

Executive Functions and Performance Academic in Primary Education from the Colombian Coast

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Abstract

Introduction. The Executive Functions (EF) are a set of supramodal functions that favor cognitive, emotional and social skills. In early childhood, EFs influence the performance of academic skills. The present research determined the relationship between executive functions and academic performance in an educational context.

Method. A correlational study was conducted involving 195 students between 6 and 12 years of age, randomly selected from primary grades (from 1 to 5). The executive functions measured were: verbal fluency (phonological and semantic), selective attention, cognitive flexibility, planning and inhibition; for which, the Neuropsychological Evaluation of the executive functions in children (ENFEN) was used and the academic performance was evaluated from the cumulative academic average in the year.

Results. According to Spearman's correlation analysis, the results show that there is a statistically significant relationship between academic performance and the components of executive functions: phonological fluency ($p = .01$) and cognitive flexibility ($p = .01$). On the other hand, the logistic regression showed that semantic fluency and inhibition are predictive factors for academic performance in 76.4%.

Discussion or Conclusion. Which suggests that executive functions are associated and in turn predict academic performance in elementary school students, especially if this is low.

Keywords: executive functions, verbal fluency, inhibition, academic achievement, elementary school.

Resumen

Introducción. Las Funciones Ejecutivas (FE) son un conjunto de funciones supramodales que favorecen a las habilidades cognitivas, emocionales y sociales. En la primera infancia las FE influyen en el rendimiento de las habilidades académicas. La presente investigación determinó la relación entre las funciones ejecutivas y el rendimiento académico en un contexto educativo.

Método. Se realizó un estudio correlacional donde participaron 195 estudiantes entre 6 y 12 años de edad, seleccionados al azar de los grados de básica primaria (de 1° a 5°). Las funciones ejecutivas medidas fueron: fluidez verbal (fonológica y semántica), atención selectiva, flexibilidad cognitiva, planificación e inhibición; para lo cual, se empleó la Evaluación Neuropsicológica de las funciones ejecutivas en niños (ENFEN) y el rendimiento académico se evaluó a partir del promedio académico acumulativo en el año.

Resultados. De acuerdo con el análisis de correlación de Spearman, los resultados arrojados señalan que existe una relación estadísticamente significativa entre rendimiento académico y los componentes de las funciones ejecutivas: fluidez fonológica ($p=.01$) y flexibilidad cognitiva ($p=.01$). Por otro lado, la regresión logística arrojó que la fluidez semántica y la inhibición son factores predictivos para el rendimiento académico en un 76.4%.

Discusión y conclusiones. Se sugiere que las funciones ejecutivas se asocian y a su vez predicen el rendimiento académico en estudiantes de básica primaria, en especial si este es bajo.

Palabras clave: funciones ejecutivas, fluidez verbal, inhibición, rendimiento académico, básica primaria.

Introducción

Executive functions (EF), a term coined by Lezak (1982), refers to a set of cognitive abilities that involve attentional control, working memory, inhibition, verbal fluency, information processing speed, cognitive flexibility, goal setting, impulse control, empathy and decision making (Anderson, 2008; Portellano, 2005; Stelzer & Cervigni, 2011; Tobar, 2014).

Likewise, the prefrontal cortex is recognized as the neuroanatomical basis of these processes necessary for the adjustment of social behavior, emotional regulation, and planning of cognitively complex behaviors (Martínez & Manoiloff, 2010; Tirapu-Ustárrroz & Luna-Lario, 2008; Yang and Raine, 2009; Wiebe et al., 2011). It is relevant to understand that their formation and consolidation have an established time in ontogenesis, and its due stimulation in the school stage can help a better academic performance (Anderson, Jacobs & Anderson, 2008).

Academic performance is a vital factor for students' permanence in school (Torres, Acevedo & Gallo, 2015). The Institute of Statistics of the United Nations Educational, Scientific and Cultural Organization UNESCO-UIS (2012) reveals that approximately 32.2 million primary school students repeated the grade they were in, and 31.2 million dropped out of school. On the Colombian Caribbean Coast, it has been found that school dropout is a problem that negatively influences the academic, cognitive, family, and social development of children (Erazo, 2012). In particular, Barranquilla has a dropout rate of 4.15% since 2008 (Ministerio de Educación Nacional [MEN], 2011).

