Executive functions and attention in school-age children according to the behavioral profile rated by their teachers

Funciones ejecutivas y atención en niños en edad escolar de acuerdo con el perfil comportamental valorado por sus docentes

Research

Vanessa Arán-Filippetti[a,b] *, Gabriela L. Krumm[a,b]

[a] *Centro Interdisciplinario de Investigaciones en Psicología Matemática y Experimental Dr. Horacio J. Rimoldi (CIIPME). Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET).* [b] *Facultad de Humanidades, Educación y Ciencias Sociales, Universidad Adventista del Plata, Argentina*

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ABSTRACT

The present study aimed at analyzing the link between school-age children's performance in neuropsychological tests that examine the executive function (EF) and attention, and their behavioral profiles (i.e., Attention Deficit (AD) and Hyperactivity (HA), as rated by their teachers. For the assessment of EF and attentional mechanisms, different tasks were administered to a sample consisting of 124 children from 3rd to 6th grade. In addition, teachers from each grade completed a behavior rating scale for every child. Bifactorial MANCOVA was used in order to analyze the effect of both AD and HA factors, controlling for the intelligence, over the child's cognitive performance. Results demonstrated significant differences according to AD level in tasks that assess (i) selective attention, (ii) working memory, (iii) reactive cognitive flexibility (iv) verbal fluency and (v) reflexivity-impulsivity. Conversely, regarding the HA level, results showed significant differences only in terms of the number of errors made in the MFFT20. This work provides evidence on the relationship between children's behavior within the school setting and their cognitive performance.

Key Words:
Attention, Hyperactivity, Executive Functions, Child, Neuropsychology

RESUMEN

El objetivo del presente estudio fue analizar la correspondencia entre el desempeño en pruebas neuropsicológicas que exploran las funciones ejecutivas (FE) y atención y el perfil conductual (i.e., Déficit de Atención (DA) e Hiperactividad (HA)) valorado por docentes, en niños en edad escolar. Para esto, se administraron diferentes tareas para valorar las FE y los mecanismos atencionales a una muestra de 124 niños de 3ro. a 6to. año de escolaridad primaria. Además, los docentes de cada grado completaron una escala comportamental

Palabras Clave:
Atención, Hiperactividad, Funciones Ejecutivas,

****Corresponding author:*** *Vanessa Arán Filippetti, Centro Interdisciplinario de Investigaciones en Psicología Matemática y Experimental (CIIPME-CONICET). Tte. Gral. Juan D. Perón 2158 C1040AAH, Buenos Aires, República Argentina, E-mail:* vanessaaranf@gmail.com

para cada niño. Para analizar el efecto del factor DA y del factor HA, controlando la inteligencia, sobre el desempeño cognitivo del niño se empleó MANCOVA bifactorial. Los resultados revelaron diferencias significativas, según el nivel de DA, en las tareas que valoran (i) atención selectiva, (ii) memoria de trabajo, (iii) flexibilidad cognitiva reactiva, (iv) fluidez verbal y (v) reflexividad-impulsividad. En cambio, respecto al nivel de HA, los resultados revelaron diferencias significativas sólo en cuanto al número de errores cometidos en el MFFT20. Este trabajo aporta evidencia sobre la relación entre las conductas del niño en el ámbito escolar y su rendimiento cognitivo.

Neuropsicología Infantil

1. INTRODUCTION

In recent years, *executive functions* (EF) as well as *attention* have been the subject of numerous studies within the field of child neuropsychology. This increasing interest is partly motivated by the fact that they are constructs related to academic performance (Latzman, Elkovitch, Young & Clark, 2010; van der Sluis, de Jong & van der Leij, 2007) and because they are processes involved in various childhood disorders such as Attention Deficit Hyperactivity Disorder (ADHD) (Arán Filippetti & Mías, 2009; Barkley, 1997, Brown, 2005, 2006), and autism (Ozonoff, Pennington, & Rogers, 1991; Pennington et al., 1997), among others.

