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Domain-specific and -general factors involved on mathematical performance: similarities and differences between elementary school stages

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Abstract

Mathematical performance is crucial throughout students' academic experiences. Given its significance, researchers have examined which domain-specific and domain-general factors are related to math performance. However, most studies have primarily focused on analyzing these factors separately rather than in conjunction and considered elementary school years as a continuum, without exploring the potential differences between students at the first (1^{st}–3^{rd} grades) and second (4^{th}–6^{th} grades) stages of education. The present study aimed to analyze the influence of domain-specific and domain-general factors on mathematical performance comparing 1^{st}–3^{rd} graders *vs* 4^{th}–6^{th} graders. The sample comprised 282 schoolchildren (140 boys, 142 girls) aged between 6 and 12 years *(M* = 8.75, *SD* = 1.94). Paper-and-pencil and computer tasks were administered to schoolchildren to measure their domain-specific factors (numerical processing, math anxiety) and domain-general factors (non-verbal intelligence, working memory, inhibitory control; effortful control was reported by their families), whereas mathematical performance was informed by teachers at the end of the academic year. Results showed that child's age, numerical processing, numerical processing anxiety factor, and non-verbal intelligence were related to mathematical performance across elementary school years, whereas numerical processing anxiety factor was the most powerful predictor for the first elementary stage (1^{st}–3^{rd} grades), and numerical processing for the second elementary stage (4^{th}–6^{th} grades). Moreover, educational stage was found not to moderate the relationship between domain-specific and domain-general factors and mathematical performance, suggesting that the developmental stage exerts a direct contribution, rather than a moderation effect, on mathematical performance.

Keywords Domain-specific factors · Domain-general factors · Mathematical performance · Childhood

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Introduction

Mathematics is a discipline included in school curricula worldwide (Kadijevich et al., 2023; Mereku, 2023) and essential for a wide variety of everyday tasks, ranging from handling monetary resources to carry out the analysis of an investigation. While appropriate performance in mathematics is essential for schoolers to understand, interpret and apply mathematical concepts and procedures efficiently, mathematics struggles have been associated with negative consequences across children's lifespans, such as a high likelihood of developing math disabilities (Swanson et al., 2022) or higher probability to have lowest levels of full-time employment, to be unemployed-compared to those with competent numeracy-and, overall, poor numeracy has been related to low economic well-being at adulthood (Parsons & Bynner, 2005). Given its relevance, the educational community and researchers are committed to discovering which factors are involved in individual differences in mathematical performance across elementary school years, distinguishing between mathematics domain-specific and general factors.

Domain-specific and -general factors and mathematical performance

Reviewing the domain-specific factors in mathematics exposed in De Smedt (2022), described as those abilities that are specific to mathematics learning, the literature has consistently highlighted the relevance of schoolchildren's mathematical anxiety (MA) (Quintero et al., 2022; Sánchez-Pérez et al., 2015; Shi et al., 2022) and numerical magnitude processing (Brankaer et al., 2017; Lonnemann et al., 2011, 2013; Starling-Alves et al., 2021). Numerical magnitude processing, which involves the ability to represent and process non-symbolic (e.g., dot patterns) and symbolic representations (Arabic numerals), is one of the domain-specific factors repeatedly highlighted in previous meta-analyses (Schneider et al., 2017, 2018). However, when studies have differentiated the effect of non-symbolic representation *versus* the symbolic representation on mathematical performance, the results indicate that symbolic magnitude processing is more relevant to mathematical performance (for a meta-analysis see Schneider et al., 2017). MA refers to the specific fear, tension, and worry associated with mathematical stimuli and situations (Luttenberger et al., 2018); it appears during mathematics exams and extends to math-related tasks such as grocery shopping or doing math homework. Not surprisingly, MA shows a negative and moderate relation with mathematical performance (for meta-analyses studies: Barroso et al., 2021; Zhang et al., 2019).

On the other hand, domain-general factors are required for a broad range of learning areas. In this sense, the literature has consistently highlighted the importance of schoolchildren's non-verbal intelligence (non-verbal IQ), working memory (WM), inhibitory control (IC), and effort control (EC). Non-verbal IQ is defined as the ability to reason and solve novel problems independently of prior knowledge (for a meta-analysis study see Peng et al., 2019). WM is described as maintaining, updating, and manipulating information (De Smedt, 2022; for a meta-analysis study see Friso-Van Bos et al., 2013; Peng et al., 2016); which is traditionally conceptually divided and measured as visual-spatial working memory (VSWM; for a meta-analysis study see Allen et al., 2020) and verbal working memory (VWM). IC is characterized as the ability to inhibit a dominant response or resist interference (for empirical data: De Smedt, 2022; for meta-analysis study Spiegel et al., 2021). Lastly, EC is defined as the ability to utilize attentional resources and to inhibit behavioral responses in order to regulate emotions and related behaviors (Rothbart et al., 1994; Sánchez-Pérez et al., 2024; Swanson et al., 2022). The aforementioned empirical studies and meta-analyses have demonstrated that schoolchildren with high scores in these domain-general factors also tend to achieve better mathematical performance, but this literature has not clarified specifically which domain-specific and domain-general factors are more predominant during the different stages of elementary education.

Mathematics domain-specific and -general factors across elementary school

Examining the potentially different effects of domain-specific and -general factors depending on children's educational stage, a superficial examination might suggest that, for domain-specific factors, numerical processing (De Smedt et al., 2009; Durand et al., 2005; Holloway & Ansari, 2009; for a meta-analysis study see Zhang et al., 2019) and MA (for a review see Wijns et al., 2019; for meta-analyses studies see Namkung et al., 2019; Zhang et al., 2019) are robustly linked to mathematical performance across elementary school. However, some contradictory findings have been reported. Although MA is believed to influence mathematical performance longitudinally across elementary school (Ramirez et al., 2013; Vukovic et al., 2013), other studies have reported that their negative effect might be more detrimental in the first years of elementary education (Krinzinger et al., 2009; Ramani et al., 2017; Sánchez-Pérez et al., 2021). As regards numerical processing magnitude, the review published by De Smedt et al. (2013) showed that typically developing children's performance on symbolic comparison tasks is robustly correlated with mathematics achievement, although not all the studies reviewed found significant relations. In this sense, a meta-analysis published by Schneider and his colleagues (2017) found that the relation between magnitude comparison and broader mathematical competence was moderated by age, decreasing the strength of the correlation as age increased.

