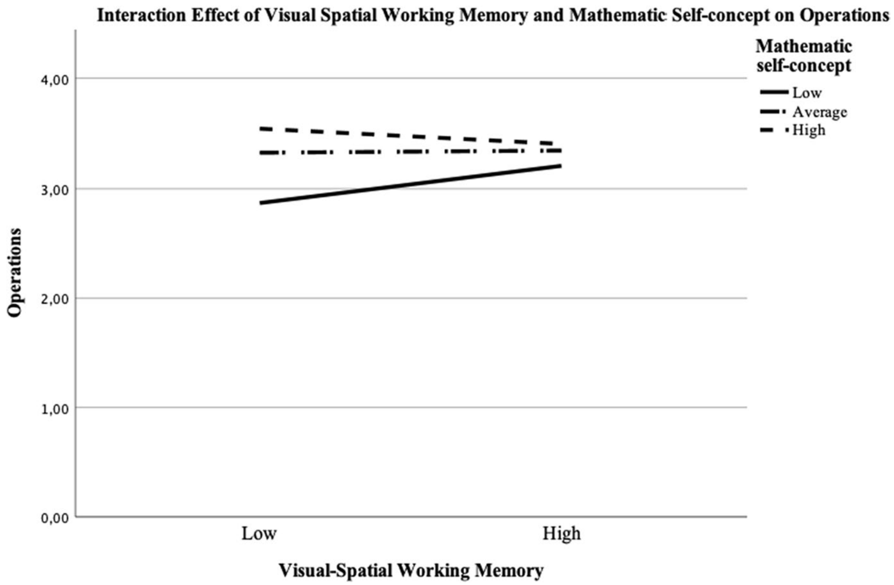

Figure 1. Interaction effects of visual spatial working memory and mathematic self-concept on operations

$SE = 4.58$, $p < .05$), math self-concept ($b = 29.22$, $SE = 10.6$, $p < .01$), and the interaction between visuo-spatial working memory and math self-concept ($b = -5.64$, $SE = 2.46$, $p < .05$) significantly predicted numeric judgment. Simple slope analysis revealed that visuo-spatial working memory was associated positively with numeric judgment at low levels of self-concept ($b = 1.31$, $SE = 0.54$, $p < .05$), but not at medium ($b = 0.18$, $SE = 0.41$, $p = .66$) or high levels ($b = -0.38$, $SE = 0.54$, $p = .48$). As shown in Fig. 2, children with low levels of visuo-spatial working memory and low math self-concept had the lowest levels of math ability in the judgment domain.

8 Discussion and conclusions

The aim of the present study was to investigate the effects of visuo-spatial working memory and math self-concept on mathematical skills in primary school children. In line with previous research, our study showed that visuo-spatial working memory predicts mathematical abilities in second grade children (Holmes & Adams, 2006; Holmes et al., 2008; Passolunghi & Mammarella, 2010). At the same time, results showed that children's more positive beliefs about their own math abilities (self-concept) are associated with higher mathematical abilities (Cai et al., 2018; Denissen et al., 2007). These results emerged for two domains, operations and numeric judgement, but not for mathematical accuracy. This finding might be explained by previous studies in this field. For example, Geary (2011) found that the relevance of the different components of WM vary depending on the content of the mathematical ability that is being evaluated, and accuracy has been found to be less related to

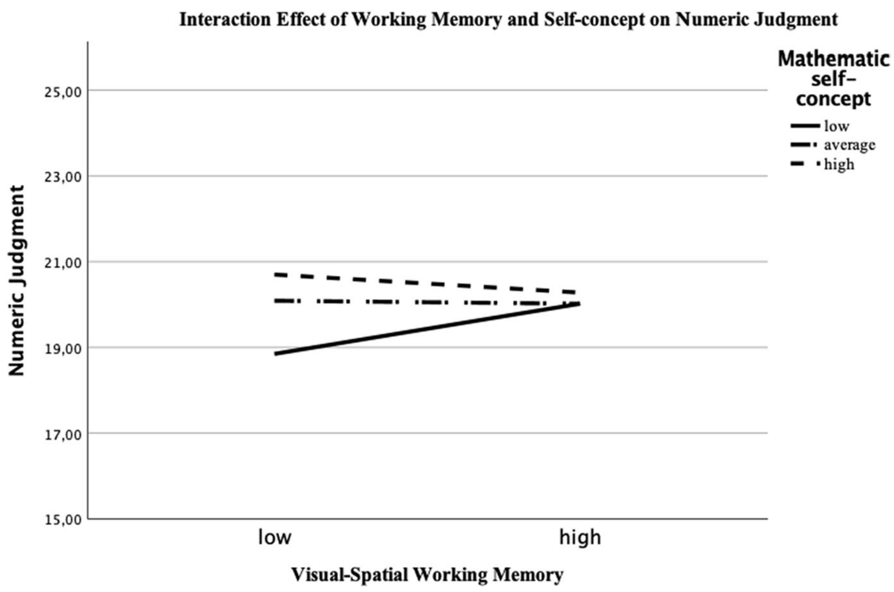

Fig. 2 Interaction Effects of Working Memory and Self-Concept on Numeric Judgment

the visual-spatial component of WM, and more to the verbal one, which was not assessed in our study (Swanson, 2011).

