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CHARACTERIZATION OF NEUROPSYCHOLOGICAL FUNCTIONING IN CHILDREN WITH CLINICAL FEATURES OF ADHD

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Abstract

Attention deficit with/without hyperactivity is one of the most controversial and currently studied disorders. From a neuropsychological point of view, its characterization is gaining ground with a view to obtaining a more effective diagnosis and treatment. However, there are not many studies that have compared the different profiles of ADHD from this approach. Thus, the aim of the present study was to compare groups of school-aged children with characteristics of attention deficit, hyperactivity-impulsivity and controls, with respect to the neuropsychological variables: saccadic movements, auditory discrimination, executive functions and working memory. A sample of 36 students aged 8-10 years was evaluated, distributed equally among the 3 groups. After analyzing the results obtained from the application of different tests: King-Devick,(KD), Phoneme Articulation Test (PAF), Stroop Color and Word Test and the index of working memory of the Weschler Intelligence Scale for children; it was confirmed that subjects with behavioral characteristics of attention deficit and hyperactivity showed a worse performance than the control group in all variables, and no statistically significant differences were found between inattentive and hyperactive ADHD profiles. Results were discussed and it is concluded that based on the present comparative study, a differential neuropsychological profile cannot be established between children with a characteristic pattern of inattention versus one of hyperactivity-impulsivity, and generally the children with clinical features of ADHD presented a decrease in the neuropsychological variables evaluated.

Keywords: Auditory Discrimination, Clinical Features of ADHD, Executive Functions, Neuropsychological Profile, Saccadic Movements, Working Memory

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1. Introduction

Attention deficit with and without hyperactivity has been of great interest to neuropsychological and clinical research. It is of high prevalence in the child population and social relevance it has, since it is a condition that continues until adolescence and in some cases until adulthood, causing functional alterations in the individual (APA., 2013) with the consequent emotional impact for those who suffer it. Since the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (APA., 2014), ADHD has been included among the disorders of neurodevelopment and not among behavioral disorders as before, which consequently accentuates its chronicity (Isorna, 2016).

From the neurobiological viewpoint, attention is a complex process involving various cortical and subcortical structures that participate from sensory integration of stimuli, allowing selective attention, to the inhibitory control of responses and the ability to ignore other stimuli to maintain attentional focus, among others. At school age, normally between 7 and 11-12 years of age, children must have mastered basic movement patterns, improve comprehension and expression through reading and writing, acquire basic instrumental techniques such as reading, writing and calculating with increasing skill and thinking becomes more complex. Therefore, attentional failures that interfere with information processing and behaviour are already evident.

Among the factors involved, saccadic movements are a measure of visual functionality that primarily influence reading, so deficits in ocular motor skills are at the base of many reading difficulties (Miguel, 2017). On the other hand, auditory discrimination of speech sounds, hinders the learning process and can lead to school failure, according to Portellano 2005, quoted in (García-Castellón & Gamazo, 2015).

Each subtype of ADHD has behavioral characteristics that are particularly noticeable in the educational setting, for example, children who exhibit inattentive behaviors may go unnoticed in their classroom, are often identified by the product of their work: noncompliance with tasks, disorder in materials, poorly presented notebooks, etc. On the other hand, children with hyperactivity or impulsivity are quickly detectable through direct observation, their restlessness and impulsivity often lead to friction with their peers or more notorious behavior problems, their execution of tasks is usually quick to the detriment of quality and they may skip test instructions or interpret questions quickly and incorrectly (Abad-Mas et al., 2013).

These behavioral manifestations, if not addressed early, can develop significant learning problems (Aguilera et al., 2014), as well as conflicts between peers, since in adolescence and adulthood the most prevalent symptom is impulsivity, which can be associated with more complicated situations such as substance use and antisocial behavior (APA., 2013).

Among the neuropsychological variables related to attention/hyperactivity, mainly executive functions have been studied (Gaitán & Rey-Anacona, 2013; Romero-Ayuso et al., 2006), and sensory functioning (García & Vergara, 2015), especially visual and auditory, as well as working memory (Dean, 2006).

