

# Executive functioning and learning in primary school students

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## Abstract

**Introduction.** Executive functions involve cognitive and metacognitive abilities that make up a sophisticated system that monitors and reviews conduct involved in decision-making. These functions are critical for carrying out tasks and adaptive behavior. Among its components are inhibitory and attentional control, planning, self-regulation and cognitive flexibility, all relating directly to academic performance. This study examines how variables linked to executive functions and learning are related to mathematics achievement in primary school students.

**Method.** A total of 519 boys and girls participated in the study, with a mean age of 10.74 years ( $SD = .66$ ). Students were classified into three groups (low, medium and high) according to their math achievement.

**Results.** The results show significant, negative relations between math performance and attention deficit, hyperactivity and impulsivity; as well as positive relations with learning strategies, attitude towards study and academic self-concept. Differences between the math achievement groups are significant in practically all the variables studied.

**Discussion and conclusions.** School interventions that address both executive functions and intentional training in learning strategies are needed in order to encourage better academic performance.

**Key words:** Executive functions, learning strategies, academic motivation, achievement, mathematics.

## Resumen

**Introducción:** Las funciones ejecutivas implican habilidades cognitivas y metacognitivas que configuran un sofisticado sistema de control y revisión de las conductas implicadas en la toma de decisiones, cruciales en la realización de las tareas y la conducta adaptativa. El control inhibitorio y atencional, la planificación, la autorregulación o la flexibilidad cognitiva son algunos de sus componentes directamente relacionados con el rendimiento académico. Este estudio examina la relación entre variables vinculadas al funcionamiento ejecutivo y al aprendizaje con el rendimiento en Matemáticas en alumnos de Educación Primaria.

**Método:** Participaron en el estudio 519 alumnos de ambos géneros, con una edad media de 10,74 años ( $DT = .66$ ), clasificados en tres grupos (bajo, medio y alto) según el rendimiento matemático.

**Results:** Los resultados muestran relaciones significativas y negativas del rendimiento en matemáticas con el déficit de atención, hiperactividad e impulsividad; así como positivas con las estrategias de aprendizaje, la actitud hacia el estudio y el autoconcepto académico. Las diferencias entre los grupos de rendimiento matemático son significativas prácticamente en todas las variables estudiadas.

**Discusión o conclusión:** Es necesario plantear intervenciones en contextos escolares que tengan en cuenta tanto las funciones ejecutivas como el entrenamiento intencional en estrategias de aprendizaje, y así favorecer un mayor rendimiento académico.

**Palabras clave:** Funciones ejecutivas, estrategias de aprendizaje, motivación académica, rendimiento, matemáticas.

## Introduction

The executive functions, which chiefly involve frontal areas critical to both cognitive and emotional development, play an essential role in learning, and therefore, in academic achievement. This set of cognitive and metacognitive skills influence one's ability to plan, direct and modify behavior (Gilmore & Cragg, 2014), self-regulating one's action by inhibiting responses and changing strategies (Rosenberg, 2014), directing each behavior toward a particular purpose (Delgado-Mejía & Etchepareborda, 2013; Flores-Lázaro, Castillo-Preciado & Jiménez Miramonte, 2014). From a pragmatic point of view, they are considered fundamental mental capacities for the development of effective behaviors. Most researchers in this topic concur in including emotional control, attentional capacity, response inhibition, task planning and organization, working memory and cognitive flexibility as some of their components (Diamond, 2013; Nigg, 2017). In task performance, for example, these skills explain the ability to identify, organize, and plan objectives, and to maintain their purpose, even while changing strategies, inhibiting distractions and self-regulating one's learning, thus controlling one's course of action (Portellano, 2018).

