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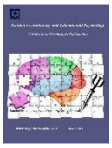

IEEPJ Vol. 5, No. 2, 2023, 306-319

http://ieepj.hormozgan.ac.ir/

Iranian Evolutionary and Educational Psychology Journal

IEEPJ

Comparing the Effectiveness of Brain-based Learning and Cognitive Rehabilitation on Inhibition and Attention Shifting Functions in 10-12 Year-old Children with Attention Deficit Hyperactivity Disorder

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Abstract: The aim of the present study was to compare the effectiveness of brain-based learning and cognitive rehabilitation interventions on the inhibition and attention shifting functions in 10-12 year-old children with attention deficit hyperactivity disorder. The research employed an experimental method with a pre-test-post-test design, with a control group. Participants were selected by random sampling and assigned to two experimental groups and one control group (with 15 members in each group) using the random assignment method. Data was collected using the Behavior Rating Inventory of Executive Function (BRIEF). Brain-based learning and cognitive rehabilitation interventions were carried out in the experimental groups, while no intervention was performed in the control group. The data was analyzed using SPSS software version 26. The MANCOVA analysis for the scores of inhibition and attention shifting functions showed there was a significant difference between groups ($p<0.05$). The results indicated a significant difference between the effectiveness of brain-based learning and cognitive rehabilitation interventions in terms of inhibition and attention shifting. Therefore, it was found that the effectiveness of brain-based learning was significantly greater than cognitive rehabilitation intervention. Based on these findings, it is suggested to prioritize brain-based learning intervention in order to increase the functions of inhibition and attention shifting.

Keywords: Brain-based learning, cognitive rehabilitation, inhibition, orientation, 10-12-year-old children, attention deficit hyperactivity disorder

Introduction

No doubt, the foundational and foremost stage for transformation and advancement in the realm of psychology is the elementary level. This stage lays the groundwork for children to progress to higher levels, and if it is enriched both quantitatively and qualitatively at an advanced level, it will lead to reduced academic decline and lower dropout rates in subsequent stages (Powell et al., 1998).

Attention-deficit/hyperactivity disorder (ADHD) stands as the most prevalent psychiatric disorder during childhood, characterized by symptoms such as limited attention span, lack of focus, impulsive behavior, and hyperactivity, as stated in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders by the American Psychiatric Association (Jensen & Steinhausen, 2015). In Iran, the estimated prevalence of this disorder ranges from ten to twenty percent (Shams et al., 2021).

Research has demonstrated that children with ADHD suffer from significant deficits in executive functions, which can persist into later ages, posing serious challenges for their academic and personal

Article information: Received: 2022/10/13 | Accepted: 2023/02/11 | Published: 2023/06/1. https://doi.org/10.52547/ieepj.5.2.306

endeavors. Therefore, it becomes crucial to timely diagnose and intervene to address the issues faced by these children (Kazemi & Kazempoor Dehbidi, 2022).For the treatment of ADHD and its related indicators, there are pharmacological and educational methods. Pharmacological methods, apart from incurring significant costs for patients, result in irreversible physical and psychological effects, whereas educational and behavioral methods will not have side effects and, if successful, will benefit patients significantly in terms of education and upbringing (Young et al., 2018). Based on this, the researcher will endeavor to provide solutions for addressing problems related to children with attention deficits accompanied by hyperactivity by presenting at least two educational methods and comparing them. Brain-based learning methods and cognitive rehabilitation are considered innovative approaches for enhancing executive functions, according to researchers and educational psychologists (Soleimani Daudli et al., 2019).

In recent years, the study of brain function, which is the primary factor in human learning, has received attention, and significant research has been conducted on neurophysiology of growth. These studies have led to extensive research on the structure and function of the human brain, focusing on mental health, brain disorders, and the effects of drugs on the brain. However, international interests have driven research towards educational and training aspects (Soleimani Daudli et al., 2019).

The philosophy of whole-brain teaching asserts that left-brain and right-brain teaching methods and approaches alone are not effective in eliciting holistic brain learning. Instead, by integrating and connecting left-brain and right-brain teaching methods and approaches in the learning content and the instructional path selected by the instructor, effective support can be provided for both left-brain and right-brain learning and thinking (Amini et al., 2012). Brain-based learning theory, based on research on how the brain works and how educators can utilize this knowledge, focuses on helping students quickly and efficiently learn languages (Ebadi, 2018). Learning styles are related to right or left hemisphere dominance of the brain. This has a significant impact on the learning process. Therefore, having an idea about students' brain dominance is essential (Oflaz, 2011).