In an investigation of executive functions in relation to ADHD subtypes, they found that subjects with ADHD-inattentive subtype and ADHD-subtype combined showed significant differences in verbal

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working memory and persistent errors in categorical fluency. They found no significant differences between the ADHD subtypes in inhibition, set switching, verbal fluency, cognitive flexibility and planning, but they did find significant differences in each of the verbal working memory tasks. Also, the ADHD-comorbid group with ODT or CT reached more severe levels of executive functions impairment, without finding differences between the inattentive group and the control group in such executive functions (Saydam et al., 2015). In other research, it was found that the combined subtype of ADHD had generalized deficiencies while the attempt had a lower performance in working memory and planning tasks, but not in all the executive functions evaluated (Romero-Ayuso et al., 2006).

According to Aguilera et al. (2014), ADHD is associated with learning disabilities: with dyslexia in 39% of cases, with dysgraphia in 60% and dyscalculia in 26% of cases. In turn, sensory maturation problems affect the processing of information making it ineffective (López Juez, 2010), therefore, affect the attention process and consequently learning. In the line of sensory research, (Torcal, 2012) found associations between saccadic movements and difficulties in reading speed and comprehension in the first grades of primary school. On the other hand, links have been reported between a history of otitis media and hyperactive and inattentive behaviors in school children (Adesman et al., 1990) and signs of dysfunctional auditory processing through electrophysiological assessments, findings that seem to reaffirm the incidence of sensory processing on inattentive and hyperactive-impulsive behaviors of ADHD.

García and Vergara (2015) found significant differences in saccadic movements and auditory phoneme discrimination, but not in laterality of children with and without ADHD between 7 and 11 years. They emphasize the importance of working with different information processing systems for the maturation of the central nervous system as a whole.

The importance of working memory in relation to ADHD has also been investigated. In a study on the detection of cognitive profiles using the WISC-IV (Fenollar-Cortés et al., 2015), significant differences were found in the indices of working memory and processing speed between the clinical subgroups of ADHD, with the index of processing speed being clearly lower than that of working memory in the inattentive group and vice versa, the combined subgroup obtained lower scores in working memory than in processing speed. They found no difference between the other indices, so verbal comprehension and perceptual reasoning were not affected by belonging to one or another subtype of AD-H.

Although there is a lot of research that relates learning and neuropsychological variables to ADHD (Aguilera et al., 2014; Martín-González et al., 2008), few establish differentiations by profile or clinical subgroups of the disorder (Filippetti & Mías, 2009), evaluating rather groups with the presence of the disorder as a whole -without differentiating subtype- versus control groups, and a precise neuropsychological characterization of this disorder has not been achieved.

2. Problem Statement

The problem posed in the present study is to discern the specific neuropsychological characteristics of each diagnostic subtype of ADHD on the basis of some criteria for comparison between them. This raises the question of what the specific neuropsychological substrate for each subtype of

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ADHD is, with the interest of helping to refine the detection, diagnosis and effective treatment for this problem. Specifically, we want to compare the variables of visual functioning through saccadic movements, auditory functioning through auditory phoneme discrimination, working memory and executive functions through Stroop-type tasks, in primary school children with behavioural characteristics of ADHD inattentive and hyperactive-impulsive subtype in contrast with a control group, and to discern whether there are specific neuropsychological characteristics of each of these groups.

3. Research Questions

How is the visual, auditory, executive functions and working memory functioning in primary school children with an inattentive versus a hyperactive/impulsive profile?

4. Purpose of the Study

Specifically, the following research objectives are proposed:

4.1. General objective:

To study visual, auditory, executive functions and working memory functioning in a group of primary school children with an inattentive versus a hyperactive/impulsive profile.