In terms of domain-general factors, previous studies have claimed that non-verbal IQ (Dündar-Coecke et al., 2020; Lohman & Gambrell, 2012; Mecca et al., 2014), WM (Allen et al., 2020; Hu et al., 2023; Fanari et al., 2019; Mix et al., 2016), IC (Barradas Cordeiro et al., 2024; Ren et al., 2019), and EC (Sánchez-Pérez et al., 2024) are required across elementary school, whereas others have failed to find the same relevance for WM (Carr et al., 2008; Haciomeroglu, 2015; for a meta-analysis: Xie et al., 2020), IC (Wilkinson et al., 2020), and EC (Sánchez-Pérez et al., 2015). For example, Xie et al. (2020) affirmed that, while a positive association was found between mathematics and WM in genetic and brain studies, behavioral studies yielded inconsistent findings depending on the main tasks for measuring WM. When looking at potential age differences, a meta-analysis confirmed that age would be a moderator variable in the association between WM and mathematical performance, with younger children relying more on VSWM processing and suggesting that mathematical performance becomes more and more dependent on updating capacities rather than storage capacities (Friso-Van Bos, et al., 2013). In the same line, Wilkinson et al. (2020) argued that their task employed to measure IC (a paper-and-pencil version of the Stroop-like task) may not be a sufficiently sensitive measurement, with meta-analyses confirming that the method of assessing IC would be a moderator of the relation between IC and mathematics (Allan et al., 2014; Zhu et al., 2025). Moreover, when focusing the attention at the potential moderator role of age, the meta-analyses that include preschool and kindergarten samples do not find differences (Allan et al., 2014; Emslander et al., 2022), but it seems to be a relevant variable in elementary school children (Zhu et al., 2025). In the case of EC, as it includes multiple self-regulatory skills, the inconsistent results might be explained by the fact that each of these skills might make a differential contribution to mathematical performance (Sánchez-Pérez et al., 2015). In fact, measuring these psychological constructs is notoriously challenging, due to the significant overlap between cognitive skills and the concerns regarding the ecological validity of cognitive tasks conducted in laboratory settings (Chaytor et al., 2006; Green et al., 2019).

The present study

As shown in the previous section, multiple domain-general and -specific factors have been highlighted by studies to explain individual differences in mathematical performance. However, the search for a comprehensive approach considering a wide range of factors and including the analyses for different elementary stages has not yet been undertaken. Specifically, while numerical processing and WM are the most documented predictors (Vanbinst & De Smedt, 2016; for meta-analysis study see Agostini et al., 2022), other factors have not received the same attention. Furthermore, studies usually focus on specific samples, such as preschoolers (Birgisdottir et al., 2020; for a review see Nogues & Dorneles, 2021), students enrolled in the first elementary stage (1st–3rdgrades) (1stgrade studies: Vanbinst et al., 2015; 2nd and 3rd grades: Szűcs et al., 2014), or with math disabilities (Barnes et al., 2020; Toll et al., 2011), but did not consider a wide range of grades to compare the potential differences between elementary school stages.

As we noted above, previous research indicates that both domain-specific (e.g., numerical processing and MA) and domain-general factors (e.g., WM, IC, and EC) influence mathematical performance, but their effects may vary across developmental stages (Geary et al., 2017). For instance, MA has been shown to exert a more detrimental impact in early elementary years (Krinzinger et al., 2009; Ramani et al., 2017), while the association between numerical magnitude processing and mathematical achievement appears to weaken with age (Schneider et al., 2017). Similarly, meta-analytic evidence suggests that the contribution of WM to math performance shifts over time, with younger children relying more on visual-spatial storage and older children on updating abilities (Friso-Van Bos et al., 2013; Peng et al., 2016). The relation between IC and math outcomes also seems moderated by both age and task type (Allan et al., 2014; Zhu et al., 2025). These developmental trends underscore the importance of dividing participants into age groups to capture age-specific patterns and better understand the evolving contributions of different domain factors to mathematical performance.

The relevance of identifying domain-general and domain-specific factors is essential for designing targeted interventions that strengthen mathematical performance. For example, knowing that WM is a process underlying mathematical performance, Sánchez-Pérez et al. (2018a) implemented a computerized WM training program in a schoolchildren sample, which led to significant improvements in cognitive skills, such as non-verbal IQ and mathematical performance. These findings highlight the potential of basic science to reveal the key factors of mathematical performance in order to develop targeted interventions to improve these students' abilities.

Given the research gaps, the main objective of this research was to analyze the influence of domain-general and -specific factors on mathematics performance across elementary school and, specifically, in two different educational stages: the first stage (1st–3rd grades) and second stage (4th–6th grades), with three specific objectives:

1. Identify which domain-specific and -general factors predict mathematics performance across elementary school.
2. Examine which of these domain-specific and -general factors predict mathematical performance in each stage (1^{st}-3^{rd} grades *vs.* 4^{th}-6^{th} grades).
3. Determine whether students' education stage moderates the influence of these factors on mathematical performance.

Materials and methods

Participants

A total of two hundred and eighty-two (140 boys, 142 girls) schoolchildren participated in this study. The inclusion criteria were that the students had to be from first to sixth grade of primary school and did not have any special educational needs. Children were aged between 6 and 12 years ($M = 8.75$, $SD = 1.94$), and were enrolled in 1^{st} grade ($n = 64$; 22.70%), 2^{nd} grade ($n = 40$; 14.20%), 3^{rd} grade ($n = 42$; 14.90%), 4^{th} grade ($n = 47$; 16.70%), 5^{th} grade ($n = 37$; 13.10%) and 6^{th} grade ($n = 52$; 18.40%).

As regards parents' education reports, 90.40% of mothers and 87.90% of fathers completed the questionnaire. Information on monthly income was provided by 92% of parents. In terms of parents' education, 16.90% of the mothers were educated to elementary school level, 22.70% to high school level, and 60.40% to university level. For fathers, the analogous percentages were: 30.60%, 26.60% and 42.70%, respectively. As regards monthly income, 3.10% stated that they received less than 750€ (lower extreme compared to the average family income), 5.80% from 751 to 1200 (well below average), 14.60% from 1201 to 1600 (below average), 10.40% from 1601 to 2000 (in average), 28.80% from 2001 to 3000€ (above average), and 37.30% more than 3000€ (well above average) as their monthly family income.