Since there is certain overlapping between the concepts of EFs and attention (Fletcher, 1998) and they are considered as constructs composed of multiple components, the definition and operationalization of these processes are not without controversy. The term EF refers to a series of cognitive processes necessary for goal-directed behavior (Luria, 1966; Stuss & Benson, 1986). It is a construct that includes different dimensions such as (a) inhibition, (b) working memory, (c) set shifting, (d) planning and (e) fluency (Pennington & Ozonoff, 1996).

Similarly, attention has been defined according to different sub-processes. For example, Sohlberg & Mateer (2001) propose a clinical model of attention composed by five components hierarchically related, namely (a) focused attention, (b) sustained attention, (c) selective attention, (d) alternating attention, and (e) divided attention.

Several authors argue that EFs and attention are related processes and that the latter is even one of the main aspects of the EF construct. In this sense, the model proposed by Posner and Petersen (1990) appears as a clear example of this relationship. These authors divided the attentional system into three different networks: (a) the alerting network, (b) the orienting network and (c) the executive network. This last network or system (i.e., executive control) would refer to the EF and includes mechanisms such as inhibition of irrelevant responses, attentional change and planning (Zhan et al., 2011). Other models supporting this superposition between the two constructs are the Supervisory Attentional System (SAS) of Norman and Shallice (1986), the working memory model of Baddeley (1986, 2010), and the Barkley's (1997) hybrid model. From a neurofunctional point of view, both the EFs and the attentional processes are associated with frontal lobe regions in connection with other cortical areas and subcortical structures (Bench et al., 1993; Fuster, 1997; Smith, & Jonides, 1999).

Recently, there has been a growing interest in the study of children's cognitive performance in tasks that assess the EFs and the attentional ability according to their level of inattention, hyperactivity and impulsivity (i.e., ADHD symptoms). The importance of this analysis lies in the fact that the association between these behaviors and the cognitive functioning has not been only shown in children with ADHD (see e.g. Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005) but also in non-clinical child populations.

An example favoring this association is found in a study carried out by Adams and Snowling (2001), who found that children defined as *hyperactive* by their teachers obtained a lower performance in relation to a control group in tasks that assess EFs and literacy processes.

In line with this, Wilding (2003) analyzed the performance achieved by 6-to 15-year-old children in a computerized task based on visual searching according to their attentional abilities as rated by their teachers. The author found that children with low attentional abilities made more errors in the most complex aspects of the task with respect to children with higher abilities.

Consistently, Scope, Empson and McHale (2010) studied the cognitive performance in two groups of 8- and 9-year-old children categorized in terms of their attentional skill level. The authors found that children with low attentional abilities, compared to those with higher ones, obtained a lower performance in tasks assessing the EFs. Besides, these differences would not be explained by individual differences in children's level of intelligence.

A significant longitudinal study conducted by Friedman et al. (2007), analyzed how attentional problems –as assessed by teachers- in children aged 7 to 14 years, eventually related to the executive functioning at the age of 17 years. Authors found that attentional problems of children 7 - 14 years old are associated with individual differences in response inhibition, working memory, and set shifting at the age of 17 years. Besides, the differences found in EFs would be mainly due to the attentional problems initially noticed rather than to their changes over the years.

Another relevant study in this area is the one conducted by Gathercole et al. (2008), who investigated the relationship between working memory and different behavior related to attention and executive functioning problems in the school setting. Authors found that children with low scores in tasks assessing working memory showed - in terms of behavior and according to their teachers' assessment- inattentive symptoms, cognitive problems, difficulties to monitor the quality of their works and to create new solutions to problems. According to these authors, these results support the hypothesis which maintains that working memory problems and inattentive behaviors coexist in non-clinical child population.

Overall, empirical evidence suggests that child's behavior - assessed from teacher's point of view- would be associated with individual differences of cognitive achievement.