4.2. Specific objectives:

1. To evaluate saccadic movements, auditory discrimination, executive functions and working memory in a sample of primary school children with an inattentive profile, with a hyperactive/impulsive profile, and with a comparison control group.
2. Compare the inattentive profile group versus the hyperactive/impulsive profile group and the control group in terms of their saccadic movements.
3. Compare the inattentive versus the hyperactive/impulsive profile group and the control group in terms of their ability to discriminate phonemes in hearing.
4. Compare the inattentive versus the hyperactive/impulsive profile group and the control group in terms of their performance in executive functions.
5. Compare the inattentive versus control and the hyperactive/impulsive profile group in terms of their working memory.

5. Research Methods

For the selection of the groups, Barkley's Disruptive Behavior Evaluation Scale (EECP) for parents and teachers created in 1997 was administered to all 4th, 5th, and 6th grade students on campus. This scale is based on DSM-5 criterion A for ADHD, which was considered for this study. The instrument alternates items of inattention with items of hyperactivity-impulsivity, which are scored from "0" (never) to "3" (almost always), with the possible range of scores being from "0" to "54" points. The internal consistency of the instrument is strong, with a Crombach alpha coefficient of 0.85 to 0.92 for all

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ages (Moreno & Martínez, 2010). Based on the results provided by both groups of informants, students who met criteria for inattention and hyperactivity-impulsivity (both informants had to agree on this to be considered) were selected to be part of the experimental groups (Table 1 shows the scores obtained in the predominant scale, inattention or hyperactivity) and those who did not meet them and scored in the lower end of the scale were part of the control group. Those subjects who scored on both profiles, which would correspond to the "combined" subtype, which was not considered in this study.

Table 1. Description of the selected sample (N= 36)

	Age		Sex		Barkley - Teachers		Barkley - Parents	
	M	SD	Male	Female	M	SD	M	SD
Group Inattentive (N=12)	9	0.85	75%	25%	18.58	4.1	17.3	2.38
Group Hyperactive-Impulsive (N=12)	8.42	0.66	91.67%	8.33%	19.33	3.17	17.33	2.34
Group Control (N=12)	9	0.85	58.33%	41.67%	6.25	1.48	5.3	2.17

Note: M= mean; SD= standard deviation

The King-Devick Test was used to measure saccadic movements (King, 1976). The test consists of reading sequences of numbers, first on a test plate, then the numbers are arranged with arrows indicating eye tracking, a second plate without the tracking marks, and the last plate with the numbers spaced further apart and without many visual references, which should also be read as if it were text. The reading time is measured, and the errors made are counted in order to be contrasted with the scales that exist by age from 6 to 14 years (Olivera-Plaza, 2015).

To measure auditory discrimination, we used the Phoneme Auditory Discrimination Test (PAF), developed by Vallés in 1990, which consists of reading a list of 28 items made up of syllables and words that the subject must repeat, placing the subject with their back to the examiner. This is important to avoid lip reading. From the age of 6, the presence of failures in the test suggests difficulties in auditory discrimination (García & Vergara 2015).

To measure executive functions, the Stroop Color and Word Test (Golden, 1994), which measures response inhibition (one of the components of executive functions), is used as an instrument. It throws a measure of the interference between two instructions that compete in the brain to emit a response. One of them elicits an automatic response, which consists of reading words and the other requires more selective attention and cognitive control to achieve the objective of the task. It is to nominate the color of the ink in which the word is written, being incongruent with the content of the word. For example, the word "blue" is written in red ink and the correct response is to read "red" instead of "blue". The Spanish version of Golden 2001 was used, consisting of three plates, each with 100 items. For each sheet, the subject has 45 seconds to answer as many items as possible in that time. On sheet one, Words (P), the words red, green and blue, written in black ink in columns to be read aloud, are presented. On the second sheet, Colors (C), groups of X's (XXXX) written in red, green and blue are presented, randomly arranged in 5 columns of

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20 items each, and without two continuous colors being repeated. Finally, sheet three, of Word-Color (PC), is formed by the words on sheet one written in the colors of sheet two, the word always being incongruent with the color of the ink, and the subject is asked to mention the color in which the word is written, thus inhibiting the reading of its graphemes.