Measurements

Domain-specific factors

Numerical processing The Symbolic Magnitude Processing Test (SYMP; Brankaer et al., 2017) was administered to children to evaluate symbolic numerical processing. Students had to complete two numerical magnitude comparison tasks: the one-digit subtest with digits between 1 and 9, and a two-digit subtest with digits ranging from 11 to 99. They had to choose the larger number and had 30 s for each condition to solve as many items as they could. Each subtest contained 60 digit pairs, presented in four columns of 15 pairs (Brankaer et al., 2017). The score was determined by summing the number of items correctly solved in the two subtests.

Mathematics anxiety The Spanish version (Sánchez-Pérez, et al., 2021) of the Scale for Early Mathematics Anxiety (SEMA; Wu et al., 2012) was used to report MA. This scale captures children's anxiety reactions associated with performing tasks and solving mathematics-related problems, named as the Numerical processing anxiety factor (7 items, e.g., "George bought two pizzas that had six slices each. How many total slices did George have to share with his friends?"; $\alpha = 0.79$), and anxiety stemming from social and examination situations that involve the application of mathematics, reflected in the Situational and performance anxiety factor (8 items, e.g., "You are in math class and your teacher is about to teach something new," $\alpha = 0.75$). A 5-options Likert scale was used to respond, ranging from "not nervous at all" to "very, very nervous." The Numerical processing anxiety factor and Situational and performance anxiety factor scores were calculated by summing their corresponding items.

Domain-general factors

Non-verbal IQ The Spanish adaptation (Cordero & Calonge, 2000) of the Matrices subtest of the Kaufman brief intelligence test (K-BIT; Kaufman, 1990) was employed to measure non-verbal IQ. Children were required to solve abstract and figure-based visual stimuli, choosing the correct answer from multiple choices. Cronbach's alpha was $\alpha = 0.93$.

Visual-spatial short-term memory Two computerized versions (Kessels et al., 2000) of the Corsi blocks test (Corsi, 1972) were used to test visual-spatial short-term memory. In a standard testing trial, nine white squares initially appear on the computer screen. Following a one-second interval, the squares are sequentially highlighted, changing their color to red for 1 s. Once the sequence concludes, the nine white squares reappear on a black background, now framed in red. Participants are then instructed to reproduce the sequence of highlighted squares, either in the original order (forward) or in reverse order (backward), using the computer mouse to click on the squares. After a 1-s intertrial interval, the next trial commences. The length of the series was augmented by one number for each correct response and testing concludes when participants make two consecutive mistakes. All the participants began with the forward condition, followed by the backward condition. The maximums reached in forward and backward conditions were collected. As a result, two variables were run in the data analysis: visual-spatial short-term memory (forward) and visual-spatial short-term memory (backward). These two measures are incorporated independently following previous studies stating that the two memory processes are distinct (Clair-Thompson & Allen, 2013; Levi & Heled, 2024).

Verbal working memory The computerized version of the Digits test (Sowinski et al., 2015), which contains the Digit Span Backward DSB, was used to evaluate VWM. DSB was based on the Digits subtest of the Wechsler Intelligence Scales for Children (WISC-IV; Wechsler, 2003). Participants were asked (by a woman's voice presented to the students via the computer) to repeat a sequence of numbers in the opposite order in which they were presented. The length of the series increased by one number for each correct response. The total score was derived from the longest accurately reproduced number sequence.

Inhibitory control A computerized Go/No-Go task (adapted from Durston et al., 2002) was used to measure IC considered as motor inhibition/impulsivity. For more details of the task, see Sánchez-Pérez et al., (2018b).

Effortful control A Spanish version (used before in Sánchez-Pérez et al., 2015) of the Temperament in Middle Childhood Questionnaire (TMCQ; Simonds & Rothbart, 2006) was reported by children's parents to measure EC. EC, as a self-regulatory temperamental factor, was composed of three dimensions of temperament: Activation control, defined as the capacity to perform an action when there is a strong tendency to avoid it (Simonds, 2006) (15 items, e.g., "Can make him/herself do homework, even when s/he wants to play," $\alpha = 0.68$, r = [0.08 to 0.42]); Attentional focusing, characterized as the tendency to maintain attentional focus on task-related channels (for empirical data: Simonds, 2006) (7 items, e.g., "Gets distracted when trying to pay attention in class," $\alpha = 0.89$, $r = [0.69$ to $0.55]$); and Inhibitory control, described as the capacity to plan and to suppress inappropriate approach responses under instructions or in novel or uncertain situations (for empirical data: Simonds, 2006) (10 items, e.g., "Has an easy time waiting to open a present," $\alpha = 0.66$, $r = [0.13$ to $0.46]$). The parents had to read 32 statements describing children's reactions to various situations and decide how likely that reaction was in their child's case using a 5-point Likert scale from "almost always false" to "almost always true". The score of each dimension was computed by calculating the average of all the answered items. Unlike the inhibition measured by the Go/No-Go task, this scale reflects cognitive inhibition and allows an ecological measurement of the construct.

Mathematical performance

Mathematical performance The Calculation and Fluency math tests of the Spanish version (Diamantopoulou et al., 2012) of the Woodcock-Johnson III (WJ-III) Achievement battery (Woodcock et al., 2001) were paper-and-pencil tasks administered to evaluate children's mathematical achievement. The total score for mathematical achievement was calculated by averaging the standardized scores of each task.

Procedure

The research was approved by the Ethics Committee for Research of the Community of Aragon (CEICA) (PI21/053) and performed in accordance with the Helsinki declaration. Public primary schools in the regions of Teruel and Zaragoza (Spain) were invited to participate by telephone and email, with a total of four schools agreeing to participate. Informed consent forms were sent to the children's families through their teachers, together with a sociodemographic questionnaire, and the Spanish version of the TMCQ. Families that agreed to participate returned the completed documents to their children's teachers; otherwise, they could return them blank. If questions arose, the families could telephone the principal researcher to solve any concerns. A two-week period was established for submitting the completed documents, with a reminder sent after one or two weeks.

Children's abilities were tested in 3 group sessions by a trained assistant during school hours, which were previously agreed with the teachers: while the first (with an approximate duration of 20 min) and second (approx. 20 min) sessions were performed at the beginning of the second semester (both in the same week), the third session (approx. 25 min) was performed at the end of the academic year. In the first session, students were administered the tasks related to MA, numerical processing, and non-verbal IQ. In the second session, they completed the computerized tests to collect the data related to visual-spatial short-term memory (forward and backward), VWM, and impulsivity/IC. In the final session, calculation and fluency math tasks were performed.

