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Executive Functions and Academic Performance in Children With ADHD: A Correlational Study

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Abstract

Attention Deficit Hyperactivity Disorder (ADHD) corresponds to a behavioral pattern of impulsivity and attention deficit, caused by alterations in executive functions. The study aimed to investigate the relationship between executive functions and academic performance in children with ADHD. Participants were 27 children, aged between 6 and 10. Instruments: Raven's Coloured Progressive Matrices, School Performance Test II (TDE-II), Five Digits Test (FDT), Cancellation Attention Test (TAC), Stroop Task – Victoria version, WISC-IV Digits Subtest, Child Behavior Checklist (CBCL), and SNAP-IV. Descriptive analysis, Spearman's correlation analysis, and multiple regression analysis were applied, considering a significance level of $p < .05$. Attention and working memory were predictors of academic performance (adjusted R^2 of .56); in arithmetic, the attention test showed an adjusted R^2 of .46; in writing, verbal working memory presented an adjusted R^2 of .33; for reading, both attention and verbal working memory demonstrated statistical significance (adjusted R^2 of .53). Correlations between the results of the attention and cognitive flexibility tests and academic performance were moderate and positive, ranging from .43 to .82 ($p < .01$). Execution time on the Stroop task was negatively related to performance in arithmetic (rho = -.65; $p < .01$). The results demonstrate that working memory, attention, and cognitive flexibility play an important role in the academic performance of children with ADHD.

Keywords: executive functions, ADHD, academic performance, neuropsychology, childhood

FUNÇÕES EXECUTIVAS E O DESEMPENHO ACADÊMICO EM CRIANÇAS COM TDAH: ESTUDO CORRELACIONAL

Resumo

O Transtorno do Déficit de Atenção e Hiperatividade (TDAH) corresponde a um padrão comportamental de impulsividade e déficit atencional, ocasionado por alterações nas funções executivas. O objetivo do estudo foi investigar a relação entre funções executivas e desempenho acadêmico em crianças com TDAH. Participaram 27 crianças, entre 6 e 10 anos. Instrumentos: Matrizes Progressivas Coloridas de Raven, Teste de Desempenho Escolar II (TDE-II), Teste dos Cinco Dígitos (FDT), Teste de Atenção por Cancelamento (TAC), Tarefa de Stroop – versão Victoria, Subteste Dígitos do WISC-IV, Child Behavior Checklist (CBCL) e SNAP-IV. Aplicaram-se testes estatísticos de análise descritiva, análise de correlação de Spearman e análise de regressão múltipla, a nível de significância de $p<0,05$. Atenção e memória de trabalho são preditores do desempenho acadêmico (R^2 ajustado de 0,56), em aritmética, o teste de atenção demonstrou R^2 ajustado de 0,46, na escrita, a memória de trabalho verbal apresentou R^2 ajustado de 0,33, para a leitura, tanto a atenção quanto a memória de trabalho verbal demonstraram significância estatística (R^2 ajustado de 0,53). As correlações entre os resultados dos testes de atenção e de flexibilidade cognitiva com o desempenho acadêmico foram moderadas e positivas, variando de 0,43 a 0,82. ($p<0,01$). O tempo de execução na tarefa *stroop* está negativamente relacionado ao desempenho em aritmética ($rho=-0,65$; $p<0,01$). Os resultados demonstram que a memória de trabalho, atenção e flexibilidade cognitiva possuem importante papel no desempenho acadêmico em crianças com TDAH.