In the test score, the answers given to each sheet are counted and additionally the interference index is calculated based on the formula established in the manual. The higher the value, the better control the subject has over the interference, and it is an indicator of cognitive flexibility. People who have a score greater than zero have a high resistance to interference (Golden, 1994). By contrast, the lower the rate of interference, the less inhibitory control of the response.

Finally, the operating memory index of the Intelligence Scale for children (Wechsler, 2005) was used as a measure of working memory. It is obtained based on the scalar scores obtained in two subtests, which are Digit Retention and Letters and Numbers, each with age rules. The scalar score of each subtest has an average of 10 and standard deviation of 3, while the operating memory index (OMI), like the other composite scores obtained in the WISC-IV, has an average of 100 and standard deviation of 15 (Wechsler, 2005).

In table 2, the neuropsychological instruments used and their form of interpretation are summarized:

Table 2. Summary of measures and instruments in this study

Variable	Instrument	Range of possible scores	Interpretation
Attention-hyperactivity profile	Barkley Disruptive Behavior Rating Scale	From 0 to 27 points on each scale: inattention and hyperactivity - impulsivity	Higher scores are considered to have worse results in the performance of each variable (inattention/HI). Values above 15-18 points are considered clinically significant.
Saccadic movements	K-D test	Execution time (in seconds).	According to age norms. Scores from 42.05 to 106.48 seconds are considered normal adding up to the range of 8 to 10 years.
		Number of mistakes made.	Number of errors: 1 to 3 errors are expected
Auditory discrimination	PAF test	0-28.	The greater the number of errors, the greater the difficulty in phoneme discrimination. It is estimated that the presence of more than 2 errors implies a deficit.
Executive functions	Stroop test	P, C, PC and interference.	Tipical T-scores with mean of 50 and deviation of 10. Interference less than zero: difficulties in inhibiting R.
Working memory	WISC-IV digit and letter/number retention subtests to obtain the OMI	The Operative Memory Index (OMI).	Values below 85 are considered to have a poor working memory performance (below average).

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5.1. Procedure

Once the necessary permissions were requested from the authorities of the educational institution to carry out the study with the children between 8 and 10 years old, 4th, 5th and 6th grade students, the Barkley Disruptive Behavior Rating Scale for parents and teachers was administered to all of them. Based on the scale criteria, sample participants were selected in each group and their parents were asked for informed consent to authorize their participation in the study by signing it.

The administration of the tests was carried out in coordination with the teachers so as not to alter the dynamics of the study of the subjects, in flexible schedules with ease to level off later. The evaluation sessions were carried out in the Psychology Department individually, in approximately half an hour.

6. Findings

A descriptive analysis was conducted based on the mean and standard deviation of the quantitative variables (age and each of the study measures), as well as their response ranges (minimum and maximum); these data are summarized in Table 3:

Table 3. Description of the three groups in the study variables (N= 36)

		Group Inattentive (n= 12)		Group Hyperactive-Impulsive (n= 12)		Group Control (n= 12)
	M	SD (range)	M	SD (range)	M	SD (range)
SACCADIC MOVEMENTS (K-D)						
Execution time (in seconds)	94.22	24.96 (66.20-149.50)	119.18	51.57 (65-255)	69.48	9.28 (58-86)
Number of mistakes	3.33	2.84 (0-9)	5.25	3.6 (0-12)	0.58	0.66 (0-2)
AUDITORY DISCRIMINATION (PAF)						
Phoneme discrimination	21.50	1.51 (19-24)	21.50	2.46 (9-16)	26.50	0.90 (25-28)
EXECUTIVE FUNCTIONS (Stroop)	M	DT (range)	M	DT (range)	M	DT (range)
Words (P)	62.67	11.71 (36-72)	59.33	19.31 (39-109)	81.00	8.59 (68-96)
Colors (C)	46.25	8.02 (26-55)	46.50	18.53 (26-93)	53.33	8.01 (41-66)
Words-Colors (PC)	24.67	4.14 (14-29)	24.75	10.82 (14-50)	31.42	6.50 (22-44)
Interferencia (I)	-2.02	9.05 (-28.18-8.89)	-0.10	7.96 (-21.85-8.28)	2.17	4.46 (-4.43-13.26)
WORKING MEMORY (WISC-IV)						
Operative Memory Index (OMI)	81.50	10.84 (66-102)	87.25	11.33 (69-108)	100.50	11.54 (84-123)