Statistical analyses

To address the three questions posed in the current study, the following data analyses strategy was conducted: firstly, descriptive statistics, independent *t*-tests, and zero-order correlations were computed to examine the associations between domain-general and domain-specific factors and mathematical performance for all the sample, also distinguishing between younger students (those in grades 1 to 3) and older students (those in grades 4 to 6) from elementary school. Secondly, stepwise hierarchical regression analysis was conducted on the full sample to examine the independent effects of domain-specific and - general factors on mathematical performance. Moreover, separate stepwise hierarchical regression analyses were also performed for younger and older schoolchildren. Furthermore, moderated stepwise hierarchical regressions were run to test the potential moderator role of the educational stage in the relation between factors and mathematical performance. Cohen's f^2 was calculated to evaluate the effect size of each hierarchical regression. This index is obtained using the formula $f^2 = R^2/(1 - R^2)$ and allows the effect to be classified as small (≥0.02), medium (≥0.15), or large (≥0.35). All analyses were performed using the Statistical Package for Social Sciences program (SPSS; v.27) (IBM Corp., 2015).

Results

Descriptive statistics, independent t-tests and zero-order correlation

The descriptive statistics of all the variables studied are shown in Table 1. Firstly, an independent *t*-test analysis was performed to test the potential effect of the child's sex on mathematical performance, while the potential influence of age was verified through zero-order correlations. Whereas sex analysis was not significant (t (272) = 0.42, p = 0.675), age was significantly correlated with mathematical performance (r = 0.81, p < 0.001).

Secondly, independent *t*-tests were also conducted to determine whether there were significant differences between the younger group (grades 1^{st}–3^{rd}) and the older group (grades 4^{th}–6^{th}) for domain-specific and -general factors, as well as for mathematical performance (see Table 1). Regarding the *t*-tests for domain-specific factors, numerical processing, t (236.27) = − 11.01, p < 0.001, showed significant differences, whereas the Numerical processing anxiety factor, t (199.38) = 1.08, p = 0.281, and the Situational and performance anxiety factor, t (213.70) = 0.37, p = 0.711, did not.

Several domain-general factors showed significant differences according to the independent samples *t*-test: non-verbal IQ, t (277) = −13.84, p < 0.001, visual-spatial short-term memory (forward), t (188.32) = −9.09, p < 0.001, visual-spatial short-term memory (backward), t (243) = −8.88, p < 0.001, VWM, t (226.31) = −7.62, p < 0.001, impulsivity/inhibitory control, t (220.95) = 5.15, p < 0.001, attentional focusing, t (275) = −2.42, p = 0.016, IC, t (261.46), p = 0.002, and mathematical performance t (272) = −17.29, p < 0.001. No significant differences were only found for activation control t (275) = −1.75, p = 0.081.

Thirdly, zero-order correlations were computed to examine the relationships between domain-specific and domain-general factors and mathematical performance, both across the entire sample and separately by students' educational stage. When considering the

Table 1 Descriptive statistics for all variables under study

Variables	All sample M (SD)	Young sample M (SD)	Older sample M (SD)	Independent sample test
Numerical processing	42.99 (14.89) $n=272$	35.02 (14.80) $n=140$	51.43 (9.32) $n=132$	$t\,(236.27) = -11.00^{***}$
Numerical processing anxiety factor	4.46 (5.04) $n=238$	4.84 (5.83) $n=112$	4.12 (4.20) $n=126$	$t\,(199.39) = -1.08$, n.s
Situational and performance anxiety factor	6.27 (5.46) $n=233$	6.42 (5.82) $n=107$	6.15 (5.15) $n=126$	$t\,(213.70) = 0.37$, n.s
Non-verbal IQ	24.51 (6.64) $n=279$	20.41 (4.68) $n=144$	28.89 (5.54) $n=135$	$t\,(277) = -13.84^{***}$
VS short-term memory (forward)	4.67 (1.17) $n=245$	4.10 (1.26) $n=125$	5.27 (0.66) $n=120$	$t\,(188.32) = -9.09^{***}$
VS short-term memory (backward)	4.63 (1.34) $n=245$	3.97 (1.27) $n=125$	5.32 (1.03) $n=120$	$t\,(243) = -9.09^{***}$
Verbal working memory	2.90 (1.29) $n=244$	2.34 (1.02) $n=124$	3.48 (1.29) $n=120$	$t\,(226.33) = -7.62^{***}$
Impulsivity/Inhibitory control	7.14 (5.70) $n=241$	8.91 (6.19) $n=122$	5.33 (4.49) $n=119$	$t\,(220.95) = 5.15^{***}$
Activation control	3.44 (0.54) $n=277$	3.38 (0.52) $n=144$	3.50 (0.55) $n=133$	$t\,(275) = -1.75$, n.s
Attentional focusing	3.51 (0.97) $n=277$	3.37 (0.93) $n=144$	3.65 (0.99) $n=133$	$t\,(275) = -2.42^{*}$
Inhibitory control	3.59 (0.59) $n=277$	3.49 (0.54) $n=144$	3.71(0.63) $n=133$	$t\,(261.46) = -3.16^{**}$
Mathematical performance	0.00 (0.96) $n=274$	−0.66 (0.71) $n=143$	0.73 (0.61) $n=131$	$t\,(272) = -17.29^{***}$

$p<0.001^{***}$ $p<0.01^{**}$, $p<0.005^{*}$, *n.s* no significance. Since each measure was collected during three separate sessions (see Procedure section), data from some participants were unavailable due to the children's absence, or because the data collection notebook was incomplete. "VS" refers to visual-spatial

entire sample, the results showed that two domain-specific factors (numerical processing and numerical processing MA) were significantly correlated with mathematical performance. Specifically, stronger numerical processing skills were associated with better mathematical performance, whereas high numerical processing MA was linked to poorer performance. In terms of domain-general factors, non-verbal IQ, visual-spatial short-term memory (forward and backward), VWM, impulsivity/inhibitory control, activation control, and inhibitory control were all positively associated with math performance. In other words, higher scores on these domain-general measures were related to stronger math outcomes. In contrast, situational and performance MA as well as attentional focusing did not yield significant correlations (see Table 2).