Palavras-chaves: funções executivas, TDAH, desempenho acadêmico, neuropsicologia, infância

FUNCIONES EJECUTIVAS Y RENDIMIENTO ACADÉMICO EN NIÑOS CON TDAH: ESTUDIO CORRELACIONAL

Resumen

El Trastorno por Déficit de Atención e Hiperactividad (TDAH) es un patrón de comportamiento de impulsividad y déficit de atención, causado por cambios en las funciones ejecutivas. El objetivo del estudio fue investigar la relación entre las funciones ejecutivas y el rendimiento académico en niños con TDAH. Participaron 27 niños, entre 6 y 10 años. Instrumentos: Test de Matrices Progresivas de Raven, Prueba de Rendimiento Académico, Prueba de Cinco Dígitos, Prueba de Atención de Cancelación, Tarea Stroop - versión Victoria, Subprueba WISC de IV Dígitos, Inventario de Comportamiento para Niños y Adolescentes, SNAP IV. Utilizaron pruebas estadísticas de análisis descriptivo, correlación de Spearman y regresión múltiple, con un nivel de significancia $p<0.05$. La atención y la memoria de trabajo son predictores del rendimiento académico (R^2 ajustado de 0.56), en aritmética, la prueba de atención demostró un R^2 ajustado de

0.46, en escritura, la memoria de trabajo verbal mostró un R^2 ajustado de 0.33, para lectura, tanto atención como trabajo verbal. La memoria demostró significación estadística (R^2 ajustado de 0,53). Las correlaciones entre los resultados de las pruebas de atención y flexibilidad cognitiva con el rendimiento académico fueron moderadas y positivas, oscilando entre 0,43 y 0,82. ($p<0,01$). El tiempo de ejecución en la tarea stroop se relaciona con el rendimiento aritmético ($rho=-0,65$; $p<0,01$). Resultado: La memoria de trabajo, la atención y la flexibilidad cognitiva juegan un papel importante en el rendimiento académico de los niños con TDAH.

Palabras clave: funciones ejecutivas, TDAH, rendimiento académico, neuropsicología, infância

Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder characterized by a persistent pattern of inattention, hyperactivity, and impulsivity, symptoms associated with adjacent impairments in executive functions that impact learning processes (APA, 2023; Rigoni et al., 2020). Studies have been conducted to explain the neurocognitive pattern associated with ADHD as well as to detail the cognitive alterations that account for its effects on learning (Arnold et al., 2020; Tamm et al., 2021). Attention-Deficit/Hyperactivity Disorder has three different subtypes, which are determined based on the intensity and recurrence of symptom manifestations. It is necessary for the individual to meet at least six diagnostic criteria for each subtype for a minimum of six months in order to be diagnosed, with these subtypes being: the predominantly hyperactive/impulsive presentation, the predominantly inattentive presentation, and the combined presentation (APA, 2023). The prevalence of ADHD is 7.2% in the global child population and it is more common in males, with a 2:1 predominance compared to females (APA, 2023).

The clinical profile of ADHD includes attentional deficits that can be operationalized as difficulty maintaining prolonged focus on a given stimulus and failure to shift attention, resulting in missed new information as it is presented (APA, 2023). Reduced attention may trigger behaviors that negatively impact the daily lives of children with ADHD, both in school and home environments. Among these behaviors, the following stand out: carelessness, disorganization, avoidance of tasks that require prolonged cognitive effort, and frequent forgetfulness (Johnson et al., 2021). Hyperactivity and impulsivity manifest through agitated behaviors, feelings of restlessness, excessive talking, premature responding, difficulty waiting one's turn, and frequent interruptions, and may also be accompanied by aggressive behavior (Johnson et al., 2021).

In addition to the behavioral difficulties presented by individuals diagnosed with ADHD, executive functions are also identified as a deficient construct in this group (Tamm et al., 2021). Executive functions (EF) represent a set of cognitive abilities that enable individuals to exercise self-management, regulating and controlling behavior directed at specific goals (Diamond, 2013). According to the model developed by Diamond (2013), three cores constitute the functional architecture of Executive Functions: inhibitory control, working memory, and cognitive flexibility and planning. Inhibitory control enables the individual to direct their attention, behavior, thoughts, and emotions according to situational demands, resisting internal and external impulses in favor of long-term goals rather than seeking immediate rewards. Working memory allows for the temporary retention and manipulation of information, enabling the individual to assign meaning to past events and connect them to the present, as well as to identify connections between seemingly unrelated elements. Cognitive flexibility, which develops later and depends on inhibitory control and working memory, allows the individual to adapt to environmental changes by modifying courses of action, thoughts, and behaviors as necessary, through behaviors such as reprioritizing and taking advantage of unexpected opportunities. From these three functions (working memory, inhibition, and cognitive flexibility), more complex executive skills are developed, such as planning, reasoning, problem-solving, and decision-making. These

