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The contribution of children's effortful control to math performance is partially mediated by math anxiety

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Abstract
This study aimed to ascertain the contribution of children's effortful control (EC) to math achievement by testing the mediational involvement of math anxiety. Participants were 704 children (367 girls) aged between 7 and 12 years (M = 9.43, SD = 1.23). Children's EC was measured by parent's report, math anxiety was assessed through self-report, whereas math achievement was evaluated by performance on standard math tests. The models tested involved EC higher-order factor or specific EC components (activation control, attentional focusing, and inhibitory control). The results showed that activation control, attentional focusing, and EC higher-order factor contributed to math performance directly and through the mediation of math anxiety. Inhibitory control did not yield a significant effect on math performance. The findings suggest that children with higher dispositional effortful self-regulation tend to experience lower levels of math anxiety, with positive effects on math performance.

Keywords Math anxiety · Mathematics · Effortful control · Childhood · Temperament

Introduction

Mathematics constitutes a key discipline in current knowledge societies in that students with high levels of math achievement tend to enjoy several positive outcomes, such as high educational aspirations (Widlund et al., 2018), adult socioeconomic status (Ritchie & Bates,

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2013), and well-being (Zhou et al., 2022). Moreover, such students are more prone to enroll and later take Science, Technology, Engineering, and Mathematics (STEM) occupations (Wang et al., 2017), which involve high social recognition and financial rewards. Given its importance, research has been devoted to determining which factors could promote or hinder math achievement. In this respect, a traditional line of research stressed the contribution of cognitive abilities, such as intelligence or executive functions (see Cortés Pascual et al., 2019; Peng et al., 2016 for respective meta-analyses). However, in the last decades, research has additionally focused on the emotional and motivational factors that affect the process of learning and subsequent academic achievement (e.g., Eisenberg et al., 2010; Pekrun, 2006). In line with this last emphasis, the present study aims to ascertain if children's dispositional self-regulation abilities are associated with math achievement and whether this relationship is mediated by the actual negative emotions aroused in children throughout learning mathematics. More specifically, the proposed model suggests that their math anxiety level mediates the contribution of children's effortful control on mathematics performance.

Effortful control and math performance

Effortful control (EC) reflects individual differences in the efficiency of executive attention (Rothbart et al., 2006). It is operationally defined as "the ability to inhibit a dominant response in order to perform a subdominant response, to detect errors, and to engage in planning" (Rothbart, 2011, p. 57). EC covers the individual's ability to employ top-down control to self-regulate (Nigg, 2006; Rothbart, 2011) by deploying attentional control processes, the inhibition of prepotent behaviors in response to instructions or social demands, and the capacity to act when there is a strong tendency to avoid it (Rueda, 2012).

Like executive function, EC is involved in goal-directed control of cognition, emotion, and behavior. Given their overlapping conceptualization, it is worth clarifying the delimitation of both constructs: EC has been conceptualized within a developmental framework of temperament (Rothbart, 1989). It is defined at the level of attentional and behavioral control tendencies, which are influenced throughout time by heredity and experience, and it has been chiefly measured through adult ratings of children's behavior observed in real-world settings such as home or school. In contrast, executive function has been developed within cognitive neuroscience frameworks (e.g., Miyake & Friedman, 2012), is defined as the efficiency of higher-order neurocognitive processes (e.g., updating, inhibition, and shifting), and is often measured through performance in cognitive tasks.

Nonetheless, it is apparent that both constructs overlap conceptually, and even the same brain structures are proposed to underly the inhibitory and attentional control mechanisms involved in EC and executive functioning (Diamond, 2013; Kim-Spoon et al., 2019). Given these commonalities, researchers have expected EC and executive function measures to be related, but previous efforts found weak to modest correlations (Rueda et al., 2004; Simonds & Rothbart, 2004; Ten Eycke & Dewey, 2016). More recently, it has been pointed out that the low associations found could be explained by differences in the measurement strategy rather than in the conceptualization of both constructs (Nigg, 2017); in support of this idea, when both constructs have been measured using behavioral ratings, they have been found highly correlated, suggesting that the two rubrics represent the same underlying self-regulation construct (Tiego et al., 2020).

Concerning the contribution of EC to math achievement, it would promote self-regulation of work-related impulses, permitting the child to sustain attention and effort despite frustration, boredom, or confusion (Duckworth & Allred, 2015). Indeed, strong evidence shows concurrent and predictive relations between EC and mathematics achievement during school years (Hernández et al., 2017; Sánchez-Pérez et al., 2015; Swanson et al., 2014; Valiente et al., 2007, 2011).

Most of the studies above mentioned used a broad measure of effortful self-regulation. However, EC is constituted of a set of dimensions representing a variety of mechanisms that, although correlated, are also dissociable and could differentially contribute to mathematics performance. More specifically, EC includes attention focusing, inhibitory control, and activation control dimensions during school years. Attention focusing covers individual differences in the ability to persist in ongoing tasks, avoiding possible distractions, and would affect academic achievement because it is required for children's engagement in learning activities and completion of tasks, and facilitates (or disrupts) classroom processes (Ladd et al., 1999; Posner & Rothbart, 2007). In support of this hypothesis, previous studies showed that children with a higher ability to concentrate and focus on tasks achieved better mathematics performance in kindergarten (Rudasill et al., 2010) and elementary school (Ato et al., 2020; Sánchez-Pérez et al., 2015, 2018). Inhibitory control encloses individual differences in the ability to suppress incorrect/inappropriate responses under instructions or in attending to social demands (Kochanska et al., 2000; Simonds & Rothbart, 2004) and implies the maintenance in working memory of a rule for correct responding while inhibiting a prepotent response tendency. In the school routine, this ability would allow children to suppress disruptive behaviors in the classroom and to follow the instructions given by the teacher. In line with this interpretation, better inhibitory abilities have been associated with higher scores in children's mathematics performance in elementary school (Oberle & Schonert-Reichl, 2013; Welsh et al., 2010), although other studies failed to find significant associations (e.g., Sánchez-Pérez et al., 2015). Finally, activation control reflects individual differences in the ability to accomplish an action when there is a strong tendency to avoid it. At school, this ability would help students do the homework or study for an exam, albeit they would rather avoid these activities. Although much less explored than the other EC scales, previous studies reported that elementary school students who scored higher in activation control tended to obtain higher math achievement (e.g., Sánchez-Pérez et al., 2018).

Given the evidence from broad and fine-grained approaches, which one should researchers choose to examine the contribution of EC on mathematics performance? The "broad *versus* narrow measures" debate about criterion validity is ongoing (see Chapman, 2007 for a review). On the one hand, the broad score usually has higher reliability than the specific scales because the broad factor contains more items than the specific ones, and the narrow scales are highly intercorrelated (Ones & Viswesvaran, 1996). On the other hand, the meaning of the resulting composite score might be difficult to interpret. It might lose predictive power because the association of specific scales with the criterion of interest is diluted (Ashton, 1998). Aware of this issue, we considered the contribution of EC higher-order factor and each EC individual subscale to better understand the different EC mechanisms' role in children's math performance. In addition, we aimed to ascertain the interplay between children's effortful self-regulation and math anxiety in predicting math performance.

Math anxiety and math performance

Math anxiety (MA) is defined as the "feeling of tension, apprehension, or even dread that interferes with the ordinary manipulation of numbers and the solving of mathematical problems" (Ashcraft & Faust, 1994, p. 98). Although not incorporated as a separate diagnostic category in the primary diagnostic systems for mental disorders, DSM-V-R

(American Psychiatric Pub., 2013) and ICD-11 (World Health Organization, 2018), MA expressions, such as fears about performing well at school, are included as part of the symptoms of the Generalized Anxiety Disorder in children and adolescents (Papousek et al., 2012). MA can work like a phobia, affecting individuals at physiological, cognitive, and behavioral levels; previous studies found that schoolchildren (Hunt et al., 2017) and adults (Faust, 1992) who scored high in MA exhibited a greater physiological reactivity to mathematics, tended to experience more intrusive thoughts (Hunt et al., 2014), to experience difficulties for controlling emotional distraction induced by math information (Cohen & Rubinsten, 2022), to deplete their working memory resources, and to display poorer basic number processing ability (Skagerlund et al., 2019). They also showed behavioral disengagement bias, specifically away from mathematical stimuli (Pizzie & Kraemer, 2017) and higher avoidance of effortful study strategies (Jenifer et al., 2022).

Not surprisingly, MA has been negatively associated with children's math performance (Ma, 1999; Ramirez et al., 2013, 2016; Sánchez-Pérez et al., 2021; Vukovic et al., 2013; Wu et al., 2012; see Barroso et al., 2021 for a meta-analisis). Nonetheless, the causal direction of this relationship as well as the mechanisms involved are still under debate (Skagerlund et al., 2019). Some theories (referred to as *deficit models*) state that poor math skills and visuo-spatial skills, and first experiences of failing in math, altogether with poor executive functioning, would lead students to develop anxiety in math-related learning situations (e.g., Ashcraft & Kirk, 2001; Maloney, 2016). In the opposite causal direction, the *debilitating models* (e.g., Ashcraft & Moore, 2009; Dowker et al., 2016; Eysenck et al., 2007) propose that MA would affect math performance by inducing avoidance of math learning situations and through cognitive interference; specifically, MA could produce intrusive thoughts, which would overload the limited working memory capacity, hindering the necessary cognitive resources for computing math-related problems, lastly undermining math achievement. Nonetheless, the *reciprocity theory* (Carey et al., 2016) integrates the previous perspectives and establishes that MA and math performance influence each other in a bidirectional relationship.

