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PAPER

Evaluating Cognitive Aspects of ADHD Students Using Brain-Computer Interface and a Digital Game: A Study in Brazil

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ABSTRACT

In an academic setting, attention deficit hyperactivity disorder (ADHD) is a significant risk factor for suboptimal academic performance. A novel approach to the detection and treatment of children with ADHD is the brain-computer interface (BCI). The objective of this study was to develop and evaluate a computerized cognitive test (CCT) using a digital game and a BCI to identify and analyze differences in cognitive performance between students with and without ADHD. A qualitative-quantitative experimental study was conducted with 20 students' aged 8 to 14, divided into two groups: 1) 10 with ADHD and 2) 10 without ADHD. At the outset of the study, a semi-structured interview was conducted to obtain an initial understanding of the participants' backgrounds and medical histories. Subsequently, neuropsychological tests were administered for the purpose of assessing cognitive levels. Following this, the BCI was used in conjunction with the digital game. The neuropsychological instruments yielded statistically significant results between the two samples. The results of the CCT indicated that students without ADHD exhibited superior performance in eight of the nine analyzed criteria. The utilization of a digital game integrated with a BCI can assist in the identification of cognitive aspects that distinguish children with and without ADHD. Moreover, individuals diagnosed with ADHD demonstrated enhanced performance across all phases of the game.

KEYWORDS

attention deficit hyperactivity disorder (ADHD), brain-computer interface (BCI), digital game, computerized cognitive test (CCT)

1 INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental condition characterized by symptoms of inattention, hyperactivity, and/or impulsivity [1]. This disorder, which involves deficits in the maturation of brain areas responsible

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for cognitive integration and behavioral control, such as the prefrontal cortex, has a strong neurobiological influence with a multifactorial etiology that includes genetic and environmental factors [2]. It is commonly diagnosed in childhood [3], with a worldwide prevalence of around 5.29% in children and adolescents [4]. Symptoms typically manifest before the age of 12 [5]. One of the primary causes of difficulties in the learning process is attention deficit, which is a common symptom of ADHD [6]. Consequently, given that ADHD typically manifests during childhood, it can impede academic performance and behavior, particularly when a diagnosis is delayed.

At present, neurofeedback is a prevalent alternative to conventional treatments, largely due to its innovative nature. This non-invasive therapeutic modality does not involve the use of pharmacological agents and is based on the principles of brain-computer interface (BCI) technology [3]. BCIs have the potential to facilitate the treatment and early diagnosis of ADHD. In neurofeedback, electroencephalography (EEG) is used to measure the patient's brain activity in real time, and the system provides feedback based on this activity [1], [7]. Artificial intelligence (AI) is frequently employed in the context of BCI data collection. The objective of this study was to assess the cognitive aspects of elementary school students with ADHD using a BCI and digital game.

2 MATERIALS AND METHODS

2.1 Type and location of the research

This study employed an experimental research design with a quantitative and qualitative approach, conducted in the municipality of Fortaleza, Ceará, Brazil. The participants were selected from a private elementary school and a school clinic affiliated with a higher education institution.

2.2 Subjects

The sample consisted of 20 children and adolescents, aged 8–14 years. The participants were divided into two groups, each comprising 10 individuals. The first group consisted of children and adolescents who had been diagnosed with ADHD but who had not been taking any medication for a period of at least three months, as the use of such medication could have a significant impact on the results. The remaining cohort consisted of children and adolescents who did not meet the diagnostic criteria for the disorder.

2.3 Instruments and data collection techniques

In order to participate in the research, children and adolescents were required to sign the Free and Informed Assent Term (TALE), while their parents or guardians were required to sign the Free and Informed Consent Term (TCLE). The researcher provided a detailed explanation of both terms at the time of signature. Following the acquisition of consent, a semi-structured interview was conducted with the parents or guardians in order to gather the participants' clinical history from birth to the present age. The interview was based on the SNAP-IV Scale, which includes 18 ADHD criterion A symptoms from the *Diagnostic and Statistical Manual of Mental Disorders, 5th edition* (*DSM-5*). The study was approved by the Research Ethics Committee of the Federal University of Ceará, Brazil (approval number 5,456,050).