The development of executive functions is progressive and asymmetrical, occurring at uneven rates (Cassandra & Reynolds, 2005; Roselli, Jurado & Matute, 2008). Brain regions that regulate impulsivity control and motivation mature later than other regions (Valiente-Barroso, 2011), reaching their maximum maturity during adulthood (Pureza, Gonçalves, Branco, Grassi-Oliveira & Rochele, 2013). Nonetheless, studies on executive functions in children are important because these skills undergo their greatest development during the period of compulsory education. More organized behaviors appear between the ages of 6 and 8; inhibitory control is developed around age 12; and from ages 15 to 19 we find working memory, problem solving and cognitive flexibility (García et al., 2013). When children show difficulty concentrating or inhibiting interferences from certain stimuli, it will foreseeably affect their rate of learning, and consequently, their scholastic achievement. Recent studies report that students with attention disabilities and high scores in hyperactivity obtain low scores in flexibility, memory, inhibition and emotional control, and have problems organizing information, setting goals and planning tasks (López, Nieto, Conde & Bernardo, 2016).

Although there are diverse categorizations of learning strategies, all of them concur in identifying cognitive strategies, metacognitive strategies, and learning support strategies as behaviors that the subject deploys for codifying, processing, and later recovering and applying information (Beltrán, 2003). Metacognitive strategies, along with motivational strategies and strategies to control and manage resources, constitute the strategies of self-regulated learning (Suárez & Fernández, 2004). More recent research studies thereby assert self-regulated learning as one of the factors that most contributes to scholastic success (Meltzer, 2014). As a learning tool, self-regulation of learning allows students to develop the ability to plan, monitor and evaluate tasks, and is directly related to one of the seven key competencies --learning to learn-- that is promulgated in Spain's 2006 Education Act (LOE), with continuity in the current Improving Educational Quality Act (LOMCE). From the perspective of the sociocognitive theory of learning (Núñez, Solano, González-Pienda & Rosário, 2006), self-regulated learning makes it possible to attain greater academic achievement than what is obtained only from the students' own abilities and cognitive potential. It is therefore a self-directed, proactive process, where mental abilities are transformed into academic skills (Panadero & Alonso-Tapia, 2014a; Zimmerman, 2002) and result in more active, autonomous, constructive learning. In this process it is fundamental to consider motivational variables and their moderating effect on cognitive learning strategies (Suárez & Fernández, 2013). A self-regulated student is able to manage his/her cognitive and motivational resources in completing a task, making continuous adjustments to the specific demands and situations of learning (Suárez & Fernández, 2011; Suárez, Fernández, Rubio & Zamora, 2016; Valle et al., 2010).

Within self-regulated learning, we include metacognitive skills that allow the student to reflect on his/her own cognitive processes, self-efficacy beliefs and perceived utility, as well as motivational and behavioral processes (Rosário et al., 2012; Throndsen, 2011; Zimmerman 2008) that sustain task performance and assessment processes, thus enabling deep, transferable learning (Panadero & Alonso-Tapia, 2014b). Metacognitive strategies are developed around the age of eleven or twelve, following metacognitive knowledge, and they are directly related to cognitive learning strategies (Pennequin, Sorel & Mainguy, 2010). García, Rodríguez, González-Castro, Álvarez-García and González-Pienda (2016) analyzed executive functioning in two groups with different levels of metacognitive knowledge, and concluded that students with high levels of knowledge frequently use metacognitive strategies of planning, execution and revision. The use of metacognitive skills is greater during the task execu-

tion phase, and lower during preliminary planning and subsequent evaluation (Fernández et al., 2010; Montague, Enders & Dietz, 2011).

In learning situations, children often demonstrate poor metacognitive skills, going straight to action. They are impulsive and repeat the same strategies over and over, recognizing that they are not the most adequate, but sticking to trial and error. This process of defective feedback on every task can lead to negative outcomes and hence a lack of interest and motivation. Self-regulated learning is thus recognized as the main pillar of the teaching-learning process, allowing the student to activate goal-directed cognitions and behaviors, and to control comprehension, attention and review processes, using adequate strategies, and becoming the constructor of his/her own learning (Suárez, Fernández & Zamora, 2018; Pintrich, 2004; Schunk, 2000), evaluating goal achievement and thereby improving effectiveness (Boekaerts & Cascallar, 2006).

Academic performance and its different variables have been studied for some time, including the affective-motivational variables that mediate between cognitive abilities and academic achievement. Recent studies especially emphasize how all these variables are directly related to executive functions (García-Villamizar & Muñoz, 2000; Zimmerman, 2011); executive functions are at the pinnacle of learning potential and show direct relations to academic achievement (Valiente-Barroso & García-García, 2013).