Additionally, the causes of MA are multiple and complex; indeed, as proposed by Rubinsten et al. (2018), MA arises from the dynamic interplay between environmental (e.g., parenting style, teachers' attitude, instruction strategies, and cultural norms and stereotypes about mathematics performance) and intrinsic factors (e.g., brain malfunctions, heritability, predisposition towards general anxiety, general cognition, numerical cognition, and affective factors).

Effortful control, math anxiety, and math performance

Among the intrinsic vulnerability factors considered in the model mentioned above (Rubinsten et al., 2018), the neurocognitive pathways that control negative emotions are of special interest to this study. For instance, highly math-anxious individuals were found to exhibit increased activation of the connection between the amygdala and ventromedial prefrontal cortex regions, and such overactivity happened concurrently with a decreased activation of the dorsolateral prefrontal cortex (Young et al., 2012), a brain structure involved in executive control. These findings inform of a higher effort on emotion regulation to the detriment of cognitive control in highly math-anxious individuals, which could explain poorer math performance in those who suffer from MA.

If the low cognitive control exhibited by highly math-anxious individuals is interpreted as a neural predisposition (Rubinsten et al., 2018), poor levels of executive and effortful self-regulation will constitute risk factors for the development of MA. The involvement of executive functioning, either as an antecedent (Ashcraft & Kirk, 2001) or as an effect of MA (see Finell et al., 2022 for a meta-analysis on the role of working memory) has been previously explored. In the case of EC, as far as we know, its association with MA has not been proven yet. However, there is a vast literature that identifies EC as a risk factor for the development of general anxiety and other internalizing problems (see Hougland et al., 2011 for a meta-analysis).

We expect EC to influence math anxiety, affecting in turn math performance. Although this mediational pathway of EC to math performance has not been tested yet, it is justified from a theoretical point of view. As reviewed by Zhou et al. (2010), EC is hypothesized to positively predict children's academic achievement through cognitive, motivational, emotional regulation, and interpersonal pathways. In short, *cognitive mechanisms* would allow children with high EC to be better at focusing, sustaining, and shifting attention as well as inhibiting prepotent responses as needed (Gerardi-Caulton, 2000; Rothbart et al., 2003; Rueda et al., 2005); *motivational mechanisms* would explain why children with high EC tend to be better at initiating, sustaining, and regulating their motivation and engagement in goal-directed activities, including academic learning (Kwon et al., 2018); *interpersonal mechanisms* would justify that children with high EC are expected to be better at developing and maintaining positive social relationships with peers and teachers (Sánchez-Pérez et al., 2018), which might facilitate learning and academic success; lastly, and relevant to our study, EC would influence children's academic performance through *emotion regulation mechanisms*. In previous research, EC was found to regulate reactivity and stress by suppressing and activating cognitive and behavioral responses (Valiente et al., 2009). According to this pathway, children with high EC are expected to be more successful at regulating their negative emotions and behavioral impulses (Blair, 2002), which might facilitate effective learning and promote academic achievement. Applied to this study, EC would contribute to mathematics performance by reducing children's anxiety aroused while manipulating numbers and solving mathematical problems.

The present study

This study aimed to understand better the mechanisms through which EC can contribute to math performance in a sample of Spanish elementary school children. More specifically, it was proposed that the relationship of EC to math performance would be mediated by math anxiety so that children with better EC would exhibit lower levels of MA, decreasing the negative effect of MA on math performance. Given that EC is a broad construct of several correlated but different mechanisms, the specific contribution of activation control, attention focusing, and inhibitory control was explored. The models also considered the effect of grade, non-verbal IQ, sex, and socioeconomic status (SES) on the variance of math performance (see Fig. 1).

The proposed models arouse from concern about the low math performance of Spanish students. The Programme for International Student Assessment (PISA) repeatedly reported that the Spanish students' mathematics performance is lower than the average of the Organization for Economic Cooperation and Development (OECD, 2012, 2014, 2019), with 24.7% of Spanish students considered low performers in math, meaning that they cannot interpret nor recognize, without direct instructions, how a (simple) situation can be represented mathematically (e.g., comparing the total distance across two alternative routes, or converting

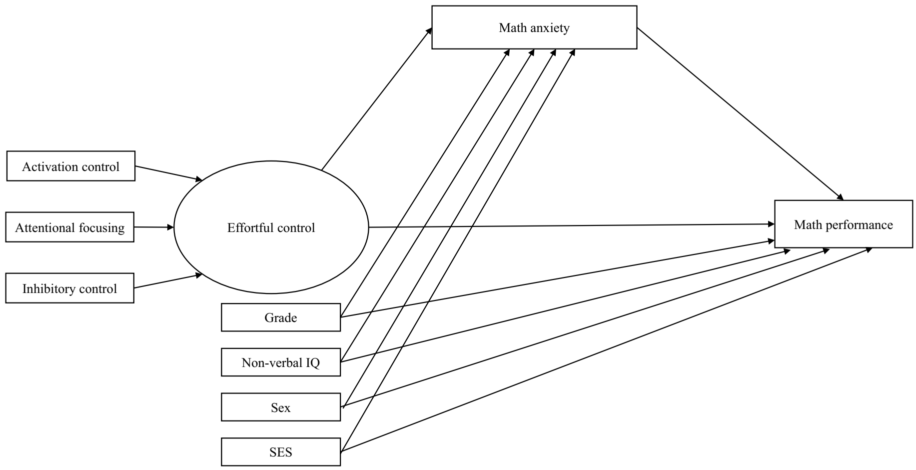

Fig. 1 Hypothesized model for the relation between effortful and math performance mediated by math anxiety

prices into a different currency; OECD, 2019). Moreover, the instructional system followed by the schools of this study may rely on particular skills to be successful. Like most State primary schools in Spain, it is characterized by a heavy load of individual work at school and home and a high student–teacher ratio; in such situations, children's differences in effortful self-regulation might be particularly relevant for academic achievement.

Material and methods

Participants

The participants were children recruited from schools collaborating in a broader project to identify individual and environmental factors associated with math performance. The schools were located in rural and urban areas of the Region of Murcia (SE, Spain). Initially, the sample was composed of 1120 children, but 416 cases (37.14%) were excluded from this study for several reasons: 143 children had been diagnosed with learning disability or clinical problems; 270 cases in that parents did not complete the temperament questionnaire, and 3 cases as their families withdrew from the study. The final sample was composed of 704 children (367 girls, 337 boys) aged 7 to 12 years ($M = 9.43$, SD = 1.23) who were enrolled in 3rd to 6th grade (additional demographic information is provided in Table 1).

Measurements

Effortful control

Parents completed the Temperament in Middle Childhood Questionnaire (TMCQ; Simonds & Rothbart, 2004), validated in a previous study in the Spanish population

Table 1 Demographic characteristics of participants

	Final sample
Gender	
Girls	367
Boys	337
Grade	
3rd	157
4th	183
5th	188
6th	176
Background	
European background	95.3%
Latin American background	2.1%
African background	.7%
Asian background	.9%
Other backgrounds	1%
Mothers' education*	
Elementary school level	31.5%
High school	25.1%
University level	43.4%
Fathers' education*	
Elementary school level	38.3%
High school	27.3%
University level	34.4%
Monthly family income*	
Less than 750€	3.6%
751–1200€	12.9%
1201–1600€	13%
1601–2000€	16.1%
2001–3000€	28.9%
More than 3000€	25.5%

*Demographic information reported by 95.17% of the sample

(González-Salinas et al., 2012). Parents assessed how each item accurately described their child's behavior within the previous 6 months. Each statement was scored using a 5-Likert type scale (1 = almost always untrue to 5 = almost always true, with an additional option of "Not applicable" if parents did not observe their child in the specified situation). In this study, TMCQ was primarily informed by the children's mothers (68.3%). Effortful control was composed of the following scales: activation control (ability to act when there is a strong tendency to avoid it; e.g., " (my child) has a hard time speaking when scared to answer a question"—reversed; 15 items, $\alpha = 0.73$, item-test correlation ranging from 0.20 to 0.43); attention focusing (tendency to maintain one's attentional focus on task-related channels, e.g., "When working on an activity, has a hard time keeping her/his mind on it"—reversed; 7 items, $\alpha = 0.88$, item-test correlation ranging from 0.48 to 0.78); and inhibitory control (ability to plan and suppress inappropriate approach responses under instructions or attending to social demands, e.g., "Can stop him/herself when s/he is told to stop"; 10 items, $\alpha = 0.69$, item-test correlation ranging from 0.21 to 0.43). The internal consistency of broad EC including all scale items was 0.87, item-test correlation ranging from 0.21 to 0.62 ($n = 32$ items). The score of each scale was computed by dividing the total by the number of items receiving a numerical response.

Math anxiety

Children completed the Spanish version (Sánchez-Pérez et al., 2021) of the Scale for Early Mathematics Anxiety—SEMA—(Wu et al., 2012). They reported how anxious they felt if they were confronted with either a situation that required solving math questions (numerical processing factor, ten items, e.g., "Is this right? $15 - 7 = 8$," $\alpha = 0.71$) or coping with social and testing situations involving mathematics (situational and performance factor, ten items, e.g., "You are about to take a math test," $\alpha = 0.78$). Following authors' instructions, a five-point scale was used (from 0 = not nervous at all to 4 = very very nervous); ratings were shown with graded anxious faces to help children identify their anxiety levels. Children responded by selecting one of the faces. The total MA score was computed by summing the items' ratings ($\alpha = 0.84$), with higher scores meaning higher MA.