2.4 Statistical analyses

Following the collection of data from the Stroop test sections in the WiMind game, statistical analyses were conducted. The F-test was employed to ascertain significant discrepancies between the means of the various sections of the Stroop test. Thereafter, the Tukey test was utilized to facilitate detailed comparisons, with a significance level fixed at $p \leq 0.05$, indicating a 5% or less probability of differences occurring by chance. Additionally, a simple correlation analysis was conducted to investigate the relationships between the different sections of the Stroop test. All analyses were performed using ASSISTAT software, version 7.7, to ensure precision in calculations and interpretation of results.

3 RESULT

This section provides an account of the system's functionality with the BCI, an analysis of the participants' performance in the WiMind game, and an evaluation of the students' performance on neuropsychological tests.

3.1 WiMind game

During the signal acquisition phase, the participants' brain commands were recorded via EEG and transmitted via Bluetooth to a computer running the acquisition system. The data were then processed for feature extraction, model comparison, and signal classification. Subsequently, neurofeedback signals were generated in response to the participants' brain activity.

The WiMind game, designed for use with a brain-computer interface, was developed based on the Stroop Test. This test is a neuropsychological assessment in which participants must identify the names of colors printed in different colored inks under congruent conditions (where the name of the color matches the ink color) and incongruent conditions (where the name of the color does not match the ink) [8], [9]. The game was controlled by mental and voice commands using a BCI and microphone, in conjunction with natural language recognition software (see Figure 1).

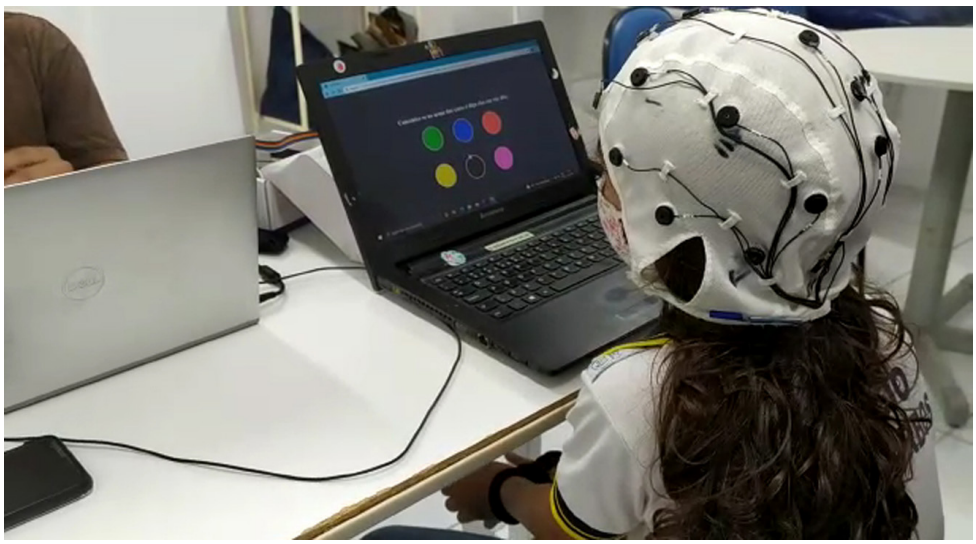

Fig. 1. Child using the WiMind game with BCI

3.2 Performance evaluation and analysis using the WiMind game

The data collected from each individual during the evaluation process is presented in Table 1. In order to facilitate an analysis and comparison of the results, the following variables were identified as being worthy of consideration: duration of the test in minutes (D), number of times distracted (VD), number of incorrect responses (RE), number of unanswered items (NR), points in phase 1 (PF1), points in phase 2 (PF2), points in phase 3 (PF3), total success (TS, TS = PF1 + PF2 + PF3), total failures (TI, TI = VD + RE + NR), and failure percentage (PI, PI = TI/(TS + TI)).