Nota: M=Media; DT= desviación típica

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Based on the descriptive statistics, there is a tendency to achieve better results in the control group than in the ADHD groups. On the other hand, between the Inattentive and Hyperactive groups a different behaviour is observed according to the study variable, for example, in the saccadic movements there is a greater time and number of errors in the H-I group than in the Inattentive group, which suggests greater deficiencies in the visual functionality of hyperactive children than inattentive ones, probably due to their impulsivity. In the discrimination of phonemes, the study groups obtain the same average, with the Inattentive group being more homogeneous than the H-I; in the executive functions, a tendency to have greater interference is observed in the H-I children and the working memory tends to be slightly lower in the Inattentive children.

Inferential statistics were also used to compare groups in the research variables as follows: for the comparison of the groups (Inattentive/Hyperactive-Impulsive/Control), the non-parametric Kruskal-Wallis test was applied, as they were three independent groups, with a sample size of less than 30, a categorical independent variable with three categories (Inattentive, Hyperactive-Impulsive and Controls) and quantitative dependent variables (Saccadic movements, auditory discrimination, executive functions and working memory). Tests were performed for each variable to compare between the three groups, using the SPSS v.25 program, considering significant the results with a p value equal to or less than 0.05.

The results of the statistical tests are compiled below:

6.1. Comparison of saccadic movements in the 3 groups

From the results obtained in the K-D test, the contrast statistic was applied and the result is shown in Table 4:

Table 4. Contrast of saccadic movements by groups

Sample 1 – Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
Control - Inattention	10.333	4.229	2.444	.015	.044
Control - Hyperactivity	15.167	4.229	3.586	.000	.001
Inattention - Hyperactivity	-4.833	4.229	-1.143	.253	.759

There are significant differences between the execution time of saccadic movements by the control group compared to the Inattention and Hyperactivity-Impulsivity groups, which took longer to read the test.

The same was done for the number of errors in the K-D test, which is shown in Table 5:

Table 5. Contrast of errors in the KD test by groups.

Sample 1 – Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
Control - Inattention	11.000	4.301	2.558	.011	.032
Control - Hyperactivity	16.000	4.301	3.720	.000	.001
Inattention - Hyperactivity	-5.000	4.301	-1.163	.245	.735

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The control group obtained a statistically lower number of errors in saccadic movements than the Inattention and Hyperactivity-Impulsivity groups.

6.2. Comparison of hearing discrimination in the 3 groups

The data obtained through the PAF test allowed the calculation of the statistical test between the groups, resulting in the information in Table 6:

Table 6. Contrast of hearing discrimination by groups

Sample 1 – Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
Inattention-Hyperactivity	-.958	4.271	-.224	.822	1.000
Inattention-Control	-18.417	4.271	-4.312	.000	.000
Hyperactivity-Control	-17.458	4.271	-.087	.000	.000

In the same way, a significant difference was obtained between the number of hits in auditory discrimination of the control group being greater than the number obtained by the Inattentive and H-I groups, with no difference between the Inattentive and Hyperactive-Impulsive groups.

6.3. Comparison of executive functions in the 3 groups

The Stroop test gives the results of tables 7,8,9 and 10:

Table 7. P contrast by groups

Sample 1 – Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
Inattention-Hyperactivity	3.333	4.295	.776	.438	1.000
Inattention-Control	-16.042	4.295	-3.735	.000	.001
Hyperactivity-Control	-12.708	4.295	-2.959	.003	.009

The control group obtained statistically different values from the rest of the groups by answering a greater number of words on the first sheet of the Stroop test than the two study groups, without finding differences between the latter.