In this sense, some programs internationally evaluate this performance, such as the Program for International Student Assessment (PISA) and the Organization for Economic Cooperation and Development (OECD, 2014), which highlight the low performance of Colombian students represented by an average score of 376 for mathematics, 403 in reading and 399 in science which is below the international average, and place it in position 62 of 65 countries evaluated (OECD, 2014). Tiramonti (2014) states that Colombia and Peru are the Latin American countries that present relatively low rates of schooling and, at the same time, do not achieve good results in the tests.

Studies in neuroscience open the way to the intersection between the study of the brain and learning. Tsujimoto et al. (2004) state that during different activities related to working memory, similar areas are activated in both children and adults. From the educational perspective, there are two positions for the study of EF. The first recognizes that the capacity for self-regulation allows the individual to obtain academic success, and the second postulates that learning in the educational context stimulates, in turn, the development of EFs (Garner, 2009). However, there is a point of cohesion between them, where it is understood that executive functions play an important role in the teaching-learning process and areas of knowledge such as calculus, solving mathematical problems, reading, and writing (Toll et al., 2012; Van der Ven et al., 2013).

In this way, the school is the setting where children develop their potential, learn concepts and behaviors that are modeled by teachers, peers, and the culture in which they are immersed (Ortiz, 2013). Academic performance is understood as the assessment of numerical records that an educational institution makes on the specific efficiency of a student it can be classified into three levels: high, medium, and low (Puerta, 2015). This performance is highly valued in mathematical sciences and the Spanish language (Valle et al., 2015). However, it depends on multiple variables, such as the physical, cognitive, family, and social (Algozzine & Algozzine, 2009; Lassen, Steele & Sailor, 2006; Rudasill, Gallagher & White, 2010; Stelzer & Cervigni, 2011).

Different investigations mention the relationship between executive functions and academic performance; the effect of age and schooling on learning, intelligence, pre-academic skills, and culture has been studied (Garner, 2009; Lan, Legare, et al., 2011; Rahbari & Vailancourt, 2015; Roebbers & Jäger, 2014; Shaul & Schwartz, 2014; Suchodoletz et al., 2013). Therefore, they have pointed out the need to study the bidirectional relationship between executive functions and academic performance (Titz & Karbach, 2013) although this link may be deficient in a population with socioeconomic disadvantages (Deer et al., 2020; Peng & Kievit, 2020) and despite the degree of motivation, performance in cognitive flexibility, working memory and inhibition of student (Nieto-Márquez et al., 2021).

Meanwhile, difficulties in mathematics, language, and other areas may be mediated by a deficit in carrying out activities in a planned and organized way or even low attentional control (De Lima et al., 2011; Toll, Van der Ven et al., 2011). Therefore, Suárez-Riveiro et al.

(2019) suggest that higher performance in attention and inhibition improves the global academic average. However, this could depend according to Grenell & Carlson (2021) on whether the teaching is based on facts or conceptual aspects.

Lan et al. (2011) compared academic performance (language and mathematics), and executive functions (working memory, inhibition, and attentional control) in Chinese and North American students; where the cultural differences between the evaluated groups were explained by the school environment and the teaching practices immersed in each context. Furthermore, Scope et al. (2010) stated that there is a relationship between inattention, hyperactivity, and impulsivity, working memory, and inhibitory control in children aged 8 to 9 years. This could be related to the influence of less favored contexts for the development of EF's (Martins & Gotuzo, 2015).

Objective

For all the above, this study aimed to determine the relationship between the following executive functions (inhibition, planning, attentional control, cognitive flexibility, and verbal fluency), and the academic performance of elementary school students in the city of Barranquilla.