Alongside the brain-based learning approach, the researcher's inclination is to study cognitive rehabilitation methods and assess their effectiveness on the sample population. Cognitive rehabilitation is a therapeutic activity based on brain-behavior relationships aimed at achieving changes in performance through the following processes: reestablishing or reinforcing previously learned behavioral patterns, creating new cognitive activity patterns through compensatory cognitive mechanisms, creating new activity patterns through external compensatory mechanisms, and helping individuals adapt to their cognitive disabilities for overall improvement (Cicerone et al., 2011).

Cognitive rehabilitation is often a part of comprehensive programs and, if properly applied, is based on theoretical and strategic structures derived from cognitive neuroscience, neurophysiology, neurobiology, neuropsychology, neurolinguistics, language development, cognitive development, and cognitive neuropsychology (Finucane & Mercer, 2006).

In the past, researchers have examined the effectiveness of two learning methods, brain-based learning and cognitive rehabilitation, on the executive functions of children with attention-deficit/hyperactivity disorder. Previous studies have reported positive outcomes in reducing the symptoms of attention-deficit/hyperactivity disorder and increased satisfaction with psychological interventions (Baweja et al., 2021; Feldman & Reiff, 2014; Shimabukuro et al., 2020; Sibley et al., 2021; Thomas & Karuppali, 2022). However, some studies have not confirmed the effectiveness of these interventions (Molina et al., 2009).

In light of the accumulated knowledge pertaining to each research variable, the primary inquiry of this study is to investigate whether there exists a notable disparity in the efficacy of brain-based learning and cognitive rehabilitation in enhancing inhibition and attention shifting functions among children aged 10 to 12 years diagnosed with attention-deficit/hyperactivity disorder (ADHD).

Material and Methods

The present research is an applied study with an experimental design, using a pretest-posttest with control group. The target population of this study consisted of all 10-12-year-old male children with symptoms of attention-deficit/hyperactivity disorder in elementary schools in Sirjan (Iran) in 2022. The sample group included 45 children with symptoms of attention-deficit/hyperactivity disorder, selected through simple random sampling from the list of all children with this disorder in elementary schools of Sirjan. The researcher obtained permission from the Education Department of Sirjan and collected and compiled a list of all children with this disorder by visiting elementary schools in the city. The list was prepared based on initial symptoms (recorded in their educational files by teachers, administrators, and counselors of elementary schools in Sirjan) and was organized by the researcher. After selecting the participants, the attention-deficit/hyperactivity disorder of each child was confirmed by administering the ADHD questionnaire.

The selected children were randomly assigned to two experimental groups and one control group, with each group containing 15 members. To assess executive functions, a pretest was administered to the three separate groups (two experimental groups and one control group) selected through random sampling. The validity of this test was determined through content validity and with the input of experts, while its reliability was assessed using the Kuder-Richardson method. With the permission of the parents, teachers, and school administrators of the students in the first and second experimental groups (a total of 30 participants), intervention sessions were held on designated afternoons (from 16:00 to 17:00). During one month, twelve sessions of brain-based learning intervention were conducted for the first experimental group, and twelve sessions of cognitive rehabilitation intervention were conducted for the second experimental group, while no intervention was provided for the control group. Subsequently, a posttest of executive functions (with the same difficulty level as the pretest) was administered to all three groups. The validity and content of the posttest were similar to the pretest.

For the implementation of the brain-based learning intervention, the protocol of Caine et al. (2005) was used. The description of the intervention sessions is presented in table 1.

Table 1. Summary of brain-based learning intervention sessions

Session	Content
1	Familiarization of the group members with each other, the therapist and the work description of the future sessions along with the work method
2	Description of the work of the previous session and further justification of the subjects and the implementation of the pre-test
3	Brainstorming about topics and information circulation
4	Using imagination and visualization in order to develop a specific topic
5	Being in a specific environment related to the students' real life and describing it
5	Teaching students the memory tree and using it in writing
7	Teaching simulation of a situation and writing based on simulation
8	Teaching how to use the table of free communication and forced communication to write a creative essay
9	Teaching the combination of words in order to create creativity in the essay
10	Teaching the combination of numbers and images in order to create creativity in the essay
11	Comparing the writings of the last sessions with the previous writings
12	Examining the strengths and weaknesses of the writings

To implement the cognitive rehabilitation-based training variable, the Sohlberg and Mateer (2001) protocol was used. Each session was held for 60 minutes. The session descriptions is provided in table 2.