higher-order skills depend on the integration and refinement of basic executive functions and are essential for dealing with new situations, organizing actions efficiently, and adapting to diverse contexts (Diamond, 2013).

The relationship between deficits in executive functions and ADHD may be an explanation for the findings of poor academic performance (Tamm et al., 2021). Academic performance refers to the student's performance in educational activities, reflecting the acquisition of school skills and new knowledge. Forms of expression of academic performance may include school grades, test results, and adaptive behaviors. A study conducted by Schmitt and Just (2021) found that approximately 80% of children with ADHD present learning difficulties. The impact of the disorder on academic performance may manifest through difficulties in recalling previously learned information, maintaining focus, organizing time, remaining quiet, and waiting for one's turn to speak (Schmitt & Just, 2021).

In 2022, Martínez Hernández, in collaboration with other researchers, published a study based on the reading difficulties of children with ADHD, aiming to identify which components of language contained the highest degree of difficulty for them. The results indicate that the children in the evaluated sample showed greater problems with syntax, referring to sentence structure and punctuation, and that promoting educational reinforcement of the syntactic components of language could lead to improved reading in children with ADHD (Hernández et al., 2022).

A study conducted by Megan Rigoni and collaborators in 2020 analyzed the association between ADHD symptoms and the school performance of students with the disorder. The results indicate that inattention symptoms are significantly associated with lower-than-expected performance in reading and writing, as well as in mathematical problems. The analyzed data also indicate that children with ADHD are more likely to receive support from an individualized study program based on the school curriculum content (Rigoni et al., 2020).

Another variable that influences the academic performance of children with ADHD is behavioral problems, such as oppositional behaviors, conduct difficulties, and symptoms related to anxiety (Abrahão & Elias, 2021; DuPaul et al., 2024). These behaviors may manifest in the classroom through resistance to rules, difficulty following instructions, impulsivity, and intense emotional reactions, which compromise engagement in school activities (Tamm et al., 2021). Furthermore, these problems tend to negatively affect relationships with teachers and peers, further hindering the learning process and academic performance.

Understanding how these executive functions affect academic performance is crucial for developing effective support strategies that address the specific needs of students with ADHD, allowing them to reach their maximum potential in the educational environment. This study aimed to investigate the relationship between executive functions and the academic performance of children diagnosed with ADHD, through an intervention program carried out at a teaching clinic in the city of Vitória da Conquista, in the state of Bahia. To evaluate which variable better explains the academic performance of these children, a regression analysis was conducted. The

hypothesis for the development of the study was: executive functions are correlated with academic performance and have predictive power for school skills in children with ADHD.

Method

The study was developed using a quantitative design with a cross-sectional approach, with the sample recruited according to the interest of the participants. The study tested the explanatory power of executive functions for academic performance.

Participants

Study participants were 27 children, aged between 6 and 10, elementary school students from public and private schools, residing in the municipality of Vitória da Conquista, Bahia, with a prior diagnosis or diagnostic hypothesis of ADHD according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5-TR). Of the total, 63.0% were male, 63.0% attended public schools, and 85.3% did not present comorbidities. The exclusion criteria for participants were (1) having another neurodevelopmental disorder, such as autism spectrum disorder or intellectual developmental disorder; (2) having uncorrected sensory impairments; (3) children younger than six years of age and older than 10; (4) children who did not have a diagnosis of ADHD.