Regarding the first (grades 1-3) and second (grades 4-6) stages, the results showed that, for the younger group, a higher numerical processing MA was associated with poorer mathematical performance, while higher numerical processing was linked to better performance. Moreover, as non-verbal IQ, visual-spatial short-term memory (forward and backward) increased, mathematical performance also improved. In the case of the older group, higher scores in numerical processing and non-verbal IQ were

Table 2 Correlations between independent variables and mathematical performance

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Numerical processing	1											
2. Numerical processing anxiety factor	−0.07	1										
3. Situacional and performance anxiety factor	−0.10	−0.01	1									
4. Non-verbal IQ	0.56**	−0.01	−0.04	1								
5. VS short-term memory (forward)	0.46**	−0.01	0.04	0.46**	1							
6. VS short-term memory (backward)	0.46**	−0.03	−0.01	0.53**	0.48**	1						
7. Verbal working memory	0.26**	0.08	−0.17*	0.54**	0.36**	0.45**	1					
8. Impulsivity/Inhibitory control	−0.25**	0.01	0.01	−0.38**	−0.22**	−0.27**	−0.26**	1				
9. Activation control	0.15*	−0.01	−0.04	0.11	0.01	0.09	0.11	0.02	1			
10. Atentional focusing	0.18**	−0.02	−0.01	0.18**	0.13*	0.24**	0.28**	−0.15*	0.31**	1		
11. Inhibitory control	0.20**	−0.03	0.04	0.18**	0.03	0.14*	0.14*	−0.13*	0.46**	0.40**	1	
12. Mathematical performance	0.65**	−0.15*	−0.05	0.63**	0.47**	0.45**	0.37**	−0.25**	0.14*	0.10	0.17**	1

$p < 0.001^{***}$ $p < 0.01^{**}$, $p < 0.005^{*}$. "VS" refers to visual-spatial

Table 3 Correlations between independent variables and mathematical performance for each educational stage

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Numerical processing	1	−0.01	−0.19*	0.37	0.34**	0.34**	0.15	-0.11	−0.15	0.17*	0.23**	0.45**
2. Numerical processing anxiety factor	−0.07	1	0.10	0.02	-0.01	0.02	0.20	-0.09	−0.03	−0.01	−0.02	−0.23*
3. Situational and performance anxiety factor	0.04	-0.15	1	-0.04	0.08	-0.11	−0.08	0.04	0.06	-0.10	0.02	-0.03
4. Non-verbal IQ	0.22*	−0.18*	−0.02	1	0.30**	0.44**	0.37**	-0.21	−0.02	0.16	0.11	0.38*
5. VS short-term memory (forward)	0.04	−0.08	−0.05	0.14	1	0.35**	0.23*	-0.04	−0.08	0.11	-0.10	0.20*
6. VS short-term memory (backward)	0.10	−0.02	−0.07	0.18*	0.21**	1	0.40**	-0.16	−0.09	0.21*	0.05	0.21*
7. Verbal working memory	−0.15	0.06	−0.27**	0.37**	0.16	0.20*	1	-0.05	−0.03	0.27**	0.06	0.03
8. Impulsivity/Inhibitory control	−0.06	0.10	−0.02	−0.32**	−0.17	−0.10	−0.26**	1	0.13	-0.15	−0.16	−0.03
9. Activation control	0.07	0.02	−0.13	0.08	-0.01	0.19*	0.14	-0.03	1	0.18*	0.44**	0.14

Table 3 (continued)

Variables	1	2	3	4	5	6	7	8	9	10	11	12
10. Attentional focusing	0.04	−0.01	0.07	0.07	-0.01	0.19*	0.22*	-0.06	0.41**	1	0.40**	0.01
11. Inhibitory control	−0.03	−0.01	0.06	0.03	-0.05	0.04	0.06	0.03	0.47**	0.37**	1	0.11
12. Mathematical performance	0.39**	−0.03	−0.06	0.22*	0.14	0.02	0.10	-0.05	0.06	-0.01	−0.01	1

Values above the diagonal are correlations for younger sample and values below the diagonal correlations for older sample. $p < 0.001^{***}$ $p < 0.01^{**}$, $p < 0.005^{*}$. "VS" refers to visual-spatial associated with better performance in mathematics (see Table 3). Although not all variables were significantly correlated with mathematical performance, all of them were included given the exploratory nature of the study.

Identifying which domain-specific and -general factors predict mathematics performance across elementary school

A stepwise hierarchical regression analysis was run for the full sample (grades 1-6) to determine which domain-specific (numerical processing, numerical processing MA and situational and performance MA) and -general factors (non-verbal IQ, visual-spatial short-term memory (forward and backward), VWM, impulsity/IC, activation control, attentional focusing, and IC) predicted mathematical performance. Child' sex and age were also included as control variables.

The stepwise regression equation yielded a significant result, F (5,167) = 53.93, $p < 0.001$, with age ($\beta = 0.52$, $p < 0.001$), numerical processing ($\beta = 0.14$, $p = 0.027$), numerical processing MA ($\beta = -0.10$, $p = 0.044$), and non-verbal IQ ($\beta = 0.19$, $p = 0.007$) factors emerging as significant predictors in the model (see Table 4). The model explained 61% of the variance in mathematical performance, (R^2 *adjusted* = 0.61, $p < 0.001$). Cohen's f^2 was 1.62 ($R^2 = 0.62$), which indicated a large effect size.

Examining which domain-specific and -general factors predict mathematical performance in each stage (1st-3rd grades vs. 4th-6th grades)

Two stepwise hierarchical regressions were run: one for the younger group (grades 1-3) and the older group (grades 4-6) to ascertain which domain-specific and -general factors predict mathematical performance (see Table 5).

The stepwise regression equation yielded a significant result for the younger group, F (3,70) = 12.41, $p < 0.001$, with age ($\beta = 0.53$, $p < 0.001$) and numerical processing MA ($\beta = -0.26$, $p = 0.009$) factors emerging as significant predictors. The R^2 *adjusted* value (R^2 *adjusted* = 0.32, $p < 0.001$) indicated that the model could potentially account for 32% of the variance in mathematical performance (see Table 5). Cohen's f^2 was 0.54 ($R^2 = 0.35$), which indicated a large effect size.

The stepwise hierarchical regression for the older group was also significant, F (3,95) = 7.79, $p < 0.001$, with age ($\beta = 0.25$, $p = 0.016$) and numerical processing ($\beta = 0.28$, $p = 0.006$) predicting 17% of the variance (R^2 *adjusted* = 0.17, $p < 0.001$) in mathematical performance (see Table 5). The effect size (Cohen's $f^2 = 0.25$) indicated a medium effect size ($R^2 = 0.20$).