Table 1. Individual data collected for each variable

	Sample	Age	D	VD	RE	NR	PF 1	PF 2	PF 3	TS	TI	PI (%)
Without ADHD	1	10	12	2	2	0	9	7	10	26	4	13.3
	2	8	10	2	0	1	8	10	9	27	3	10.0
	3	8	10	1	0	1	9	9	10	28	2	6.7
	4	10	7	0	0	0	10	10	10	30	0	0.0
	5	8	5	2	0	1	8	9	10	27	3	10.0
	6	8	6	0	1	2	9	9	9	27	3	10.0
	7	10	8	0	0	1	10	10	9	29	1	3.3
	8	8	5	0	0	1	10	9	10	29	1	3.3
	9	14	6	3	0	0	8	9	10	27	3	10.0
	10	14	5	0	0	0	10	10	10	30	0	0.0
With ADHD	11	8	11	0	2	4	8	10	6	24	6	20.0
	12	8	9	7	1	3	5	7	7	19	11	36.7
	13	8	7	0	0	1	9	10	10	29	1	3.3
	14	8	6	4	1	6	6	6	7	19	11	36.7
	15	13	8	4	1	2	6	8	9	23	7	23.3
	16	14	5	4	0	0	8	8	10	26	4	13.3
	17	12	5	0	1	0	9	10	10	29	1	3.3
	18	8	4	5	1	3	4	7	10	21	9	30.0
	19	12	5	1	0	1	9	10	9	28	2	6.7
	20	14	4	1	0	4	9	9	7	25	5	16.7

The data presented in Table 1 were subjected to an independent comparison of the means of the variables of interest, taking into account the sample size and the nature of the variables. Consequently, Wilcoxon tests [10] were performed for the continuous variables age and test duration in minutes (D), and a generalized linear model [11] with a binomial dependent variable and the condition variable (without ADHD and with ADHD) as the explanatory variable, using a logistic link function.

The results of the comparative analysis of means between participants without ADHD and those with ADHD are presented in Table 2. Consequently, it is possible to analyze the performance of the groups in the WiMind game. There was no

statistically significant difference in the mean age (p = 0.745) and test duration in minutes (p = 0.318), with a significance level of 5%. The absence of a difference between the mean ages in the participant groups corroborates the premise of no age bias in the control (without ADHD) and treatment (with ADHD) groups.

The explanatory variable ADHD was statistically significant for the number of distracted (VD), number of unanswered items (NR), points in phase 1 (PF1), points in phase 3 (PF3), total successes (TS), and total failures (TI). However, there was no significant difference in the number of incorrect responses (RE) and points in phase 2 (PF2). Thus, there are (marginal) differences between the groups for VD, NR, PF1, PF3, TS, and TI; however, no differences were observed for Age, D, RE, and PF2. Numerically, individuals with ADHD performed worse, even if not statistically significant.

Table 2. Means, standard deviations (in parentheses), and p-values of the mean comparison tests for the variables of interest

	Without ADHD	With ADHD	p-Value
Age	9.8 (2.4)	10.5 (2.7)	0.745
D	7.4 (2.5)	6.4 (2.3)	0.318
VD	1.0 (1.2)	2.6 (2.5)	0.008*
RE	0.3 (0.7)	0.7 (0.7)	0.215
NR	0.7 (0.7)	2.4 (1.9)	0.041*
PF1	9.1 (0.9)	7.3 (1.9)	0.001*
PF2	9.2 (0.9)	8.5 (1.5)	0.068
PF3	9.7 (0.5)	8.5 (1.6)	0.005*
TS	28.0 (1.4)	24.3 (3.8)	0.001*
TI	2.0 (1.4)	5.7 (3.8)	0.001*

Note: (*) indicates that the difference between the groups ("Without ADHD" and "With ADHD") is statistically significant at the 5% level (p < 0.05) for the highlighted factors.

To assess the interactions between the study variables in the probability of a participant failing to respond to items, a generalized linear model with a binomial dependent variable and a logistic link function was initially fitted. The explanatory variables included condition (without ADHD and with ADHD), phase (1, 2, or 3), age, test duration in minutes (D), and their interactions (ADHD × Phase and Age × D). The first generalized linear model fitted for this purpose is as follows:

$$ln\left[\frac{Prob(failure)}{1-Prob(failure)}\right] = \alpha + \beta_1 ADHD + \beta_2 F2 + \beta_3 F3 + \beta_4 ADHD \times F2 + \beta_5 ADHD \times F3 + \beta_6 Idade + \beta_7 D + \beta_8 D \times Age,$$

This model is a logistic regression, in which we attempt to model the probability of success (such as passing the test) based on various characteristics (independent variables). The ADHD variable represents whether a participant has a disorder (value 1) or not (value 0). The variables F2 and F3 indicate whether points were obtained in phases 2 and 3, respectively, whereas both had a value of 0 if points were obtained in phase 1. After adjusting the model and performing significance tests on the parameters, we found that only the presence of ADHD was statistically significant at the 5% significance level.