Table 1

Frequency and percentage of responses regarding the sociodemographic aspects of the participants

Sex	Frequency	%
Male	17	63.0
Female	10	37.0
Type of school		
Private	17	63.0
Public	10	37.0
Use of medication		
Yes	15	55.6
No	12	44.4
Comorbidity		
No	23	85.2
ODD	3	11.1
Anxiety	1	3.7

Note. ODD: Oppositional Defiant Disorder

Instruments

Raven's Coloured Progressive Matrices

This test assesses non-verbal fluid intelligence in children aged between 4 years and 9 months old and 11 years and 3 months old, being divided into three levels (A, AB, B) with 12 items each. Incomplete matrices are presented to the examinee, with five response options, so that they must choose only one alternative with the figure that should complete the matrix. In the end, the correct answers are summed to form the total score, which is used to determine the classification of non-verbal IQ based on age and type of school (Angelini et al., 1999). The test was used to assess general fluid intelligence and as an exclusion criterion for participants with cognitive levels below those expected for their age.

School Performance Test (Teste de Desempenho Escolar - TDE II)

The TDE II is composed of three subtests that assess essential abilities for school performance: reading, writing, and arithmetic. Each subtest presents a scale of items in increasing order of difficulty, which should be administered to children from the 1st to the 4th grade and from the 5th to the 9th grade of elementary education. The test should be interrupted as soon as the examinee is no longer able to solve the items presented (Milnitsky et al., 2019). The second edition of the instrument was used to assess school performance and identify possible academic deficits.

Five Digits Test (FDT)

The FDT (Five Digits Test) is a neuropsychological test that uses four tasks with identical content and increasing cognitive difficulty, which assess the individual's automatic reactions and their capacity to perform a voluntary cognitive effort. The objective of the instrument is to assess cognitive processing speed, the capacity to focus and switch attention, and to handle interferences (subcomponents inhibitory control and cognitive flexibility) (Sedó, 2007). The test was used to assess the abilities of shifting, inhibition, and cognitive flexibility.

Cancellation Attention Test (Teste de atenção por Cancelamento - TAC)

The TAC consists of searching for and marking stimuli that are identical to the target stimulus. For this task, a figure cancellation sheet is used with a printed matrix composed of six different types of stimuli: circle, square, triangle, cross, star, and dash, in which the examinee has one minute to complete each of the three matrices. In the first and second matrices, selective attention is assessed, and the examinee must mark the target stimulus whenever it occurs. In the second part of the instrument, two figures are used as targets. In the third matrix, the examinee must alternate the cancellation criterion based on the change of the target stimulus. The target stimulus changes with each line and is represented as the first figure of each line. The number of times the target stimulus appears alternates, appearing at least twice and at most six times along the lines. The instrument has validity evidence and standardization data obtained for

children from five to 14 years of age and young adults (Montiel & Seabra, 2012). The test was used to assess sustained, selective, and alternating attention.

Stroop Task – Victoria version

It is a computerized task that assesses executive functions through selective attention, mental monitoring, and inhibitory control abilities. In this test, the participant is presented with three different images on a computer screen. In the first image, the participant must name colored dots according to their respective colors. In the second, random words written in different colors are presented, and the participant must name the colors. Finally, in the third image, there are words that refer to color names but are printed in a non-corresponding color, so that the participant must report the color of the word instead of reading it. This last part of the task activates automatic responses related to verbal processing, which causes interference in the color naming process. The examinee must inhibit information and respond selectively according to the test instructions (Troyer et al., 2007). The instrument was used to assess inhibitory control, verifying whether the child could inhibit prepotent responses.

WISC IV Digits Subtest

The Digits Subtest of the WISC-IV was used to assess children's verbal working memory in both forward and backward conditions. In the forward task, children had to retain the sequence of numbers spoken by the examiner and repeat it in the same order. In the backward task, they had to manipulate the information and reproduce the sequence in reverse order. Number sequences are verbalized, and the examinee must verbalize the sequence in the same order when forward working memory is evaluated, and in reverse order when backward memory is evaluated. The application is finalized after two consecutive errors in two sequences with the same number of digits (Wechsler, 2013).