Math performance

Children completed the Calculation and Math Fluency subtests of the Woodcock-Johnson III (WJ-III) Achievement battery (Woodcock et al., 2001; Spanish validation developed by Diamantopoulou et al., 2012). The Calculation subtest (unlimited time task) assesses the student's ability to perform simple mathematical computations, including addition, subtraction, multiplication, and division. In contrast, Math Fluency measures the ability to quickly solve simple calculations (limited time task: 3 min). Mathematics performance was calculated by adding the standardized scores of both scales.

Non-verbal IQ

Children responded to the non-verbal IQ subtest of the Spanish version of the Kaufman Brief Intelligence Test (Kaufman & Kaufman, 1990). This measure covers children's non-verbal reasoning and flexible problem-solving skills (for our sample, $\alpha = 0.83$).

Socioeconomic status (SES)

An index of SES was obtained for each child, taking into account three variables: (1) the mother's education level in years, (2) the father's education level in years, and (3) monthly family incomes. Each variable was standardized and then averaged to form a composite score of SES.

Procedure

The study was approved by the Ethics Committee of the University of Murcia and conducted in accordance with the Declaration of Helsinki. In collaboration with the regional government, the headteachers of the schools in the area of Murcia were invited to participate. For the schools that agreed to take part in the study, we sent letters to the families describing the research project, consent forms, and questionnaires to gather demographic information. Once the parents completed the forms, they returned them to school. We sent a second letter containing the TMCQ to parents who agreed to participate so they could complete the questionnaire at home and later return it to school. A research team member was available at school to answer any questions or concerns raised by the parents. All the measures were taken in the 2018–19 academic year by research group members. Children completed SEMA and another unpublished MA-related questionnaire in an individual session in the first term. In the second term, children completed the non-verbal IQ and the math abilities subtests in a group session (range = 6–24 children). Verbal assent was obtained from each child prior to each session.

Results

Correlational, t-test, and ANOVA analyses

Descriptive statistics, including specific samples, kurtosis, skewness, means, and standard deviations for all variables under study, are presented in Table 2.

Firstly, zero-order correlations, *t*-tests, and ANOVA analyses were computed to evaluate the potential variables to be controlled (non-verbal IQ, SES, sex, and grade). Zero-order correlations revealed that SES was positively associated with Fluency, Calculation, and math grades, whereas non-verbal IQ was negatively related to scores in MA and positively to mathematics performance (see Table 3).

Sex differences were tested through independent *t*-test analyses, which yielded significant effects on mathematics performance, t [670] = −4.82, $p < 0.001$, with boys ($M = 0.41$, SD = 0.09) scoring higher than girls ($M = -0.17$, SD = 0.08), while they did not bring significant differences for MA, t [702] = 1.02, $p = 0.306$. ANOVA results showed significant grade effects in MA, $F(3, 700) = 4.40$, $p = 0.004$, and mathematics performance, $F(3, 668) = 126.99$, $p < 0.001$. Bonferroni post hoc tests showed that third-graders ($M = 14.90$, SD = 9.35) experienced more MA than fifth- ($M = 12.15$, SD = 7.39) and sixth-graders ($M = 12.05$, SD = 8.61), whereas mathematics performance was found to increase significantly from 3rd to 6th grade (3rd grade: $M = -1.28$, SD = 1.20; 4th grade: $M = -0.37$, SD = 1.21; 5th grade: $M = 0.71$, SD = 1.26; and 6th grade: $M = 1.26$, SD = 0.11). Therefore, SES, non-verbal IQ, sex, and grade were included as control variables for math performance, whereas non-verbal IQ and grade were taken into account for children's MA.

Zero-order correlations were run to elucidate significant associations between the proposed independent, mediational, and dependent variables. The results indicated that higher activation control, attention focusing, and inhibitory control were associated with lower MA and better math performance. In contrast, higher scores in MA were associated with lower math performance (shown in Table 3).

Structural equation analyses

A total of 4 structural equation models were run. In all models, the independent variable was children's self-regulation abilities, either considered broadly, including EC as a latent variable, or focused on the specific mechanisms of activation control, attentional focusing, and inhibitory control; MA was introduced as a mediator variable; math performance as the dependent

Table 2 Descriptive statistics for variables under study

	Kurtosis	Skewness	*M* (SD)					
			Boys ($n=337$)	Girls ($n=367$)	3rd graders ($n=157$)	4th graders ($n=183$)	5th graders ($n=188$)	6th graders ($n=176$)
Activation control	−.02	.03	3.46 (.54)	3.43 (.53)	3.44 (.53)	3.38 (.50)	3.45 (.55)	3.50 (.54)
Attentional focusing	−.41	−.42	3.52 (.92)	3.63 (.91)	3.47 (.90)	3.46 (.88)	3.61 (.94)	3.77 (.90)
Inhibitory control	−.08	−.08	3.44 (.57)	3.60 (.53)	3.43 (.56)	3.47 (.54)	3.59 (.53)	3.59 (.57)
Math anxiety	2.70	1.29	12.83 (8.33)	13.50 (8.86)	14.90 (9.35)	13.84 (8.70)	12.15 (7.84)	12.05 (8.78)
Fluency	.00	.44	66.23 (20.93)	57.72 (18.33)	46.54 (15.26)	57.80 (17.05)	67.30 (17.32)	74.17 (19.49)
Calculation	.09	−1.67	19.65 (5.22)	19.22 (4.50)	16.44 (3.89)	17.98 (4.26)	21.24 (3.93)	21.73 (5.23)
Math performance	.04	.12	.42 (1.64)	−.17 (1.49)	−1.29 (1.20)	−.37 (1.21)	.71 (1.26)	1.26 (1.41)

Table 3 Zero-order correlations for the proposed independent, mediational, dependent, and potential control variables

	Math anxiety	Math performance
Activation control	−.11**	.20***
Attentional focusing	−.24***	.31***
Inhibitory control	−.10**	.13***
SES	−.06	.19***
Non-verbal IQ	−.14***	.49***

**$p < .01$; ***$p < .001$

variable; SES, non-verbal IQ, sex, and grades were considered control variables for math performance, while non-verbal IQ and students' grade were taken into account to predict MA.

Broad EC predicting math performance through AM

The model including EC (see Fig. 2) yielded adequate goodness of fit, CFI = 0.93, and SRMR = 0.07. The results showed a direct contribution of children's EC to their math performance, with higher EC predicting better scores on math performance, $\beta = 0.13$, $p = 0.005$, 95% CI = [0.131, 0.196], even after including children's non-verbal IQ, SES, sex, and grade as control variables. Moreover, an indirect effect was found, in which better EC was associated with lower levels of MA and, in turn, MA predicted poorer achievement in math performance; $\beta = 0.025$, $p = 0.050$, 95% CI = [0.021, 0.189].

Specific EC components predicting math performance through AM

The respective models involving activation control, attention focusing, and inhibitory control as independent variables (see Figs. 3, 4, and 5, respectively) showed adequate goodness of fit (see Table 4). The analyses indicated that activation control and attention

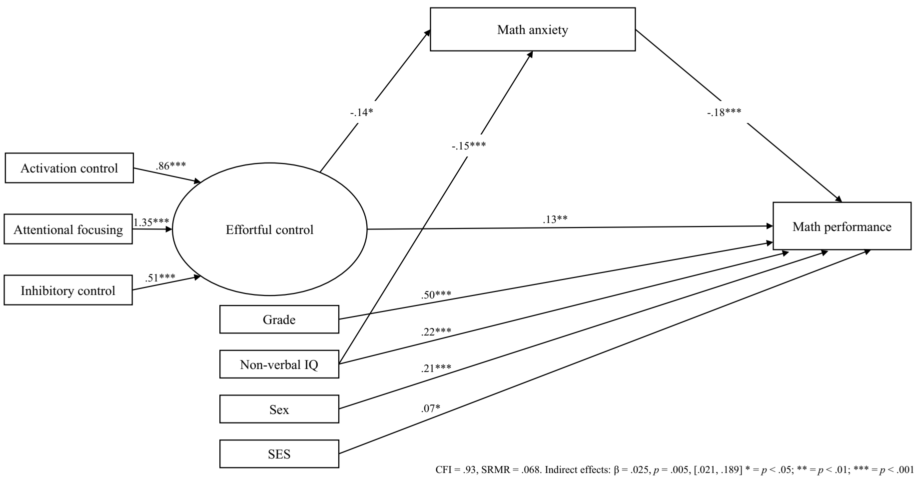

Fig. 2 Effortful control as partially mediated by math anxiety in predicting math performance

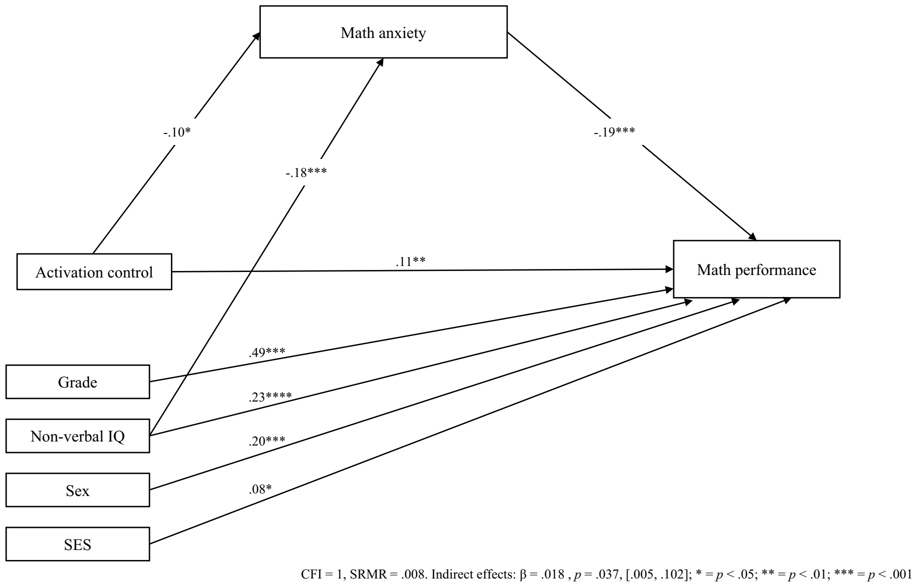

Fig. 3 Activation control as partially mediated by math anxiety in predicting math performance