Table 2. Summary of cognitive rehabilitation-based training sessions

Session	Content
1	Conducting the pre-test. Creating and establishing a therapeutic alliance and familiarizing the subjects with cognitive methods and exercises, completing the subject's consent questionnaire to participate in the research, clinical interview and assessment
2	Bridging the previous session (getting feedback from the previous session), attention exercises including listening to a bell with auditory stimuli (numbers, words, sentences, etc.), examining stressful events in the patient's life and preparing a list of stressful events based on three months the past, the past one year and the past three years (with the serious cooperation of parents)
3	Presentation of the worksheet related to cognitive-rehabilitation explanations, attention exercises including maintaining attention, increasing the skill of attention elements (reading a text by the patient and finding the designated letters and words).
4	Presentation of attention tasks including visual, image, numerical, shapes, letters and memory exercises (selective attention and attention processing exercises).

5	Exercises to change attention and event memory, and exercises for reading comprehension and cognitive development.
5	Tasks to follow the order in descending and ascending order to maintain attention and read a paragraph to understand the content and search for predetermined letters, words and meanings at the same time.
7	Auditory and visual memory exercises according to the content of numbers and letters, words, shapes, sentences and logical memory.
8	Verbal, visual memory tasks, making paired associations and verbal organization.
9	Executive performance exercises during which the subject is asked to consider a simple task, say or write the plan related to it, and express the signs that remain in the mind. Memory exercises, training to strengthen memory (imaging) are other exercises of this session.
10	Executive performance exercises include classification, differentiation and problem solving and self-directed training in problem solving (the subject must state the details of the classification, important elements, implementation steps and different parts of the activity).
11	Motor memory exercises and motor commands (one-step to multi-step)
12	Preparing the subject for the phase of exiting the cognitive-rehabilitation training program and reviewing the cognitive exercises of attention, memory and executive function.

To assess executive functions (inhibition and direction), the Behavior Rating Inventory of Executive Function (BRIEF) (parent form) by (Gioia et al., 2002) was used. This assessment has two forms, one for parents and one for teachers, with 86 items. The parents rate the child's behaviors as "never," "sometimes," and "always" on a scale from 0 to 2, based on observed conditions. Accordingly, a score of 0 indicates the lower limit, a score of 86 represents the average, and a score of 172 indicates the upper limit of the scores. This questionnaire examines the child's behaviors at school or home and is designed to interpret the behavioral performance of children aged 5 to 18 years (Gioia et al., 2002). The original version of the test has good psychometric properties, a simple and clear execution method, and has been introduced as a reliable and practical tool for therapists (Gioia et al., 2002). In Iran, the validity and reliability of the questionnaire were examined by Bahari et al. (2020). The reliability coefficients for the test-retest of the subscales of behavioral rankings in inhibitory function were 0.90, for direction 0.81, for emotional control 0.91, for initiation 0.80, for active memory 0.71, for planning 0.81, for organizing 0.79, and for monitoring 0.78. The reliability coefficient for the total executive functions was 0.89. in the present work, the internal consistency coefficient for this scale was calculated using Cronbach's alpha, yielding a value of 0.76. Moreover, the alpha coefficient for the sub-dimensions of inhibition was 0.73, for direction 0.73, for emotional control 0.74, for initiation 0.73, for active memory 0.75, for planning 0.74, for organizing 0.74, and for monitoring 0.74.

The SC4-ADHD questionnaire by Sprafkin et al. (2001) was used to confirm the eligibility of participants for the study. This questionnaire is designed to assess symptoms of inattention and hyperactivity in children aged 3 to 18 years. It consists of 50 questions, and its subscales include inattention (questions 1-9), hyperactivity (questions 10-18), and inattention and hyperactivity (questions 1-18). Additionally, the questionnaire includes 8 questions for oppositional defiant disorder and 10 questions for conduct problems and peer conflict symptoms. Side effects of medications, such as mood and behavioral symptoms, are also assessed in 14 questions. The responses are scored on a Likert scale (1: never - 2: sometimes - 3: often - 4: always).