Contributions from Neuroscience to the field of education have made it possible to account for certain students' learning disabilities, despite their good cognitive abilities. Such students have problems with planning, attention, low scholastic performance and inability to work in a team (Meltzer, 2010); disability in planning and performing complex tasks results from executive dysfunctions (Artigas-Pallarés, 2003; Meltzer, 2007) that are associated with limitations in working memory or deficits in inhibitory control. Recent studies report disabilities in organization and planning skills, working memory and emotional control in children with low achievement (Navarro & García-Villamizar, 2014).

Adequate executive functioning takes its place with the self-regulating function of language and the appearance of reasoning and formal-logical operations, thus accounting for the more frequent disabilities being related to reading/writing and mathematical reasoning, and becoming more marked as information takes on greater complexity when progressing

through different levels of schooling (García et al., 2013). Mathematics achievement is reported to have significant relationships to working memory, planning, inhibitory control and cognitive flexibility (Aragón, Navarro & Aguilar, 2016; Clark, Pritchard & Woodward, 2010), with executive functioning being a performance predictor in this area of the curriculum (Rodríguez, Llobet & Zorrilla, 2012; Toll, Van der Ven, Kroesbergen & Van Luit, 2011). Most research studies on executive functions and academic achievement have been carried out in the area of mathematics (Baggetta & Alexander, 2016): Direct, significant relationships have been found between inhibition and mathematical problem solving (Agostino, Johnson & Pascual-Leone, 2010; Passolunghi, Marzocchi & Fiorillo, 2005) and between working memory and performance in algebra, arithmetic and mathematics in general (Lee, Ng & Ng, 2009; Passolunghi & Cornoldi, 2008; Passolunghi, Lafrnachi, Altoè & Sollazzo, 2015).

### *Objectives*

Considering the foregoing, the general objective of the present study was to understand how certain variables associated with executive functioning (such as planning, inhibitory control, impulsivity and attentional control) relate to learning (including the variables of strategies, academic motivation and academic achievement) in fifth- and sixth-grade students. Based on this general objective, more specific objectives were formulated, namely, to verify whether significant differences in the variables of executive functioning and learning are found as a function of the level of mathematics achievement, and to analyze which of the study variables best explain this achievement level.

## **Method**

### *Participants*

A non-probabilistic, convenience sample was used. A total of 519 students from 28 classes participated in the study; also participating were their respective homeroom teachers (20 women and 8 men). The participants were drawn from nine middle-class schools, 3 public schools (33.33%) and 6 subsidized schools (66.66%), in the Cantabria region. Students were between 10 and 12 years of age; 279 were boys (53.8%) and 240 were girls (46.2%). Fifth-graders accounted for 52.4% of the sample (142 boys and 130 girls) and sixth-graders made up 47.6% (137 boys and 110 girls)

### *Instruments*

The first instrument used was the *Diagnóstico Integral del Estudio* [Comprehensive Diagnosis of Study (DIE)] (Pérez, Rodríguez, Cabezas & Polo, 2002), which assesses the child's behavior in personal, autonomous work in the individual learning process. It focuses on the before, during and after of schoolwork and study (motivation and planning, performance and evaluation), as well as on complementary strategies such as working in a group and extracurricular activities. The test contains 60 items on a Likert scale with three possible answers: 1 (always or almost always), 2 (sometimes), and 3 (never or almost never). The items are divided into four blocks (of 15 statements each), to which the student responds based on two different formulations, whether or not they agree with what the statement says, and whether or not the statement applies to them. The following variables were considered for this study:

-Support strategies: affirmations about factors related to the student's personal work, process, monitoring and evaluation of his/her own learning process, for example, "When I finish studying I check whether I have completed what I had planned for this study session".

-Complementary strategies: affirmations that refer to activities complementary to study, for example, "Sometimes I use synthesis-type techniques like summaries, outlines, etc."

-Attitude toward study scale: the student's expectations, concept and predisposition toward study, for example, "I have confidence in my own memory".

-Self-concept scale: the student's own assessment of himself/herself as a student, for example, "I know my reading speed".

Total strategies: the sum of the four preceding scales, producing a score that can be used to decide whether measures are needed for remediation in the elements of personal study (scores lower than 75). Reliability was calculated through internal consistency of the test in general: Cronbach's alpha was .85.