Methods

Participants

The student population belonged to El libertador Simón Bolívar District School (D.S L.S.B.), located in the city of Barranquilla and linked to a low socioeconomic level (socioeconomic stratum 1 and 2). The sample was selected through probabilistic sampling since the participants were randomly chosen with a heterogeneity of 50%, a 5% margin of error, and a 95% confidence level. 200 students were chosen of which 5 participants were eliminated due to absenteeism, leaving a total of 195 subjects. 40 students were randomly selected for each grade of elementary school (1st, 2nd, 3rd, 4th, and 5th). Regarding the representation by sex in each grade, first, it had 50% for men and women, in second grade 57.5% for men and 42.5% for women, in third grade 42.5% for men and 57.5% for women, in fourth grade 57.5% for men and 42.5% for women. Finally, the fifth grade had 47.5% for men and 52.5% for women. Regarding age, it was in a range of 6 to 12 years with an average of 8.70 (SD: 1.73)

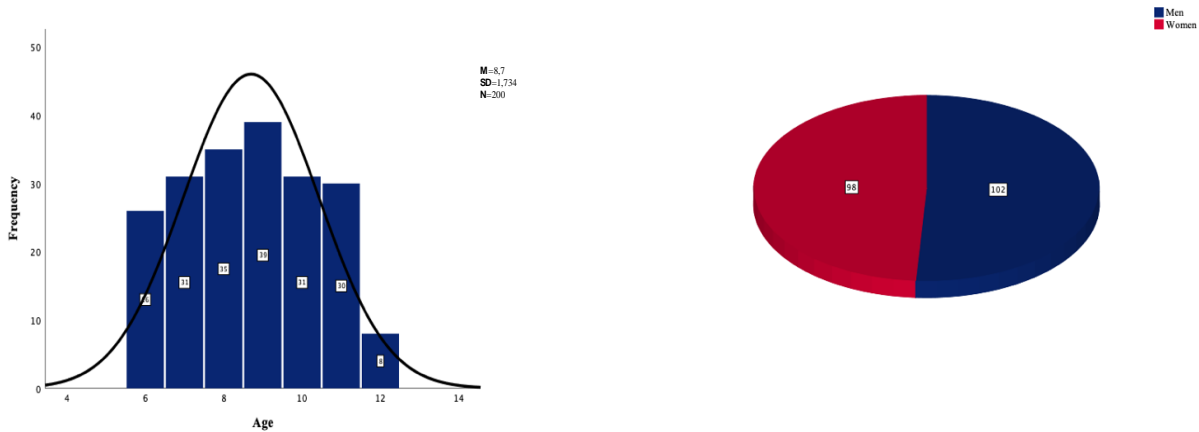


Figure 1. *Distribution by age.*

Figure 2. *Distribution by sex.*

The inclusion criteria for the sample were: attend elementary school and be between 6 and 12 years old. As an exclusion criterion, it was established not to present a history of neurological disease, autism spectrum disorders, psychiatric or neurodevelopmental disorders, intellectual disability, sensory, motor deficit, or serious language comprehension problems, evidenced by a semi-structured interview addressed to parents.

Instruments

For the evaluation of EF's, the Neuropsychological Evaluation of Executive Functions in Children (ENFEN) by Portellano et al. (2009) was used to measure the level of maturity and cognitive performance in activities related to executive functions in children through the following four tests: verbal fluency, construction of trails, construction of rings and resistance to interference. The psychometric evaluation collects 6 neuropsychological indices in datatypes that allow the measurement of phonological fluency, semantic fluency, selective attention, cognitive flexibility, planning, and inhibition. Likewise, the test includes six data types that establish a profile of executive functions from one (1) very low to ten (10) very high. The factor analysis carried out suggested by Portellano et al. (2009) of the ENFEN manual concludes a unique factor. The characteristics of the prefrontal executive system behave like a system (Navarro Soria et al., 2019).

To measure the school performance variable, the accumulated academic average was used with a score from 1 to 100, categorized into the following ranges: Between 1 and 59 (in-

sufficient), between 60 to 79 (acceptable), between 80 and 94 (excellent) and last between 95 to 100 (excellent). These measures, based on an international standardized test could be classified as 1-79 low, 80-94 medium, and 95-100 high (Puerta, 2015).