Although there is a growing interest for the study of the relationship between behavioral and cognitive profiles in school populations, there is not enough research analyzing this link in Spanish-speaking children as well as that assessing the effect of attention level and hyperactivity both separately and together over the child's cognitive performance.

Based on these premises, the aim of the present study was to analyze the relationship between the performance in tasks which explore EFs and attention, and the behavioral profile (i.e., Attention Deficit (AD) and Hyperactivity (HA)) assessed by teachers in school-age children. Given the previous empirical evidence, the following hypotheses were formulated: (H1) there are significant differences in children's attentional and executive functioning according to their levels of AD and HA, (H2) the differences found in the child's cognitive performance according to his/her behavioral profile are not explained by individual variations in the intelligence level.

2. METHOD

2.1. Participants

The intentional non-probabilistic sample consisted of 124 children from 3rd to 6th grade of primary school, of both sexes and medium socioeconomic status, from Santa Fe, Argentina. The average age was 9.31 years and the standard deviation was 1.18. Inclusion criteria were: (a) children without clinical, neurological or psychiatric history, (b) attending school on a regular basis, (c) no grade repetition.

2.2. Instruments

2.2.1. Behavioral assessment

- Conner's Teacher Rating Scale (modified and validated by Farré Riba & Narbona, 1997). It measures three distinct factors: Attention Deficit, Hyperactivity and Conduct Disorder. Each item describes a typical children's behavior that teachers should assess according to the intensity in which they occur (Not at All=0, Just a Little=1, Pretty Much=2, Very Much=3). The score for each factor is given by the sum of the constituent items. The factors considered for analysis in this study were (a) Attention Deficit (AD) and (b) Hyperactivity (HA).

2.2.2. Neuropsychological assessment

-KBIT, Kaufman Brief Intelligence Test (Kaufman & Kaufman, 2000). It measures verbal and nonverbal intelligence and consists of two subtests: (a) Vocabulary (verbal / crystallized) and (b) Matrices (manipulative / fluid). By adding up the scores on both subtests, it is possible to obtain a measure of general intelligence.

-CARAS, Differences Perception Test (Thurstone & Yela, 2001). It appraises the ability to perceive similarities and differences and provides a measure of selective attention.

-d2, Test of Attention (Brickenkamp, 2004). It offers a measure of processing speed, selective attention and mental concentration capacity through the particular searching of target stimuli.

-Digit Span and Letter–Number Sequencing Subtests of the WISC-IV (Wechsler Intelligence Scale for Children - Fourth Edition) (Wechsler, 2005). It allows a measure of working memory. It includes two main sub-tests: Digit Span (DS) (Digit forward and Digit Backward) and Letter-Number Sequencing (LNS).

-Stroop Color-Word Test (Golden, 1999). It provides a measure of resistance to interference and inhibitory control. It consists of three conditions: (a) word, (b) color, (c) word-color. The last sheet (i.e., color

word condition) provides a measure of interference control, since the individual must inhibit the reading of the word in order to give the name of the color.

-*Porteus Maze Test* (Porteus, 1965, Spanish adaptation TEA, 2006). It allows assessing the child's planning ability. It consists of twelve mazes of increasing complexity. In each maze, the participant must trace the way from a starting point to an exit and must avoid blind alleys and dead ends, with no backtracking allowed.

-*Matching Familiar Figures Test (MFFT20)* (Cairns & Cammock, 1978, Spanish adaptation Buela-Casal, Carretero-Dios, & De los Santos-Roig, 2005). It evaluates the reflexivity-impulsivity cognitive style. The variables investigated are the total number of errors and mean latency of the first response. In previous studies it has been shown that MFFT indicators load on certain factor of the EF construct (Arán Filippetti, 2013; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Welsh, Pennington, & Groisser, 1991).

-*Wisconsin Card Sorting Test* (WCST) (Heaton, Chelune, Talley, Kay y Curtiss, 1993, Spanish adaptation TEA, 1997). It provides a measure of executive function particularly of reactive flexibility and categorization ability.