In order to assess the variables associated with executive functioning, the following instruments were used:

*Test de percepción de diferencias* [Perceived differences test] (Thurstone & Yela, 2012). This test assesses the subject's visuo-perceptive and attentional capacity and impulsivity in performing a task. It contains 60 visual elements, each representing a set of 3 faces;



the student must mark which of the three is different from the others in each case. The score from the Impulsivity Control Index (ICI) was considered an indicator of lack of inhibitory control for this research study. Internal consistency of this instrument, measured with Cronbach's alpha, indicated a value of .91 for the global sample.

*Evaluación del Trastorno por Déficit de Atención con Hiperactividad* [Assessment of attention deficit with hyperactivity] (Farré & Narbona, 2013). This instrument assesses ADHD, the risks of suffering from it, and possible accompanying behavioral disorders. The test is completed by the teacher, after prior observation of the student's behavior. This 20-item, Likert scale has responses ranging from 1 to 4 (1=*not at all*; 2=*a little*; 3=*quite a bit* and 4=*very much*) and is divided into two subscales of 10 items each. Hyperactivity (for example, "is impulsive") and attention deficit (for example, "is easily distracted, pays little attention") are assessed in one scale, and behavioral disorders in the other (for example, "has difficulty in cooperative activities"). Additionally, results are given for hyperactivity/impulsivity (5 items) and attention deficit (5 items). For this study, we took into account students' scores on the four subscales; the results showed good psychometric properties of the Scale, with a Cronbach alpha of .906 in hyperactivity/impulsivity, .884 in attention deficit, .913 in behavioral disorders and .901 in hyperactivity-attention deficit.

Mathematics achievement was assessed by students' numerical grade in this school subject, as recorded at the end of the school year, and provided by each group's homeroom teacher.

### *Procedure*

Authorization was requested from the participating schools. Once the permissions and the families' informed consent were obtained, the tests were applied to the groups in a 45-minute session during school hours, always in the presence of their homeroom teachers. Students had been previously informed of the purpose of the research and were assured of anonymity and confidentiality of the results. The questionnaires were delivered to the homeroom teachers with the instructions needed for their completion, and were collected some days later by one of the researchers at each participating school, where they had been deposited into the custody of the corresponding Head of studies at each school.

### *Data analyses*

Different statistical analyses were performed: descriptive analyses, Pearson bivariate correlations and multivariate analysis of variance (MANOVA), using the factors Year in School and Mathematics Achievement as dependent variables, linked to executive functions (impulsivity control index, hyperactivity/impulsivity, attention deficit, behavioral disorders, hyperactivity-attention deficit) and to learning (support strategies, complementary strategies, attitude toward study, self-concept and total strategies). The partial eta-squared coefficient was used ( $\eta_p^2$ ) to measure effect size. According to Cohen's criteria (1988), the effect size is considered small if  $\eta_p^2 \geq .01$ , medium if  $\eta_p^2 \geq .059$  and large if  $\eta_p^2 \geq .138$ .

In order to analyze the differences between the study variables as a function of Mathematics achievement, three groups were established, using the following calculated percentiles: low Mathematics achievement (percentiles under 25), medium Mathematics achievement (percentiles between 25 and 75, inclusive) and high Mathematics achievement (percentiles over 75).

In consideration of the main study objective, a regression analysis was also carried out (stepwise method) in order to determine the predictive value of the variables linked to executive functionality and to learning, with respect to Mathematics achievement. The data analyses were performed using SPSS, version 24 for Windows.

## Results

### *Relationships between Mathematics achievement, executive functioning variables and learning variables*

Pearson correlations were carried out in order to analyze any relationships between the variables associated with executive functioning, the variables associated with learning and Mathematics achievement (Table 1). Results showed that Mathematics achievement had a significant, negative correlation with attention deficit, hyperactivity/impulsivity, behavioral disorders and hyperactivity-attention deficit. Similarly, Mathematics achievement had a significant, positive correlation with support strategies, complementary strategies, attitude toward study, self-concept and total strategies. On the other hand, no significant relationships were found between Mathematics achievement and the impulsivity control index.