Child Behavior Checklist (CBCL)

This scale is part of an assessment system developed to evaluate the behaviors of children and adolescents aged 6 to 18 by age group, and is completed by caregivers. The version is composed of 138 items, of which 118 refer to behavioral problems and 20 to social competence. The scale aims to assess possible internalizing and externalizing problems, which, by category, can be classified as normal, borderline, or clinical. The behavioral scale data were used to analyze the correlation between behavioral problems and academic performance. The instrument has been validated for the Brazilian population in studies conducted in various regions of the country (Rocha et al., 2013).

SNAP-IV

This scale aims to assess children and adolescents and is composed of 26 items to be answered by caregivers. These items correspond to the diagnostic criteria for ADHD, according to

the DSM-IV. Caregivers evaluate inattention (items 1-9), hyperactive-impulsive (items 10-18), and defiant (items 19-26) behaviors, using a 4-point Likert scale ranging from 0 (not at all) to 3 (very much) (Mattos et al., 2006). The instrument was used to assess whether the behaviors reported by parents are consistent with ADHD symptoms and in which subtype of the disorder the child best fits.

Procedures

The research was submitted to the Ethics Committee of the Multidisciplinary Institute of Health at the Federal University of Bahia (IMS-UFBA), in accordance with Resolutions 466/12 and 510/16 of the National Health Council. The data collection process began after authorization was granted by the ethics committee, through opinion No. CAAE 47322521.9.0000.5556. Data collection took place at the Psychology Service of IMS-UFBA from June 2022 to October 2023. An initial session was conducted with the guardians of the participating children to administer behavioral scales and for them to sign the consent form. The children signed their assent form, and the described tests were applied in two sessions, each lasting 60 minutes.

To ensure compliance with ethical standards, the tests and questionnaires were administered individually, in a private room, ensuring the confidentiality of participants' information. If a child refused to participate in the session, the procedure was rescheduled, and in the case of persistent refusal, the session was terminated.

Data Analysis

Statistical analyses were conducted using the SPSS version 25.0 program. Descriptive analysis was used to characterize the sociodemographic aspects of the participants. Spearman's correlation analysis was used to investigate the relationships between school performance and the tests assessing executive functions. Multiple regression analysis was employed to identify which variables exerted the greatest influence on the school performance of the children with ADHD. Analysis of covariance was conducted to control for the influence of intelligence on academic performance. In all statistical tests performed, the significance level adopted was $p < .05$.

Results

A correlation analysis was conducted to investigate the relationship between behavioral problems and academic performance (Table 2). No significant correlations were found for these variables. Table 2 presents the results obtained from the Spearman correlation analysis between the scores on the TDE II, including its total score and specific subtest scores, and the CBCL subtests that assess behavioral problems.

Table 2

Correlation analysis between academic performance and behavioral problems in ADHD

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. TDE – Total	1											
2. TDE –Arithmetic	.90*	1										
3. TDE – Reading	.85**	.72**	1									
4. TDE – Writing	.97**	.80**	.80**	1								
5. CBCL– Anxiety	–.23	–.01	–.02	–.21	1							
6. CBCL– Withdrawal	.00	.22	–.11	–.06	.37	1						
7. CBCL– Somatic Complaints	–.29	.02	–.31	–.3	.43	.38	1					
8. CBCL– Social Problems	–.23	.06	–.22	–.25	.75**	.38	.67*	1				
9. CBCL– Thinking Problems	–.09	.07	–.18	–.05	.77**	.45*	.25	.59*	1			
10. CBCL– Attention Problems	–.23	–.14	–.22	–.23	.63**	.4	.32	.14	.42	1		
11. CBCL– Rule–Breaking Behavior	–.13	.05	–.13	–.11	.26	.25	.30	.59**	.42	–.09	1	
12. CBCL– Aggressive Behavior	–.14	–.02	–.16	–.16	.30	.13	.39	.48*	.25	.11	.57**	1

Note. TDE: School Performance Test; CBCL: Child Behavior Checklist (CBCL)

A correlation analysis was conducted between the tests that assess attention, selective attention, cognitive flexibility, and inhibitory control and the academic performance test. Table 3 presents the results of the Spearman correlation analysis between the scores on the TDE II and the executive function assessment tests.