Therefore, although variables F2 and F3 showed individual significance, they were not statistically significant when ADHD was considered. In other words, once the ADHD variable is included in explaining failure, there is no need to consider the phase in which points are obtained.

The model adjusted only with the ADHD variable is given by

$$Prob(\,failure) = \frac{exp(-2.6391 + 1.1890 \times ADHD)}{1 + exp(-2.6391 + 1.1890 \times ADHD)}$$

Table 3 presents the estimated probabilities from the adjusted model, along with the odds of failure. From these odds, we can calculate an important measure for comparing groups in binary data, called the odds ratio. This odds ratio was obtained from the quotient of the odds.

Therefore, the odds ratio of failure for a person with ADHD compared to a person without ADHD was 3.2839 (0.2346/0.0714). This means that the odds of a person with ADHD failing to respond to an item are approximately 3.3 times higher than those of a person without ADHD failing. The same odds ratio applies to answering an item correctly by comparing a person without ADHD to a person with attention deficit hyperactivity disorder.

Table 3. Success probabilities, failure probabilities, and odds of failure between the groups with and without ADHD for the adjusted binomial response logistic model

	Without ADHD	With ADHD
Failure Probability (PI)	0.0667	0.1900
Odds of Failure [CI = PI/(1–PI)]	0.0714	0.2346

As previously stated, failure can manifest in three distinct ways: by the number of times distracted (VD), the number of incorrect responses (RE), and the number of items unanswered (NR). To address this characteristic of the dataset, generalized linear models with multinomial explanatory variables and logistic link functions [12] were fitted. The first adjusted model considered ADHD, Age, D, and the Age × D interaction as explanatory variables in explaining the multinomial response variable, which can take the following values: success, distraction, incorrect response, and no response.

The first generalized linear model with a multinomial response is:

$$ln\left[\frac{Prob(distraction)}{Prob(sucess)}\right] = \alpha_{11} + \beta_{11} ADHD + \beta_{12} Age + \beta_{13} D + \beta_{14} D \times Age$$

$$ln\left[\frac{Prob(wrong\ aswer)}{Prob(sucess)}\right] = \alpha_{21} + \beta_{21} ADHD + \beta_{22} Age + \beta_{23} D + \beta_{24} D \times Age$$

$$ln\left[\frac{Prob(do\ not\ aswer)}{Prob(sucess)}\right] = \alpha_{31} + \beta_{31} ADHD + + \beta_{32} Age + \beta_{33} D + \beta_{34} D \times Age$$

In the model, the variable ADHD was defined as 1 if the participant had ADHD and 0 otherwise. As in the previous case, the only statistically significant variable in the model was the ADHD variable. Therefore, the adjusted multinomial generalized linear model with only the significant variable is given by

$$ln\left[\frac{Prob(distraction)}{Prob(sucess)}\right] = -3.3322 + 1{,}0972 \times ADHD$$

$$ln\left[\frac{Prob(wrong\ aswer)}{Prob(sucess)}\right] = -4.5362 + 0.9891 \times ADHD$$

$$ln\left[\frac{Prob(do\ not\ aswer)}{Prob(sucess)}\right] = -3.6889 + 1.3739 \times ADHD$$

The success probabilities indicated in Tables 3 and 4 are identical, thereby indicating that both models provide evidence that points in the same direction. Among the failure probabilities, the lowest probability was 0.01, corresponding to the probability of a person without ADHD responding incorrectly to an item. On the other hand, the highest probabilities of failure were 0.0867 and 0.08, respectively, which corresponds to the probability that a person with ADHD becomes distracted while responding or not responding to the item.

By calculating the odds ratios of failure as presented in Table 4, the following ratios were obtained: VD = 2.7512 (0.0949/0.0345), RE = 2.3752 (0.0239/0.0101), and NR = 3.6497 (0.0869/0.0234). Accordingly, the probability of an individual with ADHD becoming distracted during the response process is approximately 2.75 times that of an individual without ADHD. The probability of an individual with ADHD providing an erroneous response is approximately 2.37 times that of an individual without ADHD. The probability of an individual with ADHD failing to respond to the item in question is approximately 3.64 times that of an individual without ADHD.