Table 1. Means, standard deviations, minimum, maximum and Pearson correlations.

	1	2	3	4	5	6	7	8	9	10	11
MA (1)	1.00										
ICI (2)	.052	1.00									
H (3)	-.17**	-.11**	1.00								
AD (4)	-.46**	-.17**	.50**	1.00							
BD (5)	-.20**	-.17**	.72**	.51**	1.00						
HAD (6)	-.31**	-.11**	.67**	.75**	.60**	1.00					
SS (7)	.10*	-.04	-.11*	-.21**	-.04	-.153**	1.00				
CS (8)	.30**	-.02	.23**	-.36**	-.14**	-.303**	.60**	1.00			
AT (9)	.28**	-.03	-.17**	-.31**	-.11**	-.263**	.78**	.79**	1.00		
SC (10)	.15**	-.03	-.17**	-.27**	-.08	-.229**	.81**	.83**	.62**	1.00	
TS (11)	.231**	-.03	-.19**	-.32**	-.10*	-.257**	.89**	.90**	.88**	.92**	1.00
M	6.90	94.40	2.64	3.13	3.21	6.01	42.89	40.32	42.74	40.49	83.22
SD	1.72	9.63	3.46	3.48	4.78	7.739	7.286	7.773	6.86	8.13	13.48
Min	2	9	0	0	0	0	21	16	22	16	44
Max	10	100	14	14	25	116	60	58	58	59	116

Note: MA=Mathematics achievement; ICI= impulsivity control index; H= Hyperactivity/impulsivity; AD= attention deficit; BD= behavioral disorder; HAD= Hyperactivity-attention deficit; SS= support strategies; CS= complementary strategies; AT= Attitude; SC= self-concept; TS= total strategies

\* $p < .05$ ; \*\* $p < .01$

On the other hand, regarding relationships between the variables associated with executive functioning, the results showed significant, negative correlations between the impulsivity control index and the remaining variables associated with executive functioning (attention deficit, hyperactivity/impulsivity, behavioral disorders and hyperactivity-attention deficit), and no significant relationship was found with the learning-associated variables. Moreover, most of the correlations between the variables associated with executive functioning and learning were found to be negative and significant.

#### *Differences between the achievement groups with regard to executive functioning and learning*

The variables associated with executive functioning and learning were studied using MANOVA analysis, taking Mathematics achievement and Year in School as independent variables. The multivariate results indicated that the effect of Mathematics achievement ( $\lambda_{\text{Wilks}}=.730$ ;  $F_{(20,1008)}=8.249$ ,  $p < .001$ ;  $\eta_p^2=.141$ ) and the interaction between Year in School and Mathematics achievement are statistically significant ( $\lambda_{\text{Wilks}}=.925$ ;  $F_{(20,1008)}=2.010$ ,  $p < .01$ ;  $\eta_p^2=.038$ ), with a large effect size in the first case and a small effect size in the second. However, the effect of Year in School was not statistically significant ( $\lambda_{\text{Wilks}}=.973$ ;  $F_{(10,504)}=1.404$ ,  $p=.175$ ;  $\eta_p^2=.027$ ).

The interaction of Year in School and Mathematics achievement was statistically significant in support strategies ( $F_{(2,513)}=4.268$ ,  $p<.05$ ;  $\eta_p^2=.16$ ), complementary strategies ( $F_{(2,513)}=5.107$ ,  $p<.01$ ;  $\eta_p^2=.020$ ), self-concept ( $F_{(2,513)}=10.133$ ,  $p<.001$ ;  $\eta_p^2=.038$ ), total strategies ( $F_{(2,513)}=5.826$ ,  $p<.01$ ;  $\eta_p^2=.022$ ), attention deficit ( $F_{(2,513)}=3.865$ ,  $p<.05$ ;  $\eta_p^2=.015$ ) and the variable hyperactivity-attention deficit ( $F_{(2,513)}=4.198$ ,  $p<.05$ ;  $\eta_p^2=.016$ ), with a large effect size in support strategies and small effect sizes in the remainder. This interaction was not significant in impulsivity control index ( $F_{(2,513)}=1.365$ ,  $p=.256$ ;  $\eta_p^2=.005$ ), attitude ( $F_{(2,513)}=1.161$ ,  $p=.314$ ;  $\eta_p^2=.005$ ), hyperactivity/impulsivity ( $F_{(2,513)}=.929$ ,  $p=.396$ ;  $\eta_p^2=.004$ ) or behavioral disorders ( $F_{(2,513)}=1.810$ ,  $p=.165$ ;  $\eta_p^2=.007$ ).