Process

The research was carried out through an individual evaluation. In each evaluation, the ENFEN was administered in the same order as suggested by the authors and following the application parameters. The average duration of each individual assessment was 35.2 minutes for participants in grades 1-3 and 19.5 minutes for students in grades 4-5. For the variable of academic performance, the directives of the institution with the prior authorization of the parents provided detailed reports of the accumulated average of the students.

Ethical considerations.

All the investigative processes were guided under the established ethical norms for the investigation of human beings according to the statutes of the Colombian College of Psychologists, COLPSIC: Law 1090 of September 6, 2006. The parents signed the informed consent, and the nature of the process and the guaranteed rights were socialized. The research team followed the rules of application, correction, and interpretation as established by the authors in the respective ENFEN manual.

Analysis of data

For the statistical analysis, the SPSS program Version 20 (Statistical Package for the Social Sciences) was used to analyze the sociodemographic characteristics through the distribution of relative frequencies (percentages) for the variables of gender, school grade, and age. The study variables of average academic performance and Executive functions were described using measures of central tendency and dispersion.

Using the Spearman test, the correlation coefficient between the variables of academic performance and EF's (Phonological Fluency, Semantic Fluency, Selective Attention, Cognitive Flexibility, Planning, and Inhibition) is established. To interpret the correlation, the effect sizes suggested by Cohen (1986) were used, where values <0.10: no effect; 0.10 to 0.30: small effect; 0.31 to 0.50: moderate effect; > 0.51: large effect.

Moreover, to measure the EF factors associated with academic performance, logistic regression was performed to analyze the effect of continuous independent variables (Executive functions) on the probabilities that characterize the dependent variable (academic performance). The model coefficients, their standard errors, and the wald statistic were obtained in the process, which allowed the comparison of models in each step.

Results

195 students whose ages ranged from 6 to 12 years were evaluated with a higher proportion of men than women. Table 1 describes the distribution of frequencies concerning sociodemographic variables such as age, sex (male/women), and school grade (first, second, third, fourth, and fifth).

Figure 3 shows the average academic performance and the assessment by frequency obtained by the students. The lowest score for the measurement of academic performance was 52 which corresponds to the qualitative category of insufficient, and the highest 92 which corresponds to an outstanding category.

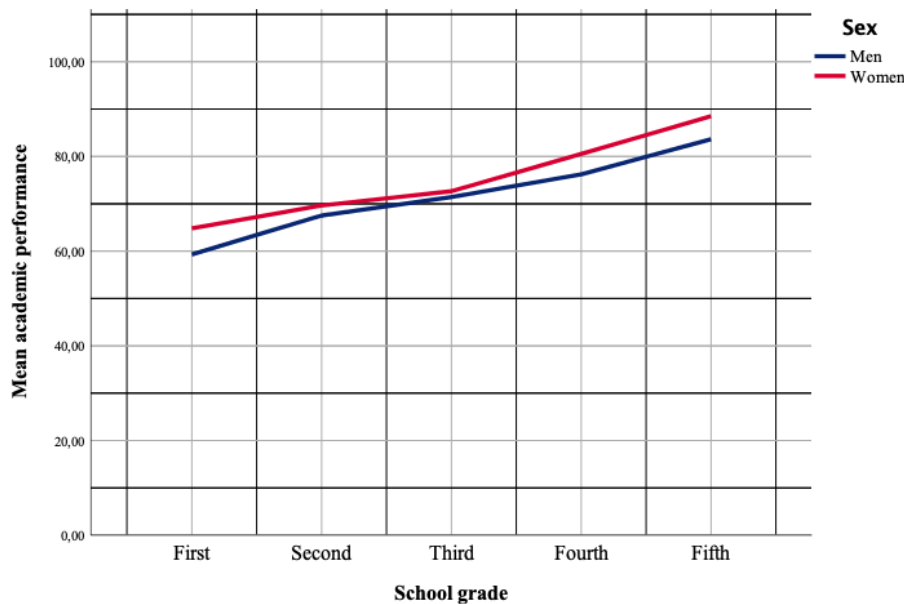


Figure 3. *Distribution of academic average.*

Table 1 presents the summary of the measures of central tendency concerning the variables analyzed: verbal fluency (phonological and semantic), selective attention, cognitive flexibility, planning, and inhibition. According to the mean scores about the percentiles for

the studied sample, the variables of verbal fluency, cognitive flexibility, planning, and inhibition were found above the second percentile (25-50), in contrast to the attention indicator selective which was located in the first percentile (0-25).