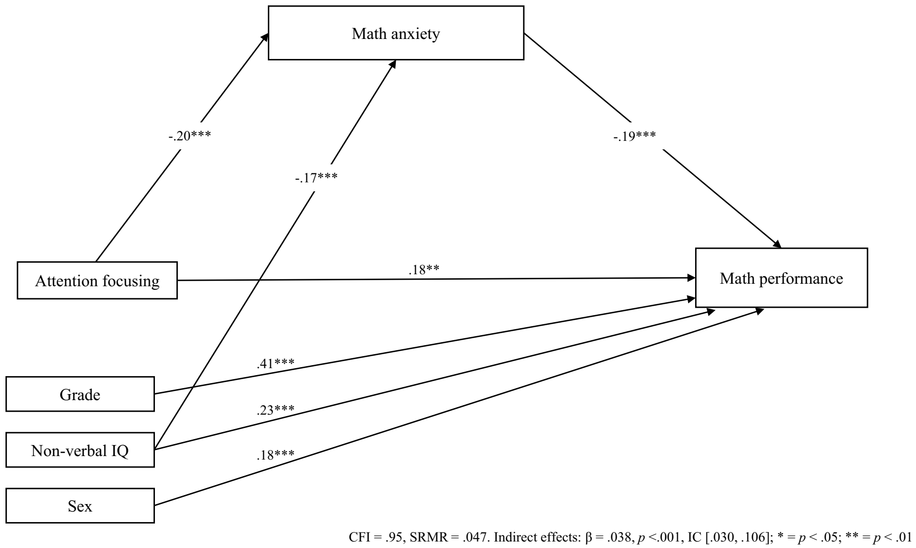

Fig. 4 Attention focusing as partially mediated by math anxiety in predicting math performance

focusing contributed directly to children's math performance, so higher scores in these scales predicted better math performance, even when children's non-verbal IQ, SES, sex, and grade were introduced in the model. However, a direct contribution of inhibitory control to math performance was not proved (see Table 4 and Figs. 3, 4, and 5 for more det ails).

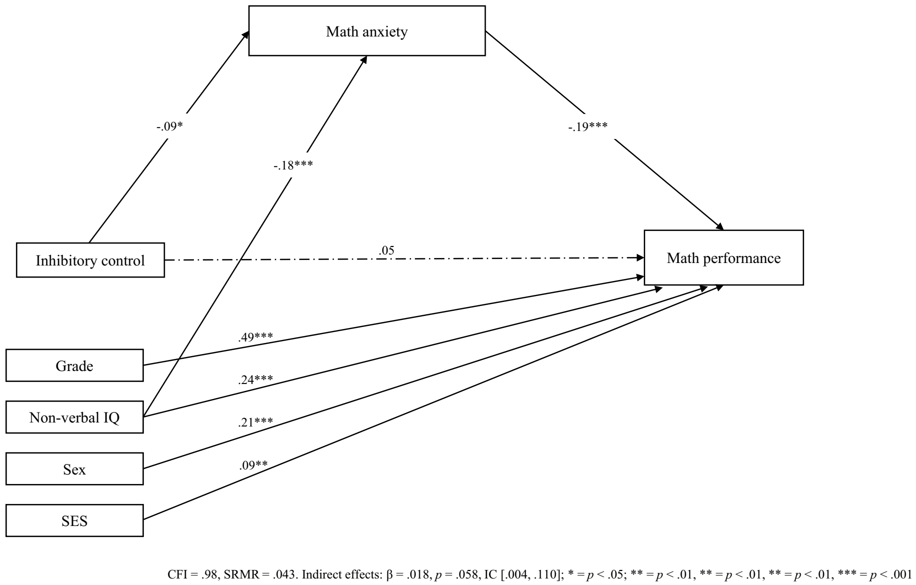

Fig. 5 Mediational model testing the contribution of inhibitory control on math performance through math anxiety

The mediational analyses confirmed that higher activation control and attention focusing were related to lower MA and, in turn, higher MA predicted lower scores on math performance. However, inhibitory control was found to exert neither direct nor indirect contribution to children's math performance (see Table 4 and Figs. 3, 4, and 5 for more details).

Discussion

The present study aimed to understand better how children's effortful self-regulation abilities affect their academic achievement. Our findings suggest that individual differences in children's effortful control contribute to mathematics performance and that children's levels of mathematics anxiety partially mediate this contribution.

Broad EC predicting math performance through MA

As hypothesized, our study confirmed that children's effortful control—as a broad factor—contributed to math performance directly and through the mediation of MA, even controlling by children's non-verbal IQ, SES, sex, and grade. Focusing first on the direct contribution, we found a positive association of EC with academic achievement, a recurrent result found previously (Hernández et al., 2017; Sánchez-Pérez et al., 2015; Swanson et al., 2014; Valiente et al., 2007, 2011). It informed that children with higher effortful self-regulation abilities obtained better performance in mathematics, as they were more ready to adequately undertake the different school tasks by paying attention to teachers' instructions and concentrating on tasks, avoiding possible distractions, suppressing possible disrupting behaviors, and putting their effort on goal-oriented activities. Similarly, executive functions

Table 4 Goodness of fit indices, AIC, BIC, and direct and indirect effects for the EC-global model and the three fine-grained models

					Direct effect			Indirect effect		
Independent variable	CFI	SRMR	AIC	BIC	Standardized coefficient	*p*	Interval confidence	Standardized coefficient	*p*	Interval confidence
Effortful control	.93	.07	9818.407	9925.407	.13	.005	[.131,.781]	.03	.050	[.021, .189]
Activation control	1	.01	6471.045	6529.004	.11	< .001	[.167, .484]	.02	.037	[.005, .102]
Attentional focusing	.95	.04	13,885.279	13,978.905	.18	< .001	[.203,.424]	.04	< .001	[.030, .106]
Inhibitory control	.98	.04	13,840.603	13,943.145	.05	.076	[− .024, .296]	.02	.055	[− .001, .107]

have been positively associated with mathematics achievement in primary school (see Cortés Pascual et al., 2019, for a meta-analysis). Altogether, these results highlight the importance of children's efficiency in goal-directed control of cognition, emotion, and behavior for successful academic achievement.

Most interesting, we found that MA partially mediated the contribution of EC. It means that children with higher EC exhibited better performance in timed and un-timed mathematics tasks by successfully regulating their negative emotions aroused in various mathematics-related situations. To our knowledge, this is the first study addressing the mediational role of schoolchildren's MA in the relation of EC to mathematics performance, extending the limited evidence that supports the emotion regulation pathway between EC and academic achievement. The involvement of self-regulation and other temperament characteristics in math negative emotions and performance has been scarcely studied. Nevertheless, Liew et al. (2014) found a mediational pathway in that highly fearful and inhibited college students suffered higher social-evaluative threats (fear of failure and being judged as unintelligent), negatively affecting their math performance. The paucity of studies involving effortful control is surprising, taking in mind the extensive research that has addressed the interactions of executive control and MA to predict math performance (e.g., Cohen & Rubinsten, 2022; Cuder et al., 2023; Hartwright et al., 2018; Orbach et al., 2020; Živković et al., 2023; see Finell et al., 2022, for a meta-analysis). In line with our results, such studies showed negative relations between executive control and MA, and higher levels of tension or apprehension in coping with math information were negatively associated with math performance. The negative association of MA with math performance has often been replicated (e.g., Ramirez et al., 2013, 2016; Sánchez-Pérez et al., 2021; Vukovic et al., 2013; Wu et al., 2012; see Barroso et al., 2021; Ma, 1999, for meta-analyses), but the interpretation of effects involving executive control has varied with the perspective adopted. From risk-factor models of MA (e.g., Rubinsten et al., 2018), poor executive functioning underlies a lower math performance and induces higher math anxiety, whereas from "debilitating models" (e.g., Eysenck et al., 2007; Suárez-Pellicioni et al., 2016; Suárez-Pellicioni et al., 2016), MA would produce intrusive thoughts, which would overload the limited working memory capacity, hindering the necessary cognitive resources for computing math-related problems. These opposite views have been integrated into the reciprocity theory (Carey et al., 2016), as both might explain different aspects of the same phenomenon.

EC components predicting math performance through MA

The mediational models that tested the contribution of each specific EC mechanism to explain individual differences in children's mathematics performance via their MA level showed different result patterns depending on the EC component analyzed.