The reliability and validity of this questionnaire have been demonstrated in previous studies, with a Cronbach's alpha of 0.95 for the attention and hyperactivity scale and a content validity agreement of over 85% (Volpe et al., 2009). The internal consistency reliability coefficient for the Iranian sample in this study was calculated to be 0.87 through internal homogeneity. The overall reliability coefficient for the scale, calculated using Cronbach's alpha, was 0.87.

For data analysis, descriptive statistics such as mean and measures of dispersion, including standard deviation, were calculated. In the inferential statistics section, multiple variable analysis of covariance (MANCOVA) and Bonferroni follow-up tests were used. The data were analyzed using SPSS version 26.

Ethical considerations: Informed consent was obtained from the participants before entering the study. The methods, purpose, potential risks, benefits, nature, and duration of the research were explained to the parents of the participating children. The information about these children was kept confidential and not disclosed. Parental consent was obtained in writing through a consent form.

The inclusion criteria for participation in the study were as follows:

1. Informed consent from parents
2. Scoring a minimum of 50% on the ADHD questionnaire
3. No other psychological disorders
4. No physical or medical conditions
5. No previous experience in brain-based learning and cognitive rehabilitation sessions
6. Non-usage of sedative drugs like Ritalin (methylphenidate) commonly prescribed for children with hyperactivity. The criteria for exclusion from the study were student fatigue and lack of consent to continue their participation.

Results

Table 3 presents the means and standard deviations of the variables related to inhibitory control and attention direction for the participants in the control, brain-based learning, and cognitive rehabilitation groups in both pretest and posttest phases. The table 1 indicates an increase in the mean scores of inhibitory control and attention shifting variables in the two experimental groups during the pretest and posttest stages. However, in the control group, a significant change in the mean scores was not observed in the pretest and posttest phases.

Table 3. Descriptive statistics of variables

Group	Variable	Pretest		Posttest	
		Mean	SD	Mean	SD
Control	Inhibition	11.47	2.26	12.13	2.69
	Attention Shifting	7.40	2.97	7.13	2.53
Brain-based learning	Inhibition	12.06	2.84	16.20	2.18
	Attention Shifting	8	2.97	12	3.05
Cognitive rehabilitation	Inhibition	12.13	2.55	17.40	2.32
	Attention Shifting	8.66	2.60	13.33	3.87

Before analyzing the data related to the research hypotheses, the following underlying assumptions of the covariance analysis were examined:

1. Normality of the research data was assessed using the Kolmogorov-Smirnov test. The results of this test showed that the p-value for the inhibitory control and attention direction variables was greater than 0.05, indicating that there is no logical basis to reject the null hypothesis. The null hypothesis in this test is based on the non-difference between the normal curve and the empirical data curve. Therefore, the research variables can be considered as normally distributed.

2. The homogeneity of variances for the variables was tested using the Levene's test. The F value for the inhibitory control variable was 0.48, and for the attention direction variable, it was 0.47, both showing no significant difference ($p>0.05$). Based on the reported values, the variances of the target groups in the inhibitory control and attention direction variables were not significantly different, confirming the assumption of variance homogeneity.

To examine the effect of the independent variables of the research intervention, a multivariate analysis of covariance (MANCOVA) was performed on the posttest scores, with the control of pretest scores as dependent variables. Table 4 shows the results of the MANCOVA analysis on the posttest scores with the control of pretest scores as dependent variables.

Table 4. Results of Multivariate Analysis of Covariance (MANCOVA)

Effect	Test	Value	F	DF hypothesis	Df error	p	Eta coefficient
Group	**Pillai's Trace**	1.61	4.84	16	56	0.001	0.58
	Wilks' Lambda	0.054	11.21	16	54	0.001	0.76
	Hoteling's Trace	13.68	22.23	16	52	0.001	0.87
	Roy's Largest Root	13.38	46.83	8	28	0.001	0.93

As the results in Table 4 show, there is a significant difference in at least one of the dependent variables between the experimental groups and the control group. This finding paves the way for examining the exact location of the differences, investigating the research's sub-hypotheses, and consequently conducting univariate covariance analyses. Table 5 presents the results of one-way covariance analysis to compare the posttest scores with the control of pretest scores for the dependent variables in the experimental and control groups.