Analyzing whether students' education stage moderates the influence of domain-specific and -general factors on mathematical performance

A moderated stepwise hierarchical regression was run to test the potential moderational role of the educational stage on the relation between children's domain-specific and general factors on mathematical performance (see Table 4). As in the previous analyses, sex and age were introduced in Step 1, and domain-specific and -general factors in Step 2, with the interaction terms in Step 3. The educational stage was coded as 0 (younger) and 1 (older

Table 4 Stepwise hierarchical regression predicting mathematical performance in the full sample and moderated stepwise hierarchical regressions predicting mathematical performance for elementary school years

Grades 1–6	F	ΔF	$R^2 adj$	$\Delta R^2 adj$	b	β	t	p
Model 1[a]	115.22	-	0.57	-	-	-	-	< 0.001
Model 2[b]	83.47	−31.75	0.59	0.02	-	-	-	< 0.001
Model 3[c]	65.18	−18.29	0.60	0.01	-	-	-	< 0.001
Model 4[d]	53.93	−11.25	0.61	0.01	-	-	-	< 0.001
Step 1								
Sex	-	-	-	-	.01	.01	.10	.918
Age	-	-	-	-	.29	.60	9.06	< 0.001
Step 2								
Numerical processing	-	-	-	-	0.01	0.14	2.23	0.027
Numerical processing anxiety factor	-	-	-	-	−0.02	−0.10	−2.02	0.044
Situational and performance anxiety factor	-	-	-	-	-	−0.03	−0.54	0.588
Non-verbal IQ	-	-	-	-	0.03	0.19	2.75	0.007
VS short-term memory (forward)	-	-	-	-	-	0.00	−0.08	0.939
VS short-term memory (backward)	-	-	-	-	-	0.01	0.19	0.851
Verbal working memory	-	-	-	-	-	0.06	1.00	0.319
Impulsivity/Inhibitory control	-	-	-	-	-	−0.01	−0.11	0.915
Activation control	-	-	-	-	-	0.08	1.60	0.112
Attentional focusing	-	-	-	-	-	−0.04	−0.81	0.418
Inhibitory control	-	-	-	-	-	0.13	0.27	0.786
Step 3								
Numerical processing × grade	-	-	-	-	-	0.20	1.21	0.229
Numerical processing anxiety factor × grade	-	-	-	-	-	0.26	1.78	0.078
Situational and performance anxiety factor × grade	-	-	-	-	-	−0.05	−1.02	0.309
Non-verbal IQ × grade	-	-	-	-	-	0.01	0.05	0.962
VS short-term memory (forward) × grade	-	-	-	-	-	0.03	0.62	0.537

Table 4 (continued)

Grades 1–6	*F*	*ΔF*	R^2adj	$ΔR^2adj$	*b*	*β*	*t*	*p*
VS short-term memory (backward) × grade	-	-	-	-	-	0.02	0.35	0.726
Verbal working memory × grade	-	-	-	-	-	0.08	1.43	0.154
Impulsivity/inhibitory control × grade	-	-	-	-	-	−0.02	−0.31	0.756
Activation control × grade	-	-	-	-	-	0.07	1.45	0.149
Attentional focusing × grade	-	-	-	-	-	−0.05	−0.97	0.332
Inhibitory control × grade	-	-	-	-	-	0.01	0.11	0.914

Models 1, 2, 3, and 4 refer to the four intermediate steps of the stepwise procedure, [a]predictors: age, [b]predictors: age and non-verbal IQ,[c]predictors: age, non-verbal IQ and numerical processing,[d]predictors: age, non-verbal IQ, numerical processing and numerical processing anxiety factor, steps 1, 2, and 3 indicate the order in which variables were entered into the regression blocks, *F* F statistic for the step, *ΔF* change in *F* statistic from the previous step, R^2adj adjusted in R^2 for the step, $ΔR^2adj$ change in adjusted R^2 of the previous step, *b* unstandardized beta coefficient, *β* standardized beta coefficient, *t* *t*-value for the individual predictor, *p* *p*-value for the individual predictor. "VS" refers to visual-spatial

Table 5 Stepwise hierarchical regressions predicting mathematical performance for younger and older group

Grades 1–3	***F***	***ΔF***	***R^2adj***	***ΔR^2adj***	***b***	***β***	***t***	***p***
Model 1[a]	13.80	-	0.26	-	-	-	-	< 0.001
Model 2[b]	12.41	− 1.39	0.32	0.06	-	-	-	< 0.001
Step 1								
Sex	-	-	-	-	− 0.07	− 0.05	− 0.50	0.616
Age	-	-	-	-	0.32	0.53	0.53	< 0.001
Step 2								
Numerical processing	-	-	-	-	-	0.14	1.19	0.238
Numerical processing anxiety factor	-	-	-	-	− 0.04	− 0.26	− 2.69	0.009
Situational and performance anxiety factor	-	-	-	-	-	0.08	0.77	0.444
Non-verbal IQ	-	-	-	-	-	0.14	1.27	0.208
VS short-term memory (forward)	-	-	-	-	-	− 0.04	− 0.40	0.694
VS short-term memory (backward)	-	-	-	-	-	0.08	0.81	0.423
Verbal working memory	-	-	-	-	-	− 0.07	− 0.71	0.483
Impulsivity/Inhibitory control	-	-	-	-	-	− 0.01	− 0.08	0.934
Activation control	-	-	-	-	-	0.11	1.11	0.273
Attentional focusing	-	-	-	-	-	0.06	− 1.15	0.505
Inhibitory control	-	-	-	-	-	0.11	1.10	0.274
Grades 4–6	***F***	***ΔF***	***R^2adj***	***ΔR^2adj***	***b***	***β***	***t***	***p***
Model 1[a]	7.21	-	0.11	-	-	-	-	< 0.001
Model 2[b]	7.79	0.58	0.17	0.06	-	-	-	< 0.001
Step 1								
Sex	-	-	-	-	0.03	0.03	0.29	0.776
Age	-	-	-	-	0.15	0.25	2.46	0.016
Step 2								
Numerical processing	-	-	-	-	0.01	0.28	2.81	0.006
Numerical processing anxiety factor	-	-	-	-	-	− 0.05	− 0.49	0.627
Situational and performance anxiety factor	-	-	-	-	-	− 0.15	− 1.56	0.122
Non-verbal IQ	-	-	-	-	-	0.15	1.60	0.112
VS short-term memory (forward)	-	-	-	-	-	0.13	1.48	0.143
VS short-term memory (backward)	-	-	-	-	-	− 0.01	− 0.12	0.907
Verbal working memory	-	-	-	-	-	0.18	1.93	0.057
Impulsivity/Inhibitory control	-	-	-	-	-	− 0.05	− 0.53	0.596
Activation control	-	-	-	-	-	0.07	0.77	0.446
Attentional focusing	-	-	-	-	-	− 0.10	− 1.10	0.276
Inhibitory control	-	-	-	-	-	− 0.03	− 0.30	0.762