Activation control, or the ability to voluntarily initiate behaviors to cope with task requests, even when there is a strong tendency to avoid them, contributed to math performance directly and indirectly through math anxiety. Focusing first on the direct contribution to math performance, children with higher activation control obtained better math performance, replicating previous research (Sánchez-Pérez et al., 2018). This EC component would allow children to initiate and maintain the behaviors that contribute to successful math learning and performance, as this ability enables the child to avoid procrastination and instead put their effort into school tasks or homework even if they find them boring or difficult. Moreover, the indirect link of activation control with math performance through MA means that children with better ability to initiate behaviors as requested by adults or attend to social demands by overriding their own impulses experienced lower levels of math anxiety, reducing, in turn, the harmful effects of MA on math performance. As stated by Ashcraft and Moore (2009), MA would activate avoidance mechanisms of mathematics-related situations, reducing math-learning experiences, consequently causing a detriment in math performance and increasing the levels of MA and other emotional problems. In support of this hypothesis, Skaalvik (2018) found a positive association of MA with performance-avoidance goals in middle school students so that those with higher MA avoided demonstrating incompetence or being negatively perceived by others and tended to use self-protective coping strategies (oriented to maintain self-worth and avoid negative self-perceptions), rather than problem-focused strategies, considered as forms of adaptive coping. In our sample, children with higher activation control could be more ready to overcome these avoidance tendencies and instead apply effortful study strategies, stopping the pernicious circle of MA.

Attention focusing also predicted math performance directly and through the mediation of AM. Concerning its direct and positive contribution, our results suggest that the ability to focus attention on tasks while ignoring possible distractors facilitates learning and performance of mathematics, in consonance with previous research (Ato et al., 2020; Rudasill et al., 2010; Sánchez-Pérezet al., 2015, 2018). The relevance of attentional processes for academic achievement was highlighted by Polderman et al. (2010) through a meta-analysis in which attentional problems were found to be associated negatively with academic achievement after controlling for intelligence, comorbidity, and SES. As Trentacosta and Izard (2007) pointed out, few constructs directly impact children's academic achievement more than their ability to pay attention in the classroom.

The indirect link between attention focusing and math performance through MA involved that children with a higher ability to focus their attention and avoid distractions experienced lower MA, reducing the negative effect of MA on math performance. Children with higher attentional control could probably use successful strategies to reduce the negative emotions experienced when coping with difficulties in math tasks. Indeed, the use of emotion regulation techniques based on attentional control, such as mindfulness or cognitive reappraisal, has proved successful in reducing the levels of math anxiety, with positive effects on math performance (e.g., Ahmed et al., 2017; Jamieson et al., 2021; Pizzie & Kraemer, 2021).

Regarding inhibitory control, this scale was negatively correlated to MA, in consonance with previous research (Justicia-Galiano et al., 2015; Mammarella et al., 2018; Van den Bussche et al., 2020) and supporting the relevance of executive inhibitory mechanisms to regulate the negative emotions aroused when faced with math tasks. However, inhibitory control in this study did not predict math performance directly nor indirectly; although contrary to our expectations, this result did not surprise us because we failed to find an association of inhibitory control with math performance in a sample of elementary school children formerly (Sánchez-Pérez et al., 2015). Probably, the processes covered by this scale and its measurement approach might not be relevant for explaining mathematics achievement at this educational stage; TMCQ inhibitory control was defined by the authors (Simonds & Rothbart, 2004) at the behavioral and emotional level, covering the ability for planning before acting, being cautious and careful, able to stop or slow down, and capable of inhibiting the expression of emotions when they are not appropriate; all these processes were rated by parents based on daily situations. In contrast, studies that found inhibitory control associated with math performance defined it at the cognitive level and used direct measures by exposing children to specific cognitive-motor conflicts such as "go-no-go tasks" or Stroop-like tasks, where prepotent responses should be inhibited (e.g., Agostino et al., 2010; Fuhs & McNeil, 2013; Neuenschwander et al., 2012; Oberle & Schonert-Reichl, 2013; Pina et al., 2015).

In addition, when comparing the contribution of the different EC components analyzed, attention focusing is the most relevant mechanism for MA and math performance. Although all EC mechanisms reflect individual differences in the executive attention network, attention focusing involves cognitive self-regulation, whereas activation and inhibitory control are mainly defined at the behavioral level. Moreover, as pointed out by Diamond (2013), the operations deployed in sustain and focused attention overlap in part with executive functions: on the one hand, working memory is necessary to hold information in mind and work with it, and on the other, the involvement of inhibitory mechanisms are requested to prevent intrusive thoughts or distractions. In short, our results support a higher relevance of the cognitive (attentional and inhibitory) aspects of effortful self-regulation over the behavioral ones to explain individual differences in MA and math performance.

Contribution of the control variables in the models tested

Although non-verbal IQ was not the main focus of this study, it is worth mentioning that it negatively predicted both MA and math performance, suggesting that children with higher abstract reasoning tend to experience fewer negative reactions to mathematics and obtain higher math achievement. In our study, non-verbal IQ was obtained through the Matrices subtest of the *K*-bit (Kaufman & Kaufman, 1990); it is a measure of figural IQ that demands the participant to analyze a series of pictures/patterns and point to the response that corresponds with that picture/pattern and for which visuospatial reasoning is required. The relation of figural IQ to math anxiety and math performance was reported previously (Ferguson et al., 2015; Schillinger et al., 2018). As interpreted by Schillinger et al. (2018), those individuals with poorer viso-spatial abilities face more challenges in learning new mathematical concepts, especially those related to geometry, putting them at risk of developing MA.

Among the other control variables, age was a prominent influence on math performance, indicating that children acquire better mathematical skills as they get older and with increasing instruction. Concerning sex, in line with the last PISA report (OECD, 2022), boys in our sample outperformed girls in math performance. However, in a meta-analysis, Lindberg et al. (2010) found inconsistent results among the studies reviewed, with an insignificant average effect. We should keep track of these differences and the possible explanatory factors. Among them, socialization influences related to math-gender stereotypes are good candidates (e.g., Justicia-Galiano et al., 2023). Finally, family SES, a robust predictor of academic achievement (see Selvitopu & Kaya, 2023, for a meta-analysis), was positively associated with math performance. This relationship suggests that wealthier and more educated families would provide their children with more opportunities for learning in a more intellectually challenging environment (Davis-Kean, 2005; Pina et al., 2014).

Limitations and future research

This study has shown that children's effortful self-regulation abilities contribute to math performance directly and through the mediation of math anxiety. The fine-grained analysis highlighted cognitive over behavioral self-regulation's relevance in explaining individual differences in MA and math performance.

Nonetheless, the scope of our results is limited in several ways. The first limitation concerns the measurement strategy adopted, as EC was measured through questionnaires based on parents' observations of their children in daily situations. Although it is admitted that parents can be proper observers of their children's behaviors (Rothbart, 2011), they could also introduce subjective biases. Alternatively, direct observations of children in laboratory tasks when asked to follow instructions to suppress/initiate behaviors, having to wait, or while performing cognitive-motor conflict tasks are well established (see Spinrad et al., 2007 for a review), but given that these methods are not equivalent forms of measurement, a multi-method approach would provide more robust results.

A second limitation has to do with the effect size. Although significant, the size of effects found in this study was small, which means that an important part of the variance of the interactions between risk factors, MA, and math performance is yet to be explained. Following Rubinsten et al. (2018), given that MA can be considered as a dynamic interplay between intrinsic and environmental factors, a comprehensive model should include additional factors, such as genetic and neural predispositions, with particular attention to the generalized anxiety disorder; cognitive aspects, such as executive control or numerical cognition; and affective factors such as motivation or self-efficacy. Environmental aspects should include interactions with parents, family members, teachers, and peers, which are influenced by the educational curriculum and broad cultural values.

Conclusions

In addressing the contribution of EC to academic achievement, previous research had scarcely explored a pathway involving the negative emotions aroused during learning processes. In this study, we have proved that children's EC contributes to their math performance directly and through the mediation of MA. Children with higher attentional control and more able to refrain from their impulses to cope with task or social demands experienced lower levels of MA and obtained better math performance. Moreover, the fine-grain approach allowed us to test the specific contribution of each EC component, whose results support a higher relevance of the cognitive (attentional and inhibitory) aspects of effortful self-regulation over the behavioral ones to explain individual differences in MA and math performance. In sum, the findings highlight the relevance of top-down control of cognition, emotion, and behavior for successful academic achievement.

The practical implications of this study suggest the importance of focusing on self-regulation, managing math anxiety, and emotional and cognitive mechanisms to enhance students' performance in mathematics. These findings can have applications in the educational field and the development of specific interventions to address students' mathematical difficulties.

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Declarations

Competing interests The authors declare no competing interests.

References

Agostino, A., Johnson, J., & Pascual-Leone, J. (2010). Executive functions underlying multiplicative reasoning: Problem type matters. *Journal of Experimental Child Psychology, 105*(4), 286–305. https://doi.org/10.1016/j.jecp.2009.09.006

Ahmed, K., Trager, B., Rodwell, M., Foinding, L., & Lopez, C. (2017). A review of mindfulness research related to alleviating math and science anxiety. *Journal for Leadership and Instruction, 16*(2), 26–30.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5®)*. American Psychiatric Pub.