In particular, our study suggests how social and motivational mechanisms could moderate the relationship between cognitive factors and performance, based on the well-established relation existing between math self-concept, math achievement, and other variables (e.g., Arens et al., 2017; Guay et al., 2003; Justicia-Galiano et al., 2017; Pinxten et al., 2014; Van Der Beek et al., 2017). Beyond the role of visuo-spatial working memory in mathematical abilities (Fanari et al., 2019), our results indicate a significant interplay with math self-concept. When children with a low level of WM have a negative math self-concept, the academic achievement in mathematics may worsen. Previous research showed that students with a negative self-concept about their math abilities are less likely to engage in math tasks, less motivated to perform, less willing to make efforts and carry the tasks through, and more prone to avoid mathematical activity (Seaton et al., 2014).

Our results show that, when this happens jointly with a low level of WM functioning, mathematical performance declines. Hence, since students may think they do not have the right abilities, while they already struggle in completing mathematical tasks due to scarce WM functioning (Mammarella et al., 2018), they might put less effort toward and have lower engagement in mathematical tasks (Pajares, 1996), therefore lowering their performance (Arens et al., 2017).

The main effects estimated by our regression models also are consistent with previous findings showing that a greater portion of variance of mathematics academic achievement is explained by WM compared to self-concept (Donolato et al., 2019). In other words, this means that even though in this study both visual spatial working memory and math self-concept were found to be predictive of children's mathematical abilities, high levels of visuo-spatial working memory functioning consistently are linked to higher abilities, even when self-concept is low.

The practical implications of the findings of this study are notable. Even though the contribution of WM appears stronger than other predictors, math self-concept might play an important role in academic achievement that should not be underestimated. Also, we argue here that self-concept compared to WM might be more easily the subject of specific educational interventions. In other words, in day-to-day practice in educational contexts, working on social and motivational factors (e.g., promoting a better math self-concept) might be easier and more feasible for teachers and caregivers, compared to working on cognitive factors strictu sensu (such as WM). Thus, when developing intervention programs for primary school children, it is also important to consider the individual difficulties they may be facing, in addition to providing cognitive skills support. Prevention and intervention programs that focus on self-concept might be useful in helping students develop new skills and support their academic achievement, as a positive math self-concept could help children to persist with math tasks longer, or help them to better cope with negative feedbacks (Marsh & Craven, 2006).

Some limitations of our study should be considered. First, it should be considered that we used a cross-sectional design study, therefore, conclusions of causality cannot be fully drawn. Future research should thus implement longitudinal research designs.

Second, it is important to acknowledge that our study had a relatively small sample size, which may limit the generalizability of the results. Future research should aim to replicate these findings with larger and more diverse samples to enhance the robustness and generalizability of the conclusions. Additionally, our study has considered only second grade primary children. Hence, future replications with different age groups also might be necessary to corroborate our findings.

To support the learning of mathematics by primary school children, a thorough understanding of the factors at the basis of their achievement is crucial. Among these factors, as our study shows, both working memory and self-concept are important for the development of early interventions to improve mathematical achievement. Thus, the findings presented here have important implications for educational research and practice, as they suggest that early interventions to promote both better working memory skills and a higher self-concept in mathematics might bring about future benefits for students' education and learning.

Appendix

See Table 3.

Acknowledgements The authors thank Francesca Caroccia, Francesca Cima, Serena Nardone, Michela Carnevale and Marta Ricci for their collaboration in collecting the data, and Dr. Suellen Crano for the careful language revision. We also wish to thank the two anonymous reviewers for their enriching and supporting comments.

Table 3 Descriptive statistics on item level for the Mathematical self-concept questionnaire (subscale of the Self-Description Questionnaire-I; SDQ-I, Italian version; Camodeca et al., 2010)

Items	*M*	*SD*
1. I hate mathematics*	1.85	0.36
2. It's easy for me to do math homework	1.80	0.40
3. I am enthusiastic about mathematics	1.90	0.31
4. I get good grades in mathematics	1.93	0.25
5. I am interested in mathematics	1.74	0.44
6. I learn mathematics quickly	1.95	0.22
7. I like mathematics	1.89	0.31
8. I am good at mathematics	1.93	0.24
9. I enjoy doing math homework	1.91	0.28
10. I am slow in mathematics*	1.90	0.30

*These items have been reversed

Author contribution All authors contributed to the study conception and design. Material preparation, and data collection were performed by YP and GG. Data analysis were performed by YP and SC. The first draft of the manuscript was written by YP, SP, SC, GC and GG. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding Open access funding provided by Università degli Studi di Roma La Sapienza within the CRUI-CARE Agreement. No funding was received to assist with the preparation of this manuscript.

Declarations

Competing interest The authors have no relevant financial or non-financial interests to disclose.

Ethical approval The study was conducted in full compliance with the ethical standards and Italian national regulations on research involving human participants. Informed consent to participation was obtained prior to the data collection.

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