- *Semantic Verbal Fluency (SVF) and Phonological Verbal Fluency (PVF).* The task consists on asking the subject to evoke all possible words that belong to a certain category (*animals and fruits*) or that begin with a particular letter (*Letters F, A, and S*) in a period of 60 seconds. The VF tasks allow assessing the spontaneous flexibility of the individual.

2.3. Ethical Procedure

Firstly, school principals were contacted so as to request permission for conducting the research. Secondly, a note was sent to children's parents or legal tutors explaining them the work objectives and the task to carry out. It was explicitly stated that collaboration was voluntary and anonymous. Finally, the written consent of all parents and legal tutors was obtained before beginning the assessment.

2.4. Statistical Procedure

Descriptive statistics was used to determine the demographic characteristics of the sample. In order to divide the groups according to their behavioral profile, each behavioral factor (i.e., AD e HA) was recoded at three levels: low, medium, and high. Low and medium levels of each dimension were considered as low-AD or low-HA, and high level as high-AD or high-HA. In addition, prior to the analysis of cognitive performance according to the groups, it was verified that there were significant differences in the scores obtained in the DA factor between the groups with low-AD and high-AD ($p < .001$), as well as significant differences between the groups with low-HA and high-HA in the HA factor ($p < .001$). Once the two groups were created, bifactorial Multivariate Analysis of Covariance (MANCOVA) was used to analyze the effect of the AD factor, the HA factor, and the interaction AD x HA, controlling for intelligence, over the child's cognitive performance. Data processing and statistical analysis were performed using the *Statistical Package for the Social Sciences* (SPSS) version 20.0.

3. RESULTS

Demographic characteristics and scores obtained on the factors of the behavior scale (i.e., AD e HA) according to the children's behavioral profile are presented in Table 1.

3.1. Performance on Attention Tasks according to the AD and HA level, controlling for intelligence

MANCOVA revealed a significant effect for the AD factor, Hotellings' $F(2, 118) = 3.89$; $p = .023$, $\eta_p^2 = .06$, but neither for the HA factor, Hotellings' $F(2, 118) = 1.93$; $p = .149$, $\eta_p^2 = .03$ nor for the interaction AD x HA, Hotellings' $F(2, 118) = 0.43$; $p = .652$, $\eta_p^2 = .01$. Univariate analysis indicates a significant AD factor effect on selective attention, $F(1, 119) = 7.84$, $p = .006$, $\eta_p^2 = .06$ (see Table 2).

3.2. Performance on EFs tasks according to AD and HA level, controlling for intelligence

MANCOVA revealed a significant effect for the AD factor, Hotellings' $F(7, 113) = 2.33$; $p = .029$, $\eta_p^2 = .13$, and for the HA factor, Hotellings' $F(7, 113) = 2.12$; $p = .047$, $\eta_p^2 = .12$, but not for the interaction AD x HA, Hotellings' $F(7, 113) = 0.68$; $p = .689$, $\eta_p^2 = .04$. Significant AD factor effects were found for working memory, $F(1, 119) = 9.22$; $p = .003$, the number of complete categories of WCST, $F(1, 119) = 4.17$; $p = .043$, verbal fluency, $F(1, 119) = 6.12$; $p = .015$, and latency time of MFFT20 $F(1, 119) = 5.25$; $p = .024$. A significant HA factor effect was found for the number of errors made in the MFFT20 $F(1, 119) = 4.60$; p = .034 (see Table 3).