Table 3

Correlation analysis between tests that assess executive functions and the TDE II School Performance Test

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. TDE – Total	1											
2. TDE -Arithmetic	.90**	1										
3. TDE - Reading	.85**	.74**	1									
4. TDE – Writing	.97**	.80**	.80**	1								
5. TAC	.74**	.82**	.67**	.70**	1							
6. Digits - Forward	.50*	.53*	.40*	.50*	.44*	1						
7. Digits - Backward	.46*	.53*	.44*	.40*	.43*	.30	1					
8. Digits – Total	.66**	.67**	.60**	.63**	.57**	.70**	.84**	1				
S9. FDT - Flexibility	.63**	.66**	.43*	.58**	.57**	.26	.17	.26	1			
10. FDT - Inhibition	.22	.36	.20	-.07	.26	.25	-.14	.25	.33	1		
11. Stroop – Sum	.27	.13	.19	.24	-.02	.07	-.06	-.07	.08	-.03	1	
12. Stroop-Execution time	-.40*	-.65**	-.28	-.27	-.38	-.43*	-.45*	-.47*	-.38	-.32	.18	1

Note. *$p < .05$; **$p < .01$; TDE: School Performance Test TDE II; TAC: Cancellation Attention Test; Digits: WISC IV Digits; FDT: Five Digit Test; Stroop: Stroop Task – Victoria version

A positive and moderate correlation was observed between the TAC and the TDE II, both in the total score (rho = .74; $p < .01$), and in the Arithmetic (rho = .82; $p < .01$), Reading (rho = .67; $p < .01$), and Writing (rho = .70; $p < .01$) subtests.

The Digits subtest (forward order) also showed a positive and moderate correlation with the TDE II total score (rho = .50; $p < .05$), as well as correlations with the Arithmetic (rho = .53; $p < .05$), Reading (rho = .40; $p < .05$), and Writing (rho = .50; $p < .05$) subtests. The Digits subtest (backward order) showed a positive and weak correlation with the TDE II total score (rho = .46; $p < .05$), and with the Arithmetic (rho = .53; $p < .05$), Reading (rho = .44; $p < .05$), and Writing (rho = .43; $p < .05$) subtests.

The total score of the Digits test also showed positive and moderate correlations with the TDE II total score (rho = .66; $p < .01$), and the Arithmetic (rho = .67; $p < .01$), Reading (rho = .60; $p < .01$), and Writing (rho = .63; $p < .01$) subtests.

Cognitive flexibility, assessed by the FDT, also showed a positive and moderate correlation with the TDE II total score (rho = .63; $p < .01$), as well as with the Arithmetic (rho = .66; $p < .01$), Reading (rho = .43; $p < .05$), and Writing (rho = .58; $p < .01$) subtests.

Finally, a negative and moderate correlation was identified between the execution time on the Stroop test and the TDE II total score (rho = -.40; $p < .05$), especially regarding the Arithmetic subtest (rho = -.65; $p < .01$), indicating that longer response time is associated with poorer school performance.

A multiple regression analysis was conducted to examine the predictive capacity of the results in the tests assessing attention and working memory on the academic performance of children with ADHD. The results are presented in Table 4.