Table 5. Results of one-way covariance analysis

Variable	Mean	F value	p	Eta
Inhibition	28.18	5.03	0.001	0.59
Attention Shifting	37.76	4.63	0.001	0.57

The results in Table 5 indicate that there is a significant difference between the experimental groups and the control group in the dependent variables. Univariate analysis of variance clarifies the differences among the groups for each variable separately but lacks the ability to pinpoint the exact location of the differences and the superiority of sample groups. To address this, a Bonferroni post-hoc test was conducted to determine the specific differences between the experimental groups and between the experimental groups and the control group. Table 6 presents the results of the Bonferroni post-hoc test.

Table 6. Results of Bonferroni Post-hoc Test

Variable	Comparison groups	Mean difference	p
Inhibition	**Brain-based learning- Cognitive rehabilitation**	6.60*	0.001
	Control- Brain-based learning	10.53**	0.001
	Control- Cognitive rehabilitation	3.93***	0.001
Attention Shifting	**Brain-based learning- Cognitive rehabilitation**	7.07*	0.001
	Control- Brain-based learning	10.33**	0.001
	Control- Cognitive rehabilitation	3.26***	0.001

* The mean of the first experimental group (brain-based learning) minus the mean of the second experimental group (cognitive rehabilitation).

** The mean of the first experimental group (brain-based learning) minus the mean of the control group.

*** The mean of the second experimental group (cognitive rehabilitation) minus the mean of the control group.

Based on the confirmed assumptions of the univariate analysis of covariance and the results of the statistical analyses, it has been determined that the effectiveness of brain-based learning and cognitive rehabilitation on the variables of inhibition and directionality is significantly different. Moreover, the difference between the means of the brain-based learning group and the cognitive rehabilitation group in the mentioned variables is statistically significant. In summary, the results indicate that both experimental groups have a positive and significant effect on inhibition and attention shifting. Furthermore, the brain-based learning group has a greater effect compared to the cognitive rehabilitation group. Therefore, the research hypothesis is confirmed. Accordingly, there is a significant difference between the effectiveness of brain-based learning and cognitive rehabilitation on the inhibition and attention shifting functions in children aged 10 to 12 years with attention deficit hyperactivity disorder.

Discussion

The research results indicate that there is a significant difference between the effectiveness of brain-based learning and cognitive rehabilitation on the inhibitory function of children with attention deficit/hyperactivity disorder in Sirjan city. This recent finding is inconsistent with the study by Feizipour et al. (2019), but aligns with the several previous studies (Bahari et al., 2020; Sibley et al., 2021; Thomas & Karuppali, 2022). It can be acknowledged that children with attention deficit/hyperactivity disorder may not be able to completely control their abnormal behaviors, even with knowledge of the consequences of some of these behaviors. In many cases, they may engage in such behaviors uncontrollably and unintentionally (mentally). Behaviors such as aimless running, breaking household items, and harming others fall under the category of behaviors that these children cannot inhibit. The effectiveness of brain-based learning in this function has been shown to be higher than cognitive rehabilitation, as this approach affects the overall functioning of the brain in psychological, emotional, and cognitive aspects, whereas cognitive rehabilitation only focuses on cognitive functions. Inhibition as the dependent variable is a multifaceted function because it involves controlling not only cognitive issues but also emotions, perceptions, and personal interests. Hence, it is evident that a method can have a more significant impact on this function of inhibition, shedding light on broader aspects of an individual's personality.

Dickstein et al. (2015) has demonstrated a strong link between brain-based learning and response inhibition; response inhibition refers to the ability to control dominant or habitual behavioral responses, allowing for the possibility of choosing more appropriate behaviors for a specific goal. The interest in how the brain influences response inhibition primarily stems from studies of patients with brain damage, insult, or some form of neurological decline (such as traumatic brain injury, tumor, stroke, epilepsy, or dementia) that seems to affect the right hemisphere, making them prone to showing unrestrained behaviors (Cicerone et al., 2011). Given the wide spectrum of brain areas potentially related to various unrestrained behaviors, neuroimaging studies have focused on cognitive tasks assessing response inhibition to investigate brain regions that might underlie unrestrained behavior (Caine et al., 2005). Therefore, brain-based learning can have a widespread impact on the physical and cognitive aspects of the brain in different areas, including the right orbitofrontal cortex, ventral medial prefrontal cortex, inferior frontal gyrus (IFG), and middle frontal gyrus (MFG), and thus strengthen the inhibitory function.