Models 1 and 2 refer to the two intermediate steps of the stepwise procedure, [a]Predictors: Age, [b]Predictors: age and numerical processing anxiety factor, Step 1 and 2 indicate the order in which variables were entered into the regression blocks, *F* F statistic for the step, *ΔF* change in F statistic from the previous step, *R^2adj* adjusted in R^2 for the step, *ΔR^2adj* change in adjusted R^2 of the previous step, *b* unstandardized beta coefficient, *β* standardized beta coefficient, t *t*-value for the individual predictor *p* *p*-value for the individual predictor. "VS" refers to visual-spatial students), and all continuous variables were mean centered prior to creating the interaction terms.

The moderated stepwise hierarchical regression was significant F (5,167) = 53.93, $p < 0.001$ and reported that age ($\beta = 0.25$, $p < 0.001$), two domain-specific factors, numerical processing ($\beta = 0.01$, $p = 0.027$) and numerical processing MA ($\beta = -0.02$, $p = 0.044$), and one -general factor, non-verbal IQ ($\beta = 0.03$, $p = 0.007$) were significant mathematical performance predictors at elementary school. The model explains 61% variance (R^2 *adjusted* = 0.61, $p < 0.001$) (see Table 7) with medium effect size (Cohen's $f^2 = 1.63$; $R^2 = 0.62$). Moreover, neither interaction between grade and each domain-specific and -general factors resulted significantly in the model. Thus, the developmental stage (in this case the age) makes a direct contribution, suggesting that the grade exerts additive effects rather than interactive effects.

Discussion

Despite the great efforts of cognitive and educational psychologists to address the factors underlying children's mathematical performance, it remains unclear if domain-specific and -general factors affect mathematical performance in a similar way across elementary school (1^{st}–6^{th} grades). It is also essential to consider young *versus* older schoolchildren separately because each elementary school stage entails different cognitive demands, which involve certain domain-specific and -general factors. Thus, the present study contributed to the effort to identify domain-specific and -general factors related to individual differences in mathematical performance across elementary school and also distinguishing between two educational stages: the first (1st-3rd grade) and second (4th-6th grade) stages in elementary school. Our findings indicate that, while numerical processing, non-verbal IQ, and numerical processing MA were relevant across elementary school years, numerical processing MA stood out as a relevant factor for the first stage, and numerical processing for students in the second stage.

Identifying which domain-specific and -general factors predict mathematical performance across elementary school

The first aim was to investigate the link between domain-specific and -general factors and mathematical performance across elementary school. Zero-order correlations informed that the majority of domain-specific and -general factors (except the situational and performance MA and attentional focusing) were significantly associated with mathematical performance across school years (grades 1-6). Regarding the domain-specific factors that had been included in the study, numerical processing and the numerical processing MA were significantly related to mathematical performance across elementary school. The results regarding the numerical processing ($r = 0.65$) are consistent with those reported in previous studies for all elementary stages (Ferreira et al., 2012), and also confirmed by two meta-analyses (Chen & Li, 2014; Schneider et al., 2017). Our findings add more empirical evidence to support the affirmation that numerical processing is a fundamental basis for mathematical development (for a review see De Smedt et al., 2013), as the comprehension of symbolic numerical magnitudes serves as a crucial scaffold for the development of advanced counting strategies (for a review see Vanbinst & De Smedt, 2016), while, in contrast, lower performance in numerical processing is associated with mathematical difficulties (Ashkenazi et al., 2008; Landerl, 2013). Moreover, our findings showed that low scores in the numerical processing MA were significantly associated with lower mathematical performance ($r = -0.15$). This result turned out to be consistent with previous studies reporting that MA influences mathematical performance longitudinally (Ramirez et al., 2013; Vukovic et al., 2013; for meta-analyses studies: Namkung et al., 2019; Zhang et al., 2019). Thus, it is noted that there is a "specific fear, tension, and worry" (De Smedt, 2022) that is related to math stimuli (for instance, when a student has to solve a division or multiplication) and this feeling is associated with poorer mathematical performance at scholar years.

On the other hand, the domain-general factors of non-verbal IQ, visospatial short-therm memory (forward and backward), VWM, impulsivity/IC, activation control and IC yielded significant associations with mathematical performance. Not surprisingly, a bulk of knowledge has described a significant relation between fluid intelligence and academic performance at different educational stages of elementary school (Li & Shi, 2021; Wechsler-Kashi et al., 2014), middle school (Soares et al., 2015) and young adults (Rohde & Thompson, 2007). On the other hand, visospatial short-therm memory (forward, $r = 0.47$; backward, $r = 0.45$), and VWM ($r = 0.37$) were linked significantly with mathematical performance. These findings are consistent with those reported in previous empirical studies (Allen et al., 2020; Dulaney, 2014; Hu et al., 2023) and a meta-analysis published by Xie et al. (2020), which showed a significant relationship in samples aged 5 to 23. On the other hand, higher scores on impulsivity/IC ($r = -0.25$) were associated with lower scores in mathematical performance. In the case of EC, two dimensions (activation control ($r = 0.14$), and IC ($r = 0.17$) had a significant correlation with mathematical performance. This significant relation with mathematical performance in the three lastly domain-general factors concords with previous studies (IC: Barradas Cordeiro et al., 2024; Ren et al., 2019; EC: Sánchez-Pérez et al., 2024). Our study provides additional evidence supporting the theoretical importance of these domain-general factors in relation to mathematical performance across elementary school years. However, it is important to note that some literature contradicts the association between these domain-general factors and mathematical performance (e.g., for WM: Carr et al., 2008; Haciomeroglu, 2015; for a meta-analysis: Xie et al., 2020; IC: Wilkinson et al., 2020; and EC: Sánchez-Pérez et al., 2015). These authors argued that the lack of significance could be explained by the measures employed to assess WM (Xie et al., 2020) or by the method used to evaluate IC, which moderates the relationship between the IC factor and mathematics (Allan et al., 2014; Zhu et al., 2025).