With respect to the second sheet of the Stroop test, which is the score in the Colour (C) test, no significant differences were found between any of the groups as shown in Table 8:

Table 8. C contrast by groups

Null Hypothesis	Test	Sig.	Decision
The distribution of Stroop_C is the same across categories of Grupo.	Independent-Samples Kruskal-Wallis Test	.114	Retain the null hypothesis

There are significant differences between the control group and the Hyperactivity-Impulsivity group in terms of the number of items read with word reading inhibition (WRI). There were no significant

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differences between the control group and the Inattention group, nor between the Inattention group and the Hyperactivity-Impulsivity group, as shown in Table 9:

Table 9. PC contrast by groups

Sample1- Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Hyperactivity-Inattention	2.750	4.290	.641	.521	1.000
Hyperactivity-Control	-11.375	4.290	-2.652	.008	.024
Inattention-Control	-8.625	4.290	-2.011	.044	.133

As for the value of interference in the Stroop test, no statistically significant differences were found between the groups as shown in Table 10:

Table 10. Group Interference Contrast

Null Hypothesis	Test	Sig.	Decision
The distribution of Interferencia en Stroop is the same across categories of Group	Independent-Samples Kruskal-Wallis Test	.436	Retain the null hypothesis

6.4. Comparison of operating memory in the 3 groups

Regarding the operating memory index, the statistical test shows that there are significant differences between the Inattention group and the control group, but not between the hyperactivity-impulsivity group and the other two, as can be seen in Table 11:

Table 11. Operational Memory Contrast by Groups

Sample1 - Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Inattention - Hyperactivity	-4.917	4.284	-1.148	.251	.753
Inattention - Control	-14.833	4.284	-3.463	.001	.002
Hyperactivity - Control	-9.917	4.284	-2.315	.021	.062

As expected, lower levels of saccadic movements, auditory discrimination and poorer performance of executive functions were found in the inattention and hyperactivity-impulsive groups compared to the control group. The decrease in saccadic movements in subjects with ADHD had already been proposed by García et al. (2014), who found a greater deficit in saccadic movements in such subjects. Also, García & Vergara (2015) found deficiencies in saccadic movements and auditory discrimination in children with ADHD at school age, so these results are in line with the evidence reviewed so far.

It seems, therefore, that the decrease in auditory discrimination and in the functionality of the ocular musculature support the statement of López Juez (2010) who highlights the presence of problems of sensory maturity underlying the failures in information processing.

Concerning the executive functions, the hyperactivity-impulsivity group performed significantly lower than the control in the nomination of colored items with word inhibition, which is the foil of the

Stroop phenomenon itself (PC). Hyperactive-impulsive subjects then presented greater difficulty in the executive functions of inhibitory control in this task. Those in the inattentive group had slight failures that did not reach significant values in the inhibition task when contrasted with the other two groups, but instead obtained notably lower levels in the working memory when contrasted with the hyperactive-impulsive and control groups, as can be seen in Table 11.

Fenollar-Cortés et al. (2015), when analyzing the cognitive profiles of the WISC in the subtypes of ADHD, found that the inattentive subtype obtained worse results in processing speed than in working memory, while the combined subtype yielded lower results in working memory than in processing speed. The data seems to indicate that inattentive profiles have deficiencies in working memory and processing speed.

7. Conclusion

It is concluded that, in the different study variables, the control group showed a better performance than the Inattentive and the Hyperactive-Impulsive, reaching notably different results. This coincides with the findings of García et al. (2014), and García and Vergara (2015), who found deficiencies in saccadic movements and auditory discrimination in school-aged children with ADHD, and with Fenollar-Cortés et al. (2015), who found deficits in working memory and processing speed in children with Inattention. Also, Morales-Avendaño and Meneses-Ortega (2003) found that children with ADHD showed alterations in the ability to focus and maintain attention, as well as failures in FFEE.

In none of the variables of the study were found statistically significant differences between the groups of Inattention and Hyperactive-Impulsive, although descriptively a certain differential tendency can be appreciated. Therefore, it is concluded that neuropsychological functioning in primary school children with ADHD is diminished compared to children without ADHD, but it is not possible to establish a differential neuropsychological profile between inattention and hyperactivity-impulsivity profiles based on the variables studied.

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