Regarding the asymmetry of the curves for the different executive functions, there is evidence of dispersion in the data obtained. However, with the variables of phonological fluency, semantic fluency, selective attention, and inhibition, they show platykurtic curves showing little concentration in the mean, according to kurtosis. For cognitive flexibility and planning, they show a higher concentration of the mean with leptokurtic curves.

Regarding the academic average variable, it was observed that the majority of the evaluated students were found in the acceptable category 72.98. Concerning dispersion, academic performance is shown to be distributed on both sides of the mean but with a trend towards higher academic averages evidenced by a mesokurtic curve.

Table 1. *Description of executive functions and academic average.*

	Phonological fluency	Semantic fluency	Selective attention	Cognitive flexibility	Planning	Inhibition	Academic average	
Media	5.54	10.55	12.3	7.65	296.82	52.01	72.98	
Median	5	10	13	7	260	52	72	
Mode	4	10	0	6	184	56	72	
Standard deviation	3.055	3.885	7.724	4.704	133.578	19.025	8.388	
Skewness	0.741	0.459	0.442	0.888	1.896	0.13	0.157	
Standard error of skewness	0.174	0.174	0.174	0.174	0.174	0.174	0.174	
Kurtosis	0.561	0.788	0.933	1.932	5.01	0.084	-0.373	
Kurtosis standard error	0.346	0.346	0.346	0.346	0.346	0.346	0.346	
Minimum	0	2	0	0	22	0	52	
Maximum	17	26	45	29	929	103	92	
Percentile								
	25	3	8	7	5	214	38	67
	50	5	10	13	7	260	52	72
	75	8	13	17	10	345	64	80

Table 2. shows the results obtained by Spearman's R showing the relationship between EF and academic average. The value obtained from q (Cohen, 1986) shows a large effect size for phonological fluency (.611) and cognitive flexibility (.607), also a minor effect for semantic fluency (.231) and inhibition (.210), and finally, for the planning variables (.109) and selective attention (.104) a small effect within the lower limit of the range for this effect size.

Table 2. *Correlation analysis (Spearman's Rho)*

	Phonological fluency	Semantic fluency	Selective attention	Cognitive flexibility	Planning	Inhibition
Academic average	.611**	.231*	.104	.607**	.109	.210*

** . The correlation is significant at the 0.01 level (two-tailed).

* . The correlation is significant at the 0.05 level (two-tailed).

Finally, we proceeded to determine the predictive factor of executive functions on the academic average variable, as shown in Table 3.

Table 3. *Results derived from the binary logistic regression for the probability of presenting high academic average.*

		Academic average		Percentage correct	
		High	low		
Academic average	High	3	45	6,3	
	low	1	146	99,3	
		<i>B</i>	<i>SE</i>	<i>Wald</i>	<i>DF</i>
	Semantic fluency	.113	.048	5.537	1
	Inhibition	-.023	.009	6.289	1
	Constant	1.216	.664	3.354	1

Note: B = coefficient; S.E. = Standard Error; DF = Degrees of Freedom.

Through the logical regression performed, the results show that the model was able to predict 76.4% of the cases through the predictive factors of semantic fluency and inhibition

with Wald significance values > 0.05 . According to the above, it can be estimated that semantic fluency and inhibition are predictive factors for academic performance.