Table 4. Success probabilities, failure probabilities, and odds of failure between groups without and with ADHD for the adjusted multinomial logistic model

		Without ADHD	With ADHD
Success Probability		0.9333	0.8100
Failure Probability	**VD**	0.0333	0.0867
	RE	0.0100	0.0233
	NR	0.0234	0.0800
Failure Odds	**VD**	0.0345	0.0949
	RE	0.0101	0.0239
	NR	0.0234	0.0869

As evidenced in Tables 2, 3, and 4, notable discrepancies were discerned in the probabilities (TS, VD, RE, NR) and scores between the two groups (those without ADHD and those with ADHD). The probability of an individual with ADHD failing to respond to an item is approximately 3.64 times higher than that of an individual without ADHD. Similarly, the odds of failing to respond are approximately 3.3 times higher for an individual with ADHD than for an individual without attention deficit hyperactivity disorder.

4 DISCUSSION

The findings of the study indicated notable discrepancies in performance between the ADHD and non-ADHD groups. For example, individuals with ADHD

exhibited a higher average number of unanswered items (NR parameter), which is likely attributable to attention deficits and anxiety. It is possible that inattention may have contributed to the tendency of ADHD participants to skip questions. It is well documented that attention is a crucial factor in the development and maintenance of cognitive abilities and other higher cortical functions [13]. Individuals with ADHD often demonstrate significant impairment in their ability to attend.

During the evaluation, participants with ADHD who made mistakes subsequently exhibited anxiety and a lack of response to subsequent questions, thereby increasing the average NR variable. It is possible that anxiety, in addition to inattention, may have contributed to a higher number of unanswered questions. As the number of unanswered questions increased, so did the total and percentage of unsuccessful attempts for this group. It can be hypothesized that the superior performance of the non-ADHD group in the NR parameter may be due to superior attention levels and lower or no anxiety, as they do not exhibit executive function impairments.

With regard to the score in phase 1 (PF1), it is postulated that the restlessness of participants with ADHD may have exerted an influence on the lower performance of this group in comparison to the group without ADHD. During the test, it was evident that the audience with ADHD exhibited restlessness during the initial phase, questioning the game's dynamics even after the example was provided. This behavior may have contributed to the lower number of correct answers in phase 1, as restlessness may have led to increased inattention, resulting in an elevated error rate during this phase.

In the ADHD group, it was observed that individuals who demonstrated less restlessness exhibited higher scores in phases 1 and 2. In contrast, the group without ADHD exhibited no restlessness and demonstrated a greater focus on the initial questions, resulting in a favorable performance for the parameter in question (PF1).

The analysis of the variable PF3 revealed that participants with ADHD exhibited a lower performance than those without the disorder. Phase 3 of the BCI assessment test was identified as the most challenging and exhibited the shortest response time, which likely contributed to the observed lower performance of the ADHD group. Due to alterations in the prefrontal cortex, these participants required an extended time to process information and respond. In the ADHD group, Phase 3 also demonstrated the highest number of unanswered questions, which likely contributed to their lower performance.

The elevated averages for total unsuccessful attempts (TI) and percentage of unsuccessful attempts (P) observed in participants with ADHD can be attributed to a greater number of unsuccessful attempts, particularly during Phases 1 and 2. The TI variable encompasses incorrect answers, unanswered questions, and distractions. Variable P indicates the percentage of total unsuccessful attempts relative to the total number of words in the game. It is plausible that higher values of these variables may be associated with lower academic performance in the ADHD group.

While some measures did not yield statistically significant differences between the ADHD and non-ADHD groups, the mean values of these parameters exhibited a statistically significant divergence. With regard to the test duration (D), the observed difference was not statistically significant; however, the mean duration was longer in the ADHD group. This indicates that individuals with ADHD may require a greater investment of time to complete the test, potentially due to challenges in maintaining focus and attention.

5 CONCLUSION

This study developed and analyzed a computerized cognitive test (CCT) using a digital game and a BCI to identify performance differences between students with and without ADHD. The results demonstrated that participants without ADHD exhibited superior performance, particularly in terms of the number of unanswered items, scores in phases 1 and 3, total scores, and the percentage of unsuccessful attempts, with statistically significant differences. Additionally, individuals with ADHD demonstrated overall performance improvement across the three game phases.