In terms of mathematical predictors, the regression analyses informed that, regarding the domain-specific factors, numerical processing and numerical processing MA showed a significant association with mathematical performance and emerged as predictors ($\beta = 0.01$; $\beta = -0.02$, respectively), which is consistent with previous studies (numerical processing: Vanbinst & De Smedt, 2016; for a meta-analysis see Agostini et al., 2022; numerical processing MA: Szczygiet & Sari 2024; for meta-analyses, see Barroso et al., 2021; Namkung et al., 2019). As regards the domain-general factors, only non-verbal IQ emerged as a predictor of mathematics performance ($\beta = 0.08$). This finding is not surprising, as non-verbal IQ is considered one of the most robust predictors (Green et al., 2017, 2019), given its role in supporting understanding and learning across several domains, including mathematics and reading (for a meta-analysis, see Peng et al., 2019). On the other hand, it might be unexpected that none of the WM variables emerged as significant predictors as WM is one of the most extensively documented predictors of mathematical performance (Geary et al., 2017; Vanbinst & De Smedt, 2016; for a meta-analysis, see Agostini et al., 2022). However, this result might be related to the measure of mathematical performance used in the present study. Concretely, our mathematical performance variable is composed of Calculation and Fluency math tests, and Pina et al. (2014) already pointed out that fluency math might depend more on recovery of number facts from long-term memory (Andersson, 2008), with less support on WM processes included in our study.

Examining which of these domain-specific and -general factors predict mathematical performance in each stage (1st-3rd grades vs. 4th-6.th grades)

The second goal was to identify which domain factors predicted mathematical performance in each stage separately (1st–3rd grades vs. 4th–6th grades). The results indicated that, for the first elementary stage (1st–3rd grades), numerical processing MA ($\beta = -0.04$) predicted mathematical performance, while all domain-general factors were found to be non-significant predictors when all variables were introduced in the model. In contrast, during the second elementary stage (4th–6th grades), numerical processing was the relevant predictor of mathematical performance. To our knowledge, this is the first study to analyze a wide range of domain-specific and -general factors distinguishing between young/old elementary schoolers. However, these factors have been described as predictors for mathematical performance in elementary education, in line with our findings.

Specifically, the results highlighting the importance of MA for younger children have been supported by previous studies in second and third grades (Vukovic et al., 2013; Wu et al., 2012, 2014), although this result turned out to be inconsistent with previous studies reporting that MA influences mathematical performance longitudinally (Ramirez et al., 2013; Vukovic et al., 2013; for meta-analyses studies: Namkung et al., 2019; Zhang et al., 2019). Our results may be related to the fact that students might react less negatively to math operations as a consequence of familiarity with school tasks throughout the elementary school years (Sorvo et al., 2017). However, another explanation related to the specific MA measurement is also possible. As affirmed by the authors of the Spanish SEMA (Sánchez-Pérez et al., 2021), the content of the items was more related to second- and third-grade math curricula, which could have produced a floor effect on the levels of anxiety experienced by the older children, resulting in a less fine approach to numerical processing MA for the second stage group (grades 4–6). It might be surprising that, whereas the numerical processing MA is highly relevant for mathematical performance for younger students, the MA factor associated with social and examination situations that involve mathematics is not. The explanation might be related to the sample's age, as social anxiety symptoms, as an expression of childhood anxiety symptoms and fears, are more prominent in adolescents (Weems & Costa, 2005) than in younger children. Consequently, younger children might not be as sensitive as adolescents to the fear of negative judgment, failure, or social awkwardness that using math in public, social or evaluative contexts can bring.

In the case of numerical processing ($\beta = 0.01$), this domain-specific factor might be more important in the second stage of the elementary school as its proficiency increases during the elementary school years (Landerl & Kölle., 2009; Mann et al., 2012; Vanbinst et al., 2018).

Educational stage as a moderator in the relationship between domain-specific and -general factors and mathematical performance

The third objective was to determine whether the elementary school stage could moderate the link between domain-general and domain-specific factors and mathematical performance. Our findings showed the educational stage did not moderate the relation between these variables, suggesting additive rather than interactive effects. To the best of our knowledge, previous research has not used the same moderating analysis as the present study. However, the non-significant results of the moderation analysis, along with the other results of this study, might reflect that children's developmental stage seems to exert a direct and additive influence on mathematical performance rather than a moderation influence. This influence would be reflected in the different results of the regression analyses when distinguishing between the sample of young children and the sample of older children, resulting in differential factors being more relevant at the beginning of schooling (such as numerical processing MA), compared to factors that are more relevant for older students (such as numerical processing).

Limitations and future research

Despite the advantages of the present study and its contributions to the state-of-the-art, two major limitations should be considered**.** Firstly, the scale used to measure MA might not capture the developmental changes in MA and, consequently, it might lose power to predict low mathematical performance in older schoolchildren. In fact, it has been widely shown that some authors reported a relation between mathematical performance and MA depending on MA assessment (for a meta-analysis study see Peng et al., 2019). In order to address this limitation, future studies should incorporate a specific method designed to evaluate all school levels. Secondly, the size of the sample prevented an analysis of the potential similarities and differences in each school grade. This limitation should be addressed in future research as our results, even with only two stages, showed that the contribution of domain-specific and -general factors in mathematical performance varies depending on the elementary school stage.

Conclusion

This study aimed to elucidate the domain-specific and -general factors that influence mathematical performance across elementary school and also distinguish between different elementary school stages (1^{st}–3^{rd} grades *vs* 4^{th}–6^{th} grades). The findings revealed that numerical processing, numerical processing MA , and non-verbal IQ are math performance predictors across elementary school, whereas numerical processing MA was the relevant predictor for the younger sample and the symbolic numerical processing the most important variable explaining mathematical performance for the older group. Moreover, the educational stage was found not to moderate the relationship between mathematical factors and mathematical performance, suggesting the existence of additive effects rather than an interactive relation between students' developmental stage and mathematical performance. Hence, future research should continue to explore these relationships longitudinally and across different contexts to further improve our understanding of mathematical performance development in elementary school students.

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Data Availability The data that support the findings of this study are available on request from the corresponding author.

Declarations

Competing interests The authors declare no competing interests.

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Current themes of research and most relevant publications

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Most relevant publications

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Current themes of research

Cognitive, social, motivational, and emotional factors that influence academic performance; children's benefit of contact with nature; new technologies applied to education.

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Current themes of research and most relevant publications

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Current themes of research

Children's temperament and adjustment, children's benefit of contact with nature, learning difficulties; cognitive, motivational, and emotional factors that influence academic performance.

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