Discussion and Conclusions

The main objective of this research was to correlate executive functions and academic performance at the school. A school is a place of interaction where cognitive and social skills are reinforced, in an environment conducive to the integral development of children. Therefore, it is relevant to evaluate executive functions since they involve a set of skills that allow the student to respond to academic demands. From the percentiles of the studied population, a mean performance is evidenced for the executive functions of verbal fluency, cognitive flexibility, planning, inhibition, and low performance for the selective attention indicator. Fernandez-Castillo & Gutiérrez (2009) affirm that low scores in attention could lead to lower performance than expected, as evidenced by the academic average of the study population, with a qualitatively acceptable or low average score.

When establishing the relationships between the study variables, concerning verbal fluency, a large effect was found for both the phonological aspect and a small effect for the semantic one to the academic average. This confirms what was found by Marino, Acosta & Zorza (2011) who report better performance of verbal fluency at higher evocative speed with the use of anticipation and monitoring. That said in the educational environment, the strategies used in the different subjects arranged for primary school by the Ministry of Education (MEN, 1984), strengthen executive functions and verbal content allowing that they are acquired at a higher level in fluency and in the ability to use them efficiently.

Likewise, when analyzing the relationship between cognitive flexibility and academic average, it was found that there is a large effect, which coincides with the findings of Vandenbroucke et al. (2017) affirm that cognitive flexibility shows small improvements in the academic performance of first-grade children.

According to the inhibition measure, although a weak relationship was found concerning academic performance, various authors maintain that inhibitory processes are fundamental for the academic performance and academic success of the child (Aydumne et al., 2016). This is differentiating in this research since the type of population and the vulnerable socio-

economic stratum to which they belong revealed a significant impact on cognitive performance (Aran-Filippetti, 2011; Deer et al., 2020; Peng & Kievit, 2020) and in the academic skills reflected in a general average of academic performance acceptable for Colombia and low according to internationalization standards. Likewise, when analyzing the measure of selective attention and planning, a statistically little effect was found within the lower limits of the sample studied, as reported by Reyes et al. (2015), which may be due to the particular sociodemographic vulnerability of the sample studied. This variable should continue to be taken into account in future studies.

The logistic linear regression analysis showed that the predictor variables in 76.4% for academic performance are semantic fluency and inhibition. Semantic fluency is explained from the speed of information processing, which has an important relationship with the ability to learn and school achievement skills; since semantic fluency is that task where it is requested to generate words belonging to a category (eg: animals, fruits, clothes, transport, vegetables, etc.), granting a time limit to execute the task (Ramírez et al., 2005). On the other hand, the inhibition is related to the capacity for self-regulation, which directly influences the learning capacity, explained by Del Valle & Urquijo (2015), who exposed these neurocognitive variables predict academic performance to a certain extent, specifically they found an association between the use of semantic coding strategies, learning capacity and academic performance of students.

The importance of establishing a frame of reference for the cognitive performance of elementary school students in the Colombian context lies in the early detection of difficulties in the school area (Gutiérrez-Martínez & Ramos, 2014); as well as in identifying those variables associated with EFs that can have a long-term impact on state tests. Likewise, our results favor and encourage early intervention in FE which benefits students in decision-making and future plans significantly improving academic performance.

Within the limitations of the study, the need to have the participation of educational institutions with students of different socioeconomic levels can be highlighted for greater representativeness of the sample, as well as increase the representative sample size for the country. Kishiyama et al. (2014) affirm that the socioeconomic stratum influences the child's performance concerning EF, since some parenting conditions, stress, lack of access to cognitive stimulation, materials, and experiences, do not contribute to the cognitive performance of

schoolchildren. It is expected in future studies to implement guidelines for the stimulation of executive functions, which allow minimizing the impact of conditions of socio-economic vulnerability, which lead to disruptive social behaviors, absenteeism, dropouts, and loss of the school year. It is suggested that this research can be replicated in other regions of the country, both in public and private schools, to have a complete picture of the performance of executive functions and their relationship with the academic average. Likewise, that a Colombian standardization of the ENFEN battery can be established to expand its uses.

In conclusion, this article suggests that there is a significant relationship between phonological fluency, cognitive flexibility, and academic performance. Despite this, the variables that could become a cognitive marker to predict the state of academic skills in a population from a vulnerable socioeconomic stratum are semantic fluency and inhibition.

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