Table 4

Multiple Regression Analysis Results for Reading, Writing, and Arithmetic

			TDE Total		
Variables	*β*	***T***	***p***		
TAC	.44	3.03	$p < .001$	R^2 adjusted: .56	*R*: .77
Digits	.46	3.18	$p < .001$		
			Arithmetic		
TAC	.69	4.88	$p < .001$	R^2 adjusted: .46	*R*:.70
			Writing		
Digits	.59	3.73	$p < .001$	R^2 adjusted: .33	*R*: .60
			Reading		
TAC	.42	2.82	$p < .001$		
Digits	.44	2.95	$p < .01$	R^2 adjusted: .53	*R*: .75

Note. TAC: Cancellation Attention Test; Digits: WISC IV Digits

The analysis presented significant results for the independent variables (Cancellation Attention Test and Digits), with an adjusted R^2 value of .56, indicating that approximately 56% of the variability in academic performance (TDE II – Total) can be explained by the variables included in the model. Accordingly, the Attention and Verbal Working Memory variables proved to be statistically significant, with $p < .001$. This suggests that both attention and verbal working memory play important roles in predicting the academic performance of children.

For arithmetic performance, the attention test showed an adjusted R^2 of .46, meaning that approximately 46% of the variability in performance can be explained by the variables included in the model, with $p < .001$ indicating a statistically significant influence. In writing, verbal working memory was considered relevant, presenting an adjusted R^2 of .33 with $p < .001$. For reading, both attention and verbal working memory demonstrated statistical significance, with an adjusted R^2 of .53, which corresponds to approximately 53% of the explained variation, and *p*-values of < .001 and < .01, respectively.

An analysis of covariance was conducted to control for the influence of intelligence on academic performance, allowing for a more precise assessment of the variables used in the regression analysis. After removing the effect of intelligence, working memory demonstrated statistical significance ($p < .003$) in predicting the overall academic performance of the children in the sample. Additionally, the analysis of covariance revealed that, even without considering the influence of intelligence, the working memory scores were able to predict the results of the

reading subtest of the TDE II with statistical significance ($p < .02$). The TAC (Cancellation Attention Test) presented statistically significant results ($p < .001$) in predicting the performance on the reading subtest of the sample, indicating its relevance even when controlling for the influence of intelligence.

Discussion

This study aimed to examine the relationship between executive functions and academic performance in children diagnosed with ADHD, identifying the predictive power of attention and verbal working memory on school skill performance in children with ADHD. The results found no significant correlations between academic performance and behavioral problems in children with ADHD (Table 2), suggesting that the learning difficulties of children with ADHD may result from other factors, such as deficits in executive functions. These findings are consistent with previous studies, such as those by Frick et al. (1991); Rogers et al. (2011); and Martinussen & Tannock (2006), which demonstrate that academic deficits in children with ADHD are a specific problem of this condition compared to other disruptive disorders, such as conduct disorder.

According to the literature, writing difficulties in children with ADHD are more related to their underlying cognitive vulnerabilities than to their behavioral symptoms (Soto et al., 2021). In another study by Spiegel et al. (2021), it was identified that the relationship between executive functions and academic success remains significant throughout elementary education. Supporting studies such as those by Faraone et al. (2021) and Tamm et al. (2021), the regression analyses in the present study showed that attention and working memory are strong predictors of academic performance in children with ADHD, influencing tasks involving reading, writing, and arithmetic (Table 3).

Studies such as those by Tamm et al. (2021) and Zheng et al. (2022) also found evidence that children with ADHD are more likely to have lower school grades and fewer skills in mathematics, reading, and writing compared to neurotypical children of the same age, as well as significantly poorer social functioning. Poor executive function performance is associated with impairments in reading, writing, and mathematics (Tamm et al., 2021).

The results of the present study demonstrate that verbal working memory correlates with academic performance in children with ADHD (Table 2). Positive and moderate correlations were found between the test assessing verbal working memory and the academic skills of reading, writing, and arithmetic. A study conducted by Rogers et al. (2011) investigated the role of inattention and working memory in predicting academic performance in 145 adolescents aged 13 to 18. They found that inattention in the classroom is related to problems in auditory-verbal and visuospatial working memory.