The univariate analyses between Mathematics achievement groups (Table 2) show that there were statistically significant differences in all the study variables except for the impulsivity control index ( $F_{(2,513)}=.573$ ,  $p=.564$ ;  $\eta_p^2=.002$ ) and support strategies ( $F_{(2,513)}=2.297$ ,  $p=.102$ ;  $\eta_p^2=.009$ ).

Table 2. Means (standard deviations) and analyses of variance of the variables of executive functioning, learning strategies and motivation, according to mathematics achievement group

Variables	Low (n=134)	Medium (n=258)	High (n=127)	F(2,513)	$\eta_p^2$
H	3.20(3.92)	2.78(3.39)	1.79(2.91)	6.391**	.024
AD	5.42(3.81)	2.86(2.98)	1.25(2.64)	60.035***	.190
BD	4.60(5.56)	3.15(4.48)	1.85(3.76)	11.827***	.044
HAD	9.44(11.31)	5.69(5.68)	3.04(4.86)	25.418***	.090
CS	37.01(7.80)	40.63(7.61)	43.19(6.76)	22.995***	.082
AT	40.17(6.87)	42.88(6.56)	45.17(6.54)	18.072***	.066
SC	38.85(8.51)	40.65(8.09)	41.89(7.54)	5.114**	.020
TS	79.00(13.55)	83.52(13.27)	87.02(12.67)	12.514***	.047

Note. Only variables with statistically significant differences are shown in the table. H= Hyperactivity/impulsivity; AD= attention deficit; BD= behavioral disorder; HAD= Hyperactivity-attention deficit; CS= complementary strategies; AT= Attitude; SC= self-concept; TS= total strategies

\*\* $p<.01$  \*\*\* $p<.001$

The *post hoc* Bonferroni test was applied in order to learn which mathematics achievement groups showed significant differences based on the results indicated above. Sig-

nificant differences were confirmed between the high achievement group and the low achievement group with respect to the variables included (see Table 3).

Table 3. *Multiple Comparisons using the Bonferroni Test*

Variables	Achievement groups	M	SD	Achievement groups	M	SD	<i>p</i>
H	Low	3.20	3.922	High	1.79	2.913	.003
	Medium	2.78	3.389				.024
AD	Low	5.42	3.812	Medium	2.86	2.985	.000
	Medium	2.86	2.985	High	1.25	2.646	.000
BD	Low	4.60	5.567	Medium	3.15	4.485	.010
	Medium	3.15	4.485	High	1.85	3.767	.000
HAD	Low	9.44	11.309	High	1.85	3.767	.029
	Medium	5.69	5.687	Medium	5.69	5.687	.000
CS	Low	37.01	7.800	High	3.04	4.864	.000
	Medium	40.63	7.614	High	3.04	4.864	.003
AT	Low	40.17	6.871	Medium	40.63	7.614	.000
	Medium	42.88	6.564	High	43.19	6.767	.000
SC	Low	38.85	8.511	High	43.19	6.767	.005
	Medium	42.88	6.564	Medium	42.88	6.564	.000
TS	Low	79.00	13.554	High	45.17	6.540	.000
	Medium	83.52	13.272	High	45.17	6.540	.005
	Low	79.00	13.554	Medium	83.52	13.272	.004
	Medium	83.52	13.272	High	87.06	12.678	.000
				High	87.06	12.678	.039

Note. H= Hyperactivity/impulsivity; AD= attention deficit; BD= behavioral disorder; HAD= Hyperactivity-attention deficit; CS= complementary strategies; AT= Attitude; SC= self-concept; TS= total strategies