Table 1. *Demographic characteristics of children according to their behavioral profile.*

	Behavioral profile			
	Low-AD	High-AD	Low-HA	High-HA
Children (*n*)	83	41	87	37
Age (M ± SD)	9.37 (1.18)	9.17 (1.18)^{ns}	9.44 (1.18)	9.00 (1.13)^{ns}
Grade	3–6	3–6	3–6	3–6
AD (M ± SD)	**1.51 (1.52)**	**9.12 (3.74)*****	3.40 (3.85)	5.49 (5.15)
HA (M ± SD)	2.08 (2.59)	4.56 (4.06)	**1.05 (1.15)**	**7.27 (2.67)** ***

ns = non-significant, ****p* < .001

Table 2. *Performance on Attention tasks according to AD and HA level.*

	Behavioral profile							
	Low-AD		High-AD		Low-HA		High-HA	
	M	SD	M	SD	M	SD	M	SD
SA	29.45	9.80	24.17	7.11	28.64	9.08	25.49	9.59
AIC	246.39	66.59	227.76	72.43	248.74	72.11	220.22	56.44

Note. SA = Selective attention (CARAS test), AIC = Attentional and inhibitory control (d2 test).

4. DISCUSSION

The purpose of this study was to analyze the performance achieved by school-age children in tasks that explore the attentional ability and the EFs according to their behavioral profile assessed by their teachers. Specifically, it aimed at analyzing if children with higher attention deficit levels (High-AD) and/or hyperactivity (High-HA) obtain lower scores in relation to children with low levels (i.e., Low-AD and Low-HA) in tasks that evaluate the cognitive areas previously mentioned.

Regarding the AD factor, it was found that children with high scores, unlike the group with lower ones, consistently demonstrated a low performance in the task that assess selective attention. Concerning the performance obtained in EFs, significant differences in the majority of the tasks administered (i.e., working memory, reactive cognitive flexibility, and verbal fluency) in favor of the low-AD group were found. It is worth noting that the differences found in the tasks of attentional ability and the tasks which explore the EFs would not be explained in terms of individual differences in children's level of general intelligence. These results suggest that the behavioral dimension “Attention Deficit” assessed from the teacher’s perspective would provide a first indicator about the underlying children’s cognitive profile. These data are in line with previous studies that found an association between children’s attentional abilities and their executive task performance (Adams & Snowling, 2001; Friedman et al., 2007; Scope et al., 2010).

However, it should be noted that no significant differences in attentional and inhibitory control (i.e., d2 and Stroop tasks) according to the AD level were found. Apparently, attentional differences in terms of behavior would not be explained by individual variations in the inhibitory processes. This would be consistent with studies indicating that ADHD inattentive subtype -unlike the hyperactive-impulsive and the combined ones- would exhibit less associated deficits in response inhibition (Arán Filippetti & Mías, 2009; Barkley, 2003; Romero-Ayuso, Maestú, González-Marqués, Romo-Barrientos, & Andrade, 2006).

Table 3. *Performance on EF tasks according to AD and HA level.*

	Behavioral profile							
	Low-AD		High-AD		Low-HA		High-HA	
	M	SD	M	SD	M	SD	M	SD
WM	35.93	3.66	34.12	3.97	35.09	3.96	35.89	3.45
Stroop	24.90	6.10	24.85	5.15	24.55	5.78	25.68	5.79
Porteus	12.20	1.71	11.61	2.09	12.08	1.86	11.84	1.87
MFFT20-E	15.82	8.22	19.32	8.62	15.82	8.03	19.70	8.98
MFFT20-L	308.77	162.01	222.53	129.75	298.01	167.47	238.51	120.89
NCC	5.28	1.24	4.83	1.40	5.08	1.37	5.24	1.16
VF	40.05	11.67	35.56	10.16	38.14	11.67	39.57	10.63

Note. WM = Working memory score of WISC IV; Stroop = color-word score of Stroop; Porteus = Total number of mazes completed; MFFT20-E = Total errors of MFFT20; MFFT20-L = latency time of MFFT20; NCC = Complete categories of WCST; FV= verbal fluency (semantic and phonological verbal fluency score)