Auditory-verbal working memory showed significant effects on both reading and mathematics performance, indicating that working memory is a risk factor for academic failure in adolescents with attention problems (Rogers et al., 2011). Inattention indirectly affects reading performance, being partially mediated by working memory (Soto et al., 2021). A study by Cohen

et al. (2021), using functional magnetic resonance imaging, investigated the relationship between language processing levels and inattention, finding that inattention impairs the syntactic and semantic integration of sentences.

Results from Spearman's correlation analysis indicate that children's performance on tests assessing attention is positively related to performance in arithmetic, reading, and writing (Table 2). In arithmetic, attention is crucial for performing calculations accurately and memorizing key concepts (Kanevski et al., 2022). In writing, attention is necessary to organize ideas, select appropriate words, and review work to eliminate errors (Berninger et al., 2017). In reading, the severity of ADHD symptoms directly influences comprehension processes (Schmitt & Justi, 2021). The results of these studies, as well as the present analysis, align with research such as Tamm et al. (2021), which found that poor executive function performance is associated with impairments in reading, writing, and mathematics.

Furthermore, results from the aforementioned analysis showed that performance on tasks evaluating cognitive flexibility is positively correlated with participants' performance in arithmetic and writing (Table 2). Consistent with this result, a study by Shabnam Foroozandeh (2022) identified that the development of this executive function, among other elements, plays a crucial role in expanding an individual's social and academic capacities. Deficits in cognitive flexibility may cause problems completing homework assignments, as well as difficulties in mathematics, reading, and planning (Foroozandeh, 2022).

Other findings from Spearman's correlation analysis indicate that execution time on the Stroop task is negatively correlated with performance in arithmetic, so that the longer the time taken to complete the Stroop task, the poorer the arithmetic performance (Table 2). Computerized tests such as the Stroop Task are very useful because, in addition to counting correct responses, they measure the time taken by the participant to complete a given task, making them considerably more sensitive to detecting reaction time (Capovilla et al., 2007). Therefore, these results suggest that the longer the time children take to respond to test stimuli, the slower their processing speed, a construct that impacts performance in school tasks involving arithmetic (Dong et al., 2021).

The results of the covariance analysis (ANCOVA) in this study demonstrated that, even after controlling for the influence of intelligence, working memory showed a significant capacity to predict overall academic performance in the children in the sample. When isolating the effect of intelligence, working memory scores remained predictive of the TDE reading subtest results. Performance on the attention test showed statistically significant results in predicting reading subtest performance, highlighting the importance of this component even when controlling for intelligence. These findings highlight the relevance of working memory and attention in explaining variations in academic performance in children with ADHD, independent of fluid intelligence.

Despite the theoretical and empirical relevance, caution is necessary in generalizing these findings due to study limitations, especially the sample size, as only 27 children diagnosed

with ADHD participated. The analyses used models designed to reduce the impact of dispersion; however, the number of participants remained small, reflecting a characteristic of clinical sample studies and not allowing for generalization to the entire child population.

Final Considerations

The findings emphasize the importance of executive functions in explaining the variability of academic performance in children diagnosed with ADHD. When addressing issues related to academic performance, it is crucial to consider the complexity of the interactions between these variables and further explore their implications. In addition to contributions in the field of clinical interventions for children with ADHD, this study also suggests possibilities for more effective school interventions aimed at improving executive functions, with an emphasis on attention and verbal working memory, to enhance the performance of these children. However, it is necessary to consider the limitations of this study, such as the difficulty in generalizing the findings due to the small sample size. Furthermore, the study's findings are specific to children with ADHD, which limits generalization to children in general. The outcomes identified represent important steps for future research focused on children with ADHD, analyzing the specificities of school performance and its long-term trajectory, seeking to verify whether instability and/or significant losses occur for these children during their academic development.

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