\**p*<.05 \*\**p*<.01 \*\*\**p*<.001

### *Predicting Mathematics Achievement*

A regression analysis (stepwise procedure) was performed, incorporating the variables linked to executive functioning and learning as predictive variables, and mathematics achievement as criterion variable (Table 4). The results indicated that mathematics achievement was predicted by four of the variables included. Thus, Model 1 shows that the attention deficit variable explains 21.4% of the total variance, having a statistically significant predictive ability for Mathematics achievement ( $\beta = -.464$ ;  $t = -11.915$ ;  $p < .001$ ). Model 2 includes the variables attention deficit ( $\beta = -.408$ ;  $t = -9.886$ ;  $p < .001$ ) and complementary strategies ( $\beta = .157$ ;  $t = 3.799$ ;  $p < .001$ ), together accounting for 23.4 % of the variance and contributing sig-

nificantly to the explanation of Mathematics achievement. Model 3, in addition to the previous variables, includes the self-concept variable. The three variables explain 26% of the total variable, where attention deficit ( $\beta = -.399$ ;  $t = -9.840$ ;  $p < .001$ ), complementary strategies ( $\beta = .408$ ;  $t = 5.838$ ;  $p < .001$ ) and self-concept ( $\beta = -.299$ ;  $t = -4.414$ ;  $p < .001$ ) significantly explain achievement in this area of the curriculum. Results obtained in Model 4 indicate that Mathematics achievement is predicted by four variables, attention deficit ( $\beta = -.448$ ;  $t = -9.833$ ;  $p < .001$ ), complementary strategies ( $\beta = .415$ ;  $t = 5.948$ ;  $p < .001$ ), self-concept ( $\beta = -.300$ ;  $t = -4.447$ ;  $p < .001$ ) and hyperactivity/impulsivity ( $\beta = .101$ ;  $t = 2.309$ ;  $p < .05$ ). Together these variables explain 26.6% of the total variance of achievement in this school subject. The following variables were excluded from the model: impulsivity control index, behavioral disorders and hyperactivity-attention deficit, support strategies, attitude toward study and total strategies.

Table 4. *Results from the regression analysis with Mathematics achievement as criterion variable and the variables linked to executive functioning, learning strategies and motivation as predictive variables.*

Model	R	R <sup>2</sup>	Adjusted R <sup>2</sup>	F (df)	p
Model 1 <sup>a</sup>	.464	.215	.214	141.963 (1,518)	.000
Model 2 <sup>b</sup>	.487	.237	.234	80.043 (2,518)	.000
Model 3 <sup>c</sup>	.514	.265	.260	61.769 (3,518)	.000
Model 4 <sup>d</sup>	.522	.272	.266	48.049 (4,518)	.000

<sup>a</sup> Attention deficit

<sup>b</sup> Attention deficit, complementary strategies

<sup>c</sup> Attention deficit, complementary strategies, self-concept

<sup>d</sup> Attention deficit, complementary strategies, self-concept, hyperactivity/impulsivity

## Discussion

The fundamental objective of this study was to contribute information about the relationship between certain variables associated with executive functions, learning and performance and the curriculum area of Mathematics. Results indicated direct relationships between the learning variables and math achievement, with significant differences found between the high- and low-achievement groups in favor of the former, in most variables. However, the results showed that the students with low achievement in mathematics presented significantly higher scores on most of the executive functioning variables than did the other groups. These results concur with previous studies reporting that students with high mathematics achieve-

ment present greater knowledge of self-regulation strategies (Cleary & Chen, 2009; Thronsen, 2011), and that these students' interest in their own learning is one of the variables that predicts the use of regulation strategies. Moreover, such studies have found significant differences in task planning and in motivation for learning mathematics at the primary school level (Cueli, García & González-Castro, 2013).

As we predicted, most of the variables used to study executive functionality had a significant, negative correlation with mathematics achievement, except for impulsivity control index, where no significant between-group differences were found, in contrast to previous studies (Corso, Sperb, Inchausti de Jou & Fumagalli, 2013). Significant differences were found in executive functioning between the high and low math-achievement groups. Higher achievement in Mathematics was related to lower scores in hyperactivity/impulsivity, attention deficit and behavioral disorders. These results are consistent with previous studies that report impulsivity and attentional efficiency in significant relationships with math achievement (Valiente-Barroso, 2014).