Ashcraft, M. H., & Faust, M. W. (1994). Mathematics anxiety and mental arithmetic performance: An exploratory investigation. *Cognition and Emotion, 8*(2), 97–125. https://doi.org/10.1080/02699939408408931

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

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

Ashton, M. C. (1998). Personality and job performance: The importance of narrow traits. *Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior, 19*(3), 289–303. https://doi.org/10.1002/(SICI)1099-1379(199805)19:3%3c289::AID-JOB841%3e3.0.CO;2-C

Ato, E., Fernández-Vilar, M. Á., & Galián, M. D. (2020). Relation between temperament and school adjustment in Spanish children: A person-centered approach. *Frontiers in Psychology, 11*, 250. https://doi.org/10.3389/fpsyg.2020.00250

Barroso, C., Ganley, C. M., McGraw, A. L., Geer, E. A., Hart, S. A., & Daucourt, M. C. (2021). A meta-analysis of the relation between math anxiety and math achievement. *Psychological Bulletin, 147*(2), 134. https://doi.org/10.1037/bul0000307

Blair, C. (2002). School readiness: Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American Psychologist, 57*(2), 111. https://doi.org/10.1037/0003-066X.57.2.111

Carey, E., Hill, F., Devine, A., & Szücs, D. (2016). The chicken or the egg? The direction of the relationship between mathematics anxiety and mathematics performance. *Frontiers in Psychology, 6*. https://doi.org/10.3389/fpsyg.2015.01987

Chapman, B. P. (2007). Bandwidth and fidelity on the NEO-five factor inventory: Replicability and reliability of item cluster subcomponents. *Journal of Personality Assessment, 88*(2), 220–234. https://doi.org/10.1080/00223890701268082

Cohen, L., & Rubinsten, O. (2022). Math anxiety and deficient executive control: Does reappraisal modulate this link? *Annals of the New York Academy of Sciences, 1513*(1), 108–120. https://doi.org/10.1111/nyas.14772

Cortés Pascual, A., Moyano Muñoz, N., & Quilez Robres, A. (2019). The relationship between executive functions and academic performance in primary education: Review and meta-analysis. *Frontiers in Psychology, 10*, 1582. https://doi.org/10.3389/fpsyg.2019.01582

Cuder, A., Živković, M., Doz, E., Pellizzoni, S., & Passolunghi, M. C. (2023). The relationship between math anxiety and math performance: The moderating role of visuospatial working memory. *Journal of Experimental Child Psychology, 233*, 105688. https://doi.org/10.1016/j.jecp.2023.105688

Davis-Kean, P. E. (2005). The influence of parent education and family income on child achievement: The indirect role of parental expectations and the home environment. *Journal of Family Psychology, 19*(2), 294–304. https://doi.org/10.1037/0893-3200.19.2.294

Diamantopoulou, S., Pina, V., Valero-Garcia, A. V., Gonzalez-Salinas, C., & Fuentes, L. J. (2012). Validation of the Spanish version of the Woodcock-Johnson mathematics achievement tests for children aged 6 to 13. *Journal of Psychoeducational Assessment, 30*(5), 466–477. https://doi.org/10.1177/0734282912437531

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*, 135. https://doi.org/10.1146/annurev-psych-113011-143750

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics anxiety: What have we learned in 60 years? *Frontiers in Psychology, 7*, 508. https://doi.org/10.3389/fpsyg.2016.00508

Duckworth, A. L., & Allred, K. M. (2015). Temperament in the classroom. En Zentner, Marcel & Shiner, L Rebecca (Eds.), *Handbook of temperament*. Guilford Press.

Eisenberg, N., Valiente, C., & Eggum, N. D. (2010). Self-regulation and school readiness. *Early Education and Development, 21*(5), 681–698. https://doi.org/10.1080/10409289.2010.497451

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*(2), 336. https://doi.org/10.1037/1528-3542.7.2.336

Faust, M. W. (1992). *Analysis of physiological reactivity in mathematics anxiety*. Bowling Green State University.

Ferguson, A. M., Maloney, E. A., Fugelsang, J., & Risko, E. F. (2015). On the relation between math and spatial ability: The case of math anxiety. *Learning and Individual Differences, 39*, 1–12. https://doi.org/10.1016/j.lindif.2015.02.007

Finell, J., Sammallahti, E., Korhonen, J., Eklöf, H., & Jonsson, B. (2022). Working Memory and its mediating role on the relationship of math anxiety and math performance: A meta-analysis. *Frontiers in Psychology, 12*, 798090. https://doi.org/10.3389/fpsyg.2021.798090

Fuhs, M. W., & McNeil, N. M. (2013). ANS acuity and mathematics ability in preschoolers from low-income homes: Contributions of inhibitory control. *Developmental Science, 16*(1), 136–148. https://doi.org/10.1111/desc.12013

Gerardi-Caulton, G. (2000). Sensitivity to spatial conflict and the development of self-regulation in children 24–36 months of age. *Developmental Science, 3*(4), 397–404. https://doi.org/10.1111/1467-7687.00134

González-Salinas, C., Valero, A. V., Carranza, J. A., Sánchez-Pérez, N., Bajo, M. T., Carreiras, M., & Fuentes, L. J. (2012). *Temperament profiles in ADHD: Low Effortful Control and poor emotional regulation*. Liedja, Belgium: BapSepex.

Hartwright, C. E., Looi, C. Y., Sella, F., Inuggi, A., Santos, F. H., González-Salinas, C., Santos, J. M. G., Kadosh, R. C., & Fuentes, L. J. (2018). The neurocognitive architecture of individual differences in math anxiety in typical children. *Scientific Reports, 8*(1), 1–10. https://doi.org/10.1038/s41598-018-26912-5

Hernández, M. M., Valiente, C., Eisenberg, N., Berger, R. H., Spinrad, T. L., VanSchyndel, S. K., Silva, K. M., Southworth, J., & Thompson, M. S. (2017). Elementary students' effortful control and academic achievement: The mediating role of teacher–student relationship quality. *Early Childhood Research Quarterly, 40*, 98–109. https://doi.org/10.1016/j.ecresq.2016.10.004

Hougland, E., Naso, M., Siler, K., & Bridgett, D. (2011). A meta-analysis of effortful control and child outcomes. Part II: Externalizing problems. *Poster presented at Biennial meeting of the Society for Research in Child Development.* Montreal.

Hunt, T., Clarck-Carter, D., & Sheffield, D. (2014). Exploring the relationship between mathematics anxiety and performance: The role of intrusive thoughts. *Journal of Education, Psychology and Social Sciences, 2*, 69–75. https://doi.org/10.1002/acp.3099

Hunt, T. E., Bhardwa, J., & Sheffield, D. (2017). Mental arithmetic performance, physiological reactivity and mathematics anxiety amongst UK primary school children. *Learning and Individual Differences, 57*, 129–132. https://doi.org/10.1016/j.lindif.2017.03.016

Jamieson, J. P., Black, A. E., Pelaia, L. E., & Reis, H. T. (2021). The impact of mathematics anxiety on stress appraisals, neuroendocrine responses, and academic performance in a community college sample. *Journal of Educational Psychology, 113*(6), 1164. https://doi.org/10.1037/edu0000636

Jenifer, J. B., Rozek, C. S., Levine, S. C., & Beilock, S. L. (2022). Effort (less) exam preparation: Math anxiety predicts the avoidance of effortful study strategies. *Journal of Experimental Psychology: General, 151*(10), 2534–2541. https://doi.org/10.1037/xge0001202

Justicia-Galiano, M. J., Martín-Puga, M. E., Linares, R., & Pelegrina, S. (2023). Gender stereotypes about math anxiety: Ability and emotional components. *Learning and Individual Differences, 105*, 102316. https://doi.org/10.1016/j.lindif.2023.102316

Justicia-Galiano, M.-J., Pelegrina, S., Lechuga, M.-T., Gutiérrez-Palma, N., Martín-Puga, E.-M., & Lendínez, C. (2015). Ansiedad a las matemáticas y su relación con las habilidades inhibitorias y la