The results of this study indicate that the constructed solution has the potential to serve as an auxiliary tool for the detection and treatment of ADHD. The performance differences between the groups and the noticeable progress in participants with ADHD demonstrate the tool's efficacy in computerized cognitive testing. Furthermore, the tools were user-friendly, with all the evaluated students successfully completing the tests.

6 REFERENCES

[1] G. Ugarte *et al.*, "Attention deficit-hyperactivity disorder (ADHD): From abnormal behavior to impairment in synaptic plasticity," *Biology*, vol. 12, no. 9, p. 1241, 2023. https://doi.org/10.3390/biology12091241

[2] H. C. M. V. Schmidek, C. R. de Araújo, J. E. M. Teixeira, A. L. F. Lucena, and H. F. de Moura, "Dependência de internet e transtorno de déficit de atenção com hiperatividade (TDAH): revisão integrativa," *J. Bras. Psiquiatr.*, vol. 67, no. 2, pp. 126–134, 2018. https://doi.org/10.1590/0047-2085000000195

[3] N. M. G. B. da Costa, E. Marçal, M. M. de Carvalho, and T. da C. S. Barbosa, "Use of brain-computer interfaces in children with ADHD: A systematic review," *Research, Society and Development, (S. l.)*, vol. 10, no. 7, p. e51110716929, 2021. https://doi.org/10.33448/rsd-v10i7.16929

[4] G. Polanczyk, M. S. de Lima, B. L. Horta, J. Biederman, and L. A. Rohde, "The Worldwide prevalence of ADHD: A systematic review and metaregression analysis," *Am. J. Psychiatry*, vol. 164, no. 6, pp. 942–948, 2007. https://doi.org/10.1176/ajp.2007.164.6.942

[5] T. A. Barbarini, "Corpos, 'mentes', emoções: uma análise sobre TDAH e socialização infantil," *Psicol. Soc.*, vol. 32, 2020. https://doi.org/10.1590/1807-0310/2020v32173058

[6] E. G. Willcutt, "Neuropsychology of attention-deficit/hyperactivity disorder," in *APA Handbook of Neuropsychology: Neurobehavioral Disorders and Conditions: Accepted Science and Open Questions*, G. G. Brown, T. Z. King, K. Y. Haaland, and B. Crosson, Eds., American Psychological Association, 2023, pp. 325–339. https://doi.org/10.1037/0000307-016

[7] L. M. Q. P. Mota, C. E. de Souza Menezes, N. M. G. B. da Costa, Y. Torres, and E. Marçal, "Attention deficit disorder with hyperactivity: Comparative analysis of executive functions between genres based on neurofeedback training," *OBSERVATORIO DE LA ECONOMIA LATINOAMERICANA*, vol. 21, no. 11, pp. 18650–18674, 2023. https://doi.org/10.55905/oelv21n11-005

[8] F. Scarpina and S. Tagini, "The Stroop color and word test," *Front. Psychol.*, vol. 8, pp. 1–8, 2017. https://doi.org/10.3389/fpsyg.2017.00557

[9] R. Ghosh *et al.*, "SAM 40: Dataset of 40 subject EEG recordings to monitor the induced-stress while performing Stroop color-word test, arithmetic task, and mirror image recognition task," *Data in Brief*, vol. 40, p. 107772, 2022. https://doi.org/10.1016/j.dib.2021.107772

[10] M. Hollander and D. Wolfe, *Nonparametric Statistical Methods, 3rd ed.,* New York, NY: John Wiley & Sons, 2013.
[11] W. Venables and B. Ripley, *Modern Applied Statistics with S, 4th ed.* New York, NY: Springer, 2010.
[12] Y. Jiang, R. Abiri, and X. Zhao, "Tuning up the old brain with new tricks: Attention training via neurofeedback," *Front. Aging Neurosci.*, vol. 9, pp. 1–9, 2017. https://doi.org/10.3389/fnagi.2017.00052
[13] A. Bünger, N. Urfer-Maurer, and A. Grob, "Multimethod assessment of attention, executive functions, and motor skills in children with and without ADHD: Children's performance and parents' perceptions," *J. Atten. Disord.*, vol. 25, no. 4, pp. 596–606, 2021. https://doi.org/10.1177/1087054718824985

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