In the regression analysis, four of the variables appeared as predictors of mathematics achievement. These variables were attention deficit, complementary strategies, self-concept, and hyperactivity/impulsivity, pointing us to a need for intervention at the executive level as well as in reinforcement of self-regulated learning strategies. This regression analysis underscores the importance of attention deficit and its predictive value in mathematics achievement, rising above the remaining variables as an essential element in explaining mathematics achievement. To date, most studies in this line of work focus on the math area of the curriculum (Gilmore & Cragg, 2014; Kolkman, Hoijtink, Kroesbergen & Leseman, 2013), perhaps because attentional control underlies a complex network of higher-order cognitive tasks and executive functioning. Moreover, the relationship between mathematics and executive functioning is justified because of the importance of inhibitory control and impulsivity (Latzman, Elkovitch, Young & Clark, 2010), as well as other components like working memory, in the development of mathematical skills (Clark, Pritchard & Woodward, 2010).

Cognitive and self-regulated learning strategies are directly linked to executive functions and therefore they all influence academic performance (Portellano & García, 2014; Portellano, 2018). Their symbiosis is understandable, given that students must use strategies for planning, execution and monitoring in the study process, in order to decide which activity

they are going to carry out and to formulate objectives and set goals. In these types of tasks, then, executive functions take on maximum importance, being the true players that coordinate all actions involved in achieving purposes and in reaching success (Portellano & García, 2014). Diverse research studies all concur in confirming the direct relationship between cognitive-motivational variables and learning strategies, which in turn depend on the students' different expectations. Management of time and effort thus emerge as positive strategies, while repetition strategies are less effective (Suárez, 2014); the role of executive functions in effort and persistence on task is therefore predominant in the learning process in general (Meltzer, 2010). It is fundamental that students be guided to improve their motivational self-knowledge, to use goal-setting strategies for learning, to improve their satisfaction with study and foster positive learning expectations (Navea-Martín & Suárez-Riveiro, 2017; Suárez et al., 2018).

Given that knowledge of metacognitive strategies is the basis for later development of metacognitive skills, students should be prompted to apply this knowledge in real tasks in the school context (García et al., 2016). Learning self-regulating strategies should be promoted at all educational levels (Boekaerts & Cascallar, 2006; Núñez, Rosário, Vallejo & González-Pienda, 2013; Schunk, 2005), especially with students who have learning disabilities and low scholastic achievement (González-Pienda, Fernández, Bernardo, Núñez & Rosário, 2014). Interventions based on the components of executive functions confirm differences between children who do or do not participate in these programs (Traverso, Viterbori & Usai, 2015), making it possible to explain the link between executive control capacity and scholastic achievement (Stelzer & Cervigni, 2011). There is hence a justified need for researchers from different disciplines in the study of executive functions, learning and academic achievement, to meet for the purpose of sharing ideas and common conceptualizations that would promote critical thinking in students (Alexander, 2014). Unquestionably, teachers must also be included, as the agents who must understand and be aware of the role that executive functions play in their students' learning process and consequently in their scholastic achievement; this response is found today in Neuro-education, a fusion of neuroscience with education (Mora, 2015).

One approach for future studies in this line of research would be the design and implementation of school interventions aimed to improve executive functioning and learning. Additional studies are needed that would enable us to investigate and understand the transfer



and effectiveness of executive functionality in educational and training programs at school, allowing us to then observe their impact on students' learning and achievement.

One of the limitations of this study is the sole use of self-reports for collecting information. It would be beneficial to have different types of assessment tools that would allow us to evaluate the different components of executive functions. In addition to student characteristics and their manner of learning, it would also be useful to take into account contextual conditions (teacher's teaching style, experience and methodology used), as the context in which students are immersed and which has a determining effect on their behavior (García, González-Castro, Areces, Cueli & Rodríguez, 2014). This way, we would be able to predict possible executive deficits and the degree to which they would interfere and affect learning in children and adolescents. Other variables such as gender, socioeconomic level and age need to be included, and secondary education considered in future studies. Moreover, given that a cross-sectional study does not allow causal relationships to be established, it would be useful to carry out quasi-experimental, longitudinal studies that could be important in verifying whether the interventions are effective and if the differences persist over time.

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