As regards the HA dimension, it was found that children with higher scores in this factor made a greater number of errors in the MFFT20. Apparently, the MFFT20 task would provide relevant information for the differentiation of children’s cognitive profile according to their behavioral profile. According to the findings of this study, children with high-AD used less *latency time* than children with low-AD, whereas children with high-HA made significantly more *errors* than children with low-HA. Thus, both inattentive and hyperactive behaviors seem to reflect some issues related to the child's cognitive impulsivity. However, the performance achieved by children with high-HA -in attention tasks and other EFs- was similar to the ones with low-HA. This data suggest that *hyperactivity*, considered as a behavioral dimension in non-clinical populations, would not demonstrate individual variations in attentional and executive performance assessed through cognitive tasks. Therefore, it could be hypothesized that in cases where hyperactive behavior is not the manifestation of a specific child disorder (e.g. ADHD), the former would not be associated with a child's cognitive performance. This could be alternatively explained through the assessment of the hyperactive behavior itself. According to Lipowska y Buliński (2007), the teacher's perception of the hyperactive behavior would be more associated with the students' assumption of a special attitude towards her and the world than with a specific brain cognitive disorder. Nevertheless, it should be added that many of the behavioral indicators that are employed to value hyperactive behaviors do not necessarily tap issues related to children's cognitive activity. Therefore, since the assessment of hyperactivity supposes certain subjectivity level, the differentiation of a "normal" behavior from a clinical symptom would require an exhaustive and ecological assessment.

In general, these results allow getting to the following conclusions regarding the behavioral assessment made by the teacher in *non-clinical* child populations. (1) Individual variations in the attentional dimension would be associated with individual differences of cognitive performance. This is in line with the characterization of attentional problems as a continuum (Levy, Hay, McStephen, Wood, & Waldman, 1997) probably associated with immaturities of variable degree of frontal lobe development (Adams & Snowling, 2001). (2) Individual variations in the HA dimension do not reflect individual differences of attentional and executive functioning.

Although data indicate that children with higher levels of inattention obtain a lower performance in attention and EFs tasks, it is important to clarify that, as this study demonstrates, this fact does not imply the presence of cognitive deficit. The characteristics of the sample used in the present study could provide an explanation to this: since children who participated had not any neurological or psychiatric history, the differences observed in behavioral and cognitive profiles are not comparable to those that are evident in different child disorders of neurobiological etiology. However, the analysis of the relationship between the cognitive and the behavioral profile in *non-clinical* child samples gains importance considering that individual variations in inattentive and hyperactive behaviors would be associated with long-term differences in socioemotional and cognitive functioning (Friedman et al., 2007; Scope et al., 2010; Wåhlstedt, Thorell, & Bohlin, 2008). According to Wåhlstedt et al. (2008), the study of ADHD symptoms, even when they are under the clinical cutoff, is relevant for the understanding of child development.

Based on these assessments, we consider it would be relevant for the clinical and educational practice to look deeper into the study of this association within the school population, since it allows understanding the relationship between individual differences of executive functioning and inattention and hyperactive behaviors when they vary within the *normal* rank and not just in the clinical extreme. Besides, it would provide initial indicators for the differentiation among behaviors that are typical and age-related or characteristic of a child, from those which are inherent to a clinical disorder. According to Lipowska y Buliński (2007), insufficient knowledge and lack of acute diagnostic criteria are often the reasons for overestimating certain behavior as a pathology indicator in the school setting. Therefore, as the child increasingly learns to anticipate the teacher's expectations and to act in response (Lipowska, 2004, cited in Lipowska & Buliński, 2007), it is important to have valid indicators for an early identification of individual variations of children's behaviors and to further recognize whether these variations are related with their cognitive performance.

Although data from this study contribute to the understanding of the relationship between children's cognitive functioning and their behavioral profile, it is necessary to point out some limitations. Firstly, we should mention that the sample was intentional and was limited to Argentinian children from third to sixth grade of primary school. For that reason, results cannot be generalized to children from other countries and of different grades. Secondly, this study deals exclusively with the school setting which limits the generalization of the findings to other contexts. We consider that research on the relationship between children's cognitive and behavioral profiles assessed from different settings (e.g. family), different ages, as well as in clinical populations could provide relevant information to gain full understanding of this relationship.

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