Despite the reasons indicating the superiority of the effectiveness of brain-based learning over cognitive rehabilitation, the desirability of the cognitive rehabilitation method in improving the level of inhibitory function should not be disregarded. Chan et al. (2020), while confirming the recent statement, acknowledge that cognitive rehabilitation plays a fundamental role in preserving remaining resources and patients' independence in daily life activities and promotes mental health.

The second part of the research results showed that there is a significant difference between the effectiveness of brain-based learning and cognitive rehabilitation on the attention shifting function of children with attention deficit/hyperactivity disorder. This recent finding is consistent with the previous studies (Amini et al., 2012; Movahedi & Bayrami, 2018; Narimani et al., 2015; Young et al., 2018).

The most prominent feature of attention deficit/hyperactivity disorder in affected children is related to the attention and directional processes. Due to brain-related issues, these children often cannot direct their attention to a specific behavioral or learning goal. Furthermore, according to Piaget and other developmental psychologists, the age range of 10 to 12 years is a period when the attention and directional processes mature in children (Anderson & Beauchamp, 2012). It is natural that during this age range, attention deficit/hyperactivity disorder is associated with a decline in directional function more than any other cognitive function.

One of the fundamental principles of brain-based learning is to direct mental faculties toward achieving a learning goal and focus the individual's attention on a specific issue. Therefore, it is evident that children trained with this method would have higher directional function compared to others. On the other hand, the effectiveness of cognitive rehabilitation on the directional function should not be disregarded, as this method also directs cognitive processes toward gaining knowledge in a targeted manner. It is essential to bear in mind that brain-based learning is primarily an instructional method, while cognitive rehabilitation is essentially a therapeutic approach. The difference between therapy and education can be explained based on the concept of negative and positive values. Therapy strives to guide psychological attributes from negative to zero and then toward positive values, while instructional methods are built on progressing values above zero. Brain-based learning is more effective in this regard as it operates based on positive psychological structures and naturally enhances achievements on the directional (attention) function.

Furthermore, the physical position of the current function in the brain makes the present hypothesis even more plausible. Researchers in neuroscience directly associate the directional function with a specific region of the brain. Brothers (1990) also attributes attention (directional function) to the prefrontal cortex of the brain. Based on this, brain-based learning (which explains the position of functions based on findings in neuroscience) is more efficient compared to cognitive rehabilitation in fostering attention and directional cognitive faculties.

The current study, in addition to its findings, encountered limitations that must be taken into account when extrapolating the results. While researchers can strive to control for confounding variables, external factors such as participants' home environment, ongoing therapeutic interventions, or changes in medication regimens might influence the study's outcomes. These uncontrollable factors could introduce variability and limit the study's ability to establish a direct causal relationship between the interventions and improvements in inhibition and attention shifting functions. Conducting interventions within a limited timeframe might not fully capture the potential long-term effects of brain-based learning and cognitive rehabilitation. A relatively short intervention period may not provide enough time for children to fully internalize the strategies and skills taught during the intervention. Consequently, the study's findings might underestimate the true efficacy of the interventions if the long-term impact is not adequately assessed.

Based on our results, it is recommended that other researchers conduct long-term follow-up studies to gain a comprehensive understanding of the lasting impact of brain-based learning and cognitive rehabilitation on inhibition and attention shifting functions in children with ADHD, it is advisable to implement a long-term follow-up study. Tracking the participants over an extended period will allow researchers to assess the sustainability of the intervention effects and determine whether any potential gains persist or diminish over time. Long-term follow-up will also help identify potential factors that might influence the maintenance of improvements, such as ongoing support from parents, educators, or additional therapeutic interventions. Also, to enhance the generalizability of the study's findings, it is essential to include a diverse and representative sample of children with ADHD. Recruiting participants from various socio-economic backgrounds, cultural contexts, and geographic regions will contribute to a more comprehensive understanding of the effectiveness of brain-based learning and cognitive rehabilitation across different populations. Moreover, including children with various ADHD subtypes and severity levels will provide insights into the differential impact of the interventions on specific ADHD profiles.

Conflict of interest: There is no conflict of interest associated with this research.

Financial sponsor: This research was conducted without any financial support and with the researcher's personal funds.

Acknowledgments: The researcher would like to express their gratitude to all the participants, as well as the professors and friends who provided support throughout this research endeavor.

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