inteligencia emocional percibida. *Anales de Psicología, 32*(1), 125–131. https://doi.org/10.6018/analesps.32.1.194891
Kaufman, A. S., & Kaufman, N. L. (1990). *K-BIT: Kaufman brief intelligence test*. American Guidance Service.
Kim-Spoon, J., Deater-Deckard, K., Calkins, S. D., King-Casas, B., & Bell, M. A. (2019). Commonality between executive functioning and effortful control related to adjustment. *Journal of Applied Developmental Psychology, 60*, 47–55. https://doi.org/10.1016/j.appdev.2018.10.004
Kochanska, G., Murray, K. T., & Harlan, E. T. (2000). Effortful control in early childhood: Continuity and change, antecedents, and implications for social development. *Developmental Psychology, 36*(2), 220–232.
Kwon, K., Kupzyk, K., & Benton, A. (2018). Negative emotionality, emotion regulation, and achievement: Cross-lagged relations and mediation of academic engagement. *Learning and Individual Differences, 67*, 33–40. https://doi.org/10.1016/j.lindif.2018.07.004
Ladd, G. W., Birch, S. H., & Buhs, E. S. (1999). Children's social and scholastic lives in kindergarten: Related spheres of influence? *Child Development, 70*(6), 1373–1400. https://doi.org/10.1111/1467-8624.00101
Liew, J., Lench, H. C., Kao, G., Yeh, Y.-C., & Kwok, O. (2014). Avoidance temperament and social-evaluative threat in college students' math performance: A mediation model of math and test anxiety. *Anxiety, Stress, and Coping, 27*(6), 650–661. https://doi.org/10.1080/10615806.2014.910303
Lindberg, S. M., Hyde, J. S., Petersen, J. L., & Linn, M. C. (2010). New trends in gender and mathematics performance: A meta-analysis. *Psychological Bulletin, 136*(6), 1123. https://doi.org/10.1037/a0021276
Ma, X. (1999). A meta-analysis of the relationship between anxiety toward mathematics and achievement in mathematics. *Journal for Research in Mathematics Education, 5*(30), 520–540. https://doi.org/10.2307/749772
Maloney, E. A. (2016). Math anxiety: Causes, consequences, and remediation. In K. R. Wentzel & D. B. Miele (Eds.), *Handbook of motivation at school* (pp. 408–423). Routledge.
Mammarella, I. C., Caviola, S., Giofrè, D., & Borella, E. (2018). Separating math from anxiety: The role of inhibitory mechanisms. *Applied Neuropsychology: Child, 7*(4), 342–353. https://doi.org/10.1080/21622965.2017.1341836
Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions four general conclusions. *Current Directions in Psychological Science, 21*(1), 8–14. https://doi.org/10.1177/0963721411429458
Neuenschwander, R., Röthlisberger, M., Cimeli, P., & Roebers, C. M. (2012). How do different aspects of self-regulation predict successful adaptation to school? *Journal of Experimental Child Psychology, 113*(3), 353–371. https://doi.org/10.1016/j.jecp.2012.07.004
Nigg, J. T. (2006). Temperament and developmental psychopathology. *Journal of Child Psychology and Psychiatry, 47*(3), 395–422. https://doi.org/10.1111/j.1469-7610.2006.01612.x
Nigg, J. T. (2017). Annual research review: On the relations among self-regulation, self-control, executive functioning, effortful control, cognitive control, impulsivity, risk-taking, and inhibition for developmental psychopathology. *Journal of Child Psychology and Psychiatry, 58*(4), 361–383. https://doi.org/10.1111/jcpp.12675
Oberle, E., & Schonert-Reichl, K. A. (2013). Relations among peer acceptance, inhibitory control, and math achievement in early adolescence. *Journal of Applied Developmental Psychology, 34*(1), 45–51. https://doi.org/10.1016/j.appdev.2012.09.003
OECD. (2012). *Results from PISA. Country note: Spain.* https://www.oecd.org/pisa/keyfindings/PISA-2012-results-spain.pdf
OECD. (2014). *PISA 2012 results in focus: What 15-year-olds know and what they can do with what they know*. OECD Publishing. https://www.oecd.org/pisa/keyfindings/pisa-2012-results-overview.pdf
OECD. (2019). *PISA 2018 assessment and analytical framework*. https://doi.org/10.1787/b25efab8-en
OECD. (2022). *PISA 2022 Results Factsheets Spain.* https://www.oecd.org/publication/pisa-2022-results/webbooks/dynamic/pisa-country-notes/f1a3afc1/pdf/spain.pdf
Ones, D. S., & Viswesvaran, C. (1996). Bandwidth–fidelity dilemma in personality measurement for personnel selection. *Journal of Organizational Behavior, 17*(6), 609–626.
Orbach, L., Herzog, M., & Fritz, A. (2020). State-and trait-math anxiety and their relation to math performance in children: The role of core executive functions. *Cognition, 200*, 104271. https://doi.org/10.1016/j.cognition.2020.104271

Papousek, I., Ruggeri, K., Macher, D., Paechter, M., Heene, M., Weiss, E. M., Schulter, G., & Freudenthaler, H. H. (2012). Psychometric evaluation and experimental validation of the statistics anxiety rating scale. *Journal of Personality Assessment, 94*(1), 82–91. https://doi.org/10.1080/00223891.2011.627959

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review, 18*, 315–341. https://doi.org/10.1007/s10648-006-9029-9

Peng, P., Namkung, J., Barnes, M., & Sun, C. (2016). A meta-analysis of mathematics and working memory: Moderating effects of working memory domain, type of mathematics skill, and sample characteristics. *Journal of Educational Psychology, 108*, 455–473. https://doi.org/10.1037/edu0000079

Pina, V., Castillo, A., Cohen Kadosh, R., & Fuentes, L. J. (2015). Intentional and automatic numerical processing as predictors of mathematical abilities in primary school children. *Frontiers in Psychology, 6*(375), 1–12. https://doi.org/10.3389/fpsyg.2015.00375

Pina, V., Fuentes, L. J., Castillo, A., & Diamantopoulou, S. (2014). Disentangling the effects of working memory, language, parental education, and non-verbal intelligence on children's mathematical abilities. *Frontiers in psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.00415

Pizzie, R. G., & Kraemer, D. J. (2017). Avoiding math on a rapid timescale: Emotional responsivity and anxious attention in math anxiety. *Brain and Cognition, 118*, 100–107. https://doi.org/10.1016/j.bandc.2017.08.004

Pizzie, R. G., & Kraemer, D. J. (2021). The association between emotion regulation, physiological arousal, and performance in math anxiety. *Frontiers in Psychology, 12*, 639448. https://doi.org/10.3389/fpsyg.2021.639448

Polderman, T. J., Boomsma, D. I., Bartels, M., Verhulst, F. C., & Huizink, A. C. (2010). A systematic review of prospective studies on attention problems and academic achievement. *Acta Psychiatrica Scandinavica, 122*(4), 271–284. https://doi.org/10.1111/j.1600-0447.2010.01568.x

Posner, M. I., & Rothbart, M. K. (2007). *Educating the human brain*. American Psychological Association.

Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2013). Math anxiety, working memory, and math achievement in early elementary school. *Journal of Cognition and Development, 14*(2), 187–202. https://doi.org/10.1080/15248372.2012.664593

Ramirez, G., Chang, H., Maloney, E. A., Levine, S. C., & Beilock, S. L. (2016). On the relationship between math anxiety and math achievement in early elementary school: The role of problem solving strategies. *Journal of Experimental Child Psychology, 141*, 83–100. https://doi.org/10.1016/j.jecp.2015.07.014

Ritchie, S. J., & Bates, T. C. (2013). Enduring links from childhood mathematics and reading achievement to adult socioeconomic status. *Psychological Science, 24*(7), 1301–1308. https://doi.org/10.1177/0956797612466268

Rothbart, M. K. (1989). Biological processes in temperament. In G. A. Kohnstamm, J. E. Bates, & M. K. Rothbart (Eds.), *Temperament in childhood* (pp. 187–247). John Wiley & Sons.

Rothbart, M. K. (2011). *Becoming who we are: Temperament and personality in development*. Guilford Press.

Rothbart, M. K., Ellis, L. K., Rueda, R., & Posner, M. I. (2003). Developing mechanisms of temperamental effortful control. *Journal of Personality, 71*(6), 1133–1144. https://doi.org/10.1111/1467-6494.7106009

Rothbart, M. K., Posner, M. I., & Kieras, J. (2006). Temperament, attention, and the development of self-regulation. In K. McCartney & D. Phillips (Eds.), *Blackwell handbook of early childhood development* (pp. 338–357). Wiley-Blackwell.

Rubinsten, O., Marciano, H., Eidlin Levy, H., & Daches Cohen, L. (2018). A framework for studying the heterogeneity of risk factors in math anxiety. *Frontiers in Behavioral Neuroscience, 12*, 291. https://doi.org/10.3389/fnbeh.2018.00291

Rudasill, K. M., Gallagher, K. C., & White, J. M. (2010). Temperamental attention and activity, classroom emotional support, and academic achievement in third grade. *Journal of School Psychology, 48*(2), 113–134. https://doi.org/10.1016/j.jsp.2009.11.002

Rueda, M. R. (2012). Effortful control. In M. Zentner (Ed.), *Handbook of temperament* (pp. 145–167). Guilford Press.

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2004). Attentional control and self-regulation. *Handbook of Self-Regulation: Research, Theory, and Applications, 2*, 284–299.

Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L., & Posner, M. I. (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences, 102*(41), 14931–14936. https://doi.org/10.1073/pnas.0506897102

Sánchez-Pérez, N., Fuentes, L. J., & González-Salinas, C. (2021). Assessing math anxiety in elementary schoolchildren through a Spanish version of the Scale for Early Mathematics Anxiety (SEMA). *PLoS ONE, 16*(8), e0255777. https://doi.org/10.1371/journal.pone.0255777

Sánchez-Pérez, N., Fuentes, L. J., Eisenberg, N., & González-Salinas, C. (2018). Effortful control is associated with children' school functioning via learning-related behaviors. *Learning and Individual Differences, 63*, 78–88. https://doi.org/10.1016/j.lindif.2018.02.009

Sánchez-Pérez, N., Fuentes, L. J., Pina, V., López-López, J. A., & González-Salinas, C. (2015). How do different components of Effortful Control contribute to children's mathematics achievement? *Educational Psychology, 6*, 1–15. https://doi.org/10.3389/fpsyg.2015.01383

Schillinger, F. L., Vogel, S. E., Diedrich, J., & Grabner, R. H. (2018). Math anxiety, intelligence, and performance in mathematics: Insights from the German adaptation of the Abbreviated Math Anxiety Scale (AMAS-G). *Learning and Individual Differences, 61*, 109–119. https://doi.org/10.1016/j.lindif.2017.11.014

Selvitopu, A., & Kaya, M. (2023). A meta-analytic review of the effect of socioeconomic status on academic performance. *Journal of Education, 203*(4), 768–780. https://doi.org/10.1177/00220574211031978

Simonds, J., & Rothbart, M. K. (2004). *The Temperament in Middle Childhood Questionnaire (TMCQ): A computerized self-report measure of temperament for ages 7-10*. Athens, GA: Poster presented at the Occasional Temperament Conference.

Skaalvik, E. M. (2018). Mathematics anxiety and coping strategies among middle school students: Relations with students' achievement goal orientations and level of performance. *Social Psychology of Education, 21*(3), 709–723. https://doi.org/10.1007/s11218-018-9433-2

Skagerlund, K., Östergren, R., Västfjäll, D., & Träff, U. (2019). How does mathematics anxiety impair mathematical abilities? Investigating the link between math anxiety, working memory, and number processing. *PloS One, 14*(1), e0211283. https://doi.org/10.1371/journal.pone.0211283

Spinrad, T. L., Eisenberg, N., & Gaertner, B. M. (2007). Measures of effortful regulation for young children. *Infant Mental Health Journal, 28*(6), 606–626. https://doi.org/10.1002/imhj.20156

Suárez-Pellicioni, M., Núñez-Peña, M. I., & Colomé, À. (2016). Math anxiety: A review of its cognitive consequences, psychophysiological correlates, and brain bases. *Cognitive, Affective, and Behavioral Neuroscience, 16*(1), 3–22. https://doi.org/10.3758/s13415-015-0370-7

Swanson, J., Valiente, C., Lemery-Chalfant, K., Bradley, R. H., & Eggum-Wilkens, N. D. (2014). Longitudinal relations among parents' reactions to children's negative emotions, effortful control, and math achievement in early elementary school. *Child Development, 85*(5), 1932–1947. https://doi.org/10.1111/cdev.12260

Ten Eycke, K. D., & Dewey, D. (2016). Parent-report and performance-based measures of executive function assess different constructs. *Child Neuropsychology, 22*(8), 889–906. https://doi.org/10.1080/09297049.2015.1065961

Tiego, J., Bellgrove, M. A., Whittle, S., Pantelis, C., & Testa, R. (2020). Common mechanisms of executive attention underlie executive function and effortful control in children. *Developmental Science, 23*(3), e12918. https://doi.org/10.1111/desc.12918

Trentacosta, C. J., & Izard, C. E. (2007). Kindergarten children's emotion competence as a predictor of their academic competence in first grade. *Emotion, 7*(1), 77. https://doi.org/10.1037/1528-3542.7.1.77

Valiente, C., Lemery-Chalfant, K., & Castro, K. S. (2007). Children's effortful control and academic competence: Mediation through school liking. *Merrill-Palmer Quarterly, 53*(1), 1–25. https://doi.org/10.1353/mpq.2007.0006

Valiente, C., Lemery-Chalfant, K., & Swanson, J. (2009). Children's responses to daily social stressors: Relations with parenting, children's effortful control, and adjustment. *Journal of Child Psychology and Psychiatry, 50*(6), 707–717. https://doi.org/10.1111/j.1469-7610.2008.02019.x

Valiente, C., Eisenberg, N., Haugen, R. G., Spinrad, T. L., Hofer, C., Liew, J., & Kupfer, A. (2011). Children's effortful control and academic achievement: Mediation through social functioning. *Early Education and Development, 22*(3), 411–433. https://doi.org/10.1080/10409289.2010.505259

Van den Bussche, E., Vanmeert, K., Aben, B., & Sasanguie, D. (2020). Too anxious to control: The relation between math anxiety and inhibitory control processes. *Scientific Reports, 10*(1), 1–10. https://doi.org/10.1038/s41598-020-76920-7

Vukovic, R. K., Roberts, S. O., & Green Wright, L. (2013). From parental involvement to children's mathematical performance: The role of mathematics anxiety. *Early Education and Development, 24*(4), 446–467. https://doi.org/10.1080/10409289.2012.693430

Wang, M.-T., Ye, F., & Degol, J. L. (2017). Who chooses STEM careers? Using a relative cognitive strength and interest model to predict careers in science, technology, engineering, and

mathematics. *Journal of Youth and Adolescence, 46*, 1805–1820. https://doi.org/10.1007/s10964-016-0618-8
Welsh, J. A., Nix, R. L., Blair, C., Bierman, K. L., & Nelson, K. E. (2010). The development of cognitive skills and gains in academic school readiness for children from low-income families. *Journal of educational psychology, 102*(1), 43. https://doi.org/10.1037/a0016738
Widlund, A., Tuominen, H., & Korhonen, J. (2018). Academic well-being, mathematics performance, and educational aspirations in lower secondary education: Changes within a school year. *Frontiers in Psychology, 9*, 297. https://doi.org/10.3389/fpsyg.2018.00297
Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson® III NU tests of achievement*. Riverside Publishing.
World Health Organization. (2018). *International Classification of Diseases, 11th version*. World Health Organization (WHO).
Wu, S., Amin, H., Barth, M., Malcarne, V., & Menon, V. (2012). Math anxiety in second and third graders and its relation to mathematics achievement. *Frontiers in Psychology, 3*, 162. https://doi.org/10.3389/fpsyg.2012.00162
Young, C. B., Wu, S. S., & Menon, V. (2012). The neurodevelopmental basis of math anxiety. *Psychological Science, 23*(5), 492–501. https://doi.org/10.1177/0956797611429134
Zhou, Q., Main, A., & Wang, Y. (2010). The relations of temperamental effortful control and anger/frustration to Chinese children's academic achievement and social adjustment: A longitudinal study. *Journal of Educational Psychology, 102*(1), 180–196. https://doi.org/10.1037/a0015908
Zhou, D., Liu, J., Ye, G., Wang, T., Xia, X., & Liu, J. (2022). Relationships among problematic smartphone use, mathematics achievement, teacher–student relationships, and subjective well-being: Results from a large-scale survey in China. *Behavioral Sciences, 12*(11), 454. https://doi.org/10.3390/bs12110454
Živković, M., Pellizzoni, S., Doz, E., Cuder, A., Mammarella, I., & Passolunghi, M. C. (2023). Math self-efficacy or anxiety? The role of emotional and motivational contribution in math performance. *Social Psychology of Education, 26*(3), 579–601. https://doi.org/10.1007/s11218-023-09760-8

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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.

Most relevant publications in the field of Psychology of Education:

Martella, D., Aldunate, N., Fuentes, L. J., & Sánchez-Pérez, N. (2020). Arousal and executive alterations in attention deficit hyperactivity disorder (ADHD). *Frontiers in psychology, 11*, 1991.
Sánchez-Pérez, N., Inuggi, A., Castillo, A., Campoy, G., García-Santos, J. M., González-Salinas, C., & Fuentes, L. J. (2019). Computer-based cognitive training improves brain functional connectivity in the attentional networks: A study with primary school-aged children. *Frontiers in behavioral neuroscience, 13*, 247.
Sánchez-Pérez, N., Fuentes, L. J., Eisenberg, N., & González-Salinas, C. (2018). Effortful control is associated with children's school functioning via learning-related behaviors. *Learning and individual differences, 63*, 78–88.
Sánchez-Pérez, N., Fuentes, L. J., Jolliffe, D., & González-Salinas, C. (2014). Assessing children's empathy through a Spanish adaptation of the Basic Empathy Scale: Parent's and child's report forms. *Frontiers in psychology, 5*, 1438.

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Current themes of research:

Facilitatory and inhibitory processes in visual attention. Cognitive, motivational, and emotional factors that influence academic performance. Use of hypnosis for the study of perceptual processes related to synesthesia and attention.

Most relevant publications in the field of Psychology of Education:

Antón, E., Duñabeitia, J. A., Estévez, A., Hernández, J. A., Castillo, A., Fuentes, L. J., … & Carreiras, M. (2014). Is there a bilingual advantage in the ANT task? Evidence from children. *Frontiers in psychology, 5*, 398.

Duñabeitia, J. A., Hernández, J. A., Antón, E., Macizo, P., Estévez, A., Fuentes, L. J., & Carreiras, M. (2014). The inhibitory advantage in bilingual children revisited. *Experimental psychology, 61*(3), 234–251.

Hernández, M., Costa, A., Fuentes, L. J., Vivas, A. B., & Sebastián-Gallés, N. (2010). The impact of bilingualism on the executive control and orienting networks of attention. *Bilingualism: Language and Cognition, 13*(3), 315–325.

Fuentes, L. J., & Campoy, G. (2008). The time course of alerting effect over orienting in the attention network test. *Experimental Brain Research, 185*, 667–672.

Pelegrina, S., Lechuga, M. T., García-Madruga, J. A., Elosúa, M. R., Macizo, P., Carreiras, M., … & Bajo, M. T. (2015). Normative data on the n-back task for children and young adolescents. *Frontiers in psychology, 6*, 1544.

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Current themes of research:

Children's temperament and adjustment. Cognitive, motivational, and emotional factors that influence academic performance. Math anxiety development.

Most relevant publications in the field of Psychology of Education:

Carranza, J. A., González-Salinas, C., & Ato, E. (2013). A longitudinal study of temperament continuity through IBQ, TBAQ and CBQ. *Infant Behavior and Development, 36*(4), 749–761.

Hartwright, C. E., Looi, C. Y., Sella, F., Inuggi, A., Santos, F. H., González-Salinas, C., … & Fuentes, L. J. (2018). The neurocognitive architecture of individual differences in math anxiety in typical children. *Scientific reports, 8*(1), 8500.

Inuggi, A., Sanz-Arigita, E., González-Salinas, C., Valero-García, A. V., García-Santos, J. M., & Fuentes, L. J. (2014). Brain functional connectivity changes in children that differ in impulsivity temperamental trait. *Frontiers in behavioral neuroscience, 8*, 156.

Sánchez-Pérez, N., Inuggi, A., Castillo, A., Campoy, G., García-Santos, J. M., González-Salinas, C., & Fuentes, L. J. (2019). Computer-based cognitive training improves brain functional connectivity in the attentional networks: a study with primary school-aged children. *Frontiers in behavioral neuroscience, 13*, 247.