journal of
Adolescent and Youth Psychological Studies
www.jayps.iranmehr.ac.ir

Fall (December) 2023, Volume 4, Issue 10 (Special issue on Education), 44-53

Comparing the effectiveness of brain-based learning training and self-regulation training on the executive functions of students with learning disabilities in reading

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ARTICLE INFORMATION

Article type
Original research
Pages: 44-53

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Email:
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Article history:
Received: 2023/06/07
Revised: 2023/08/12
Accepted: 2023/08/31
Published online: 2023/12/26

Keywords:
Brain-Based Learning, Self-Regulation, Executive Functions, Reading Disorder.

ABSTRACT

Background and Aim: Considering the fundamental role of education and development of executive functions in enhancing academic, educational, and social capabilities, and the challenges faced by students with learning disorders due to weaknesses in executive function components, the current research aimed to compare the effectiveness of brain-based learning and self-regulatory training on the executive functions of students. **Methods:** This study, in line with its objectives, was an applied research employing a quasi-experimental design, using a pre-test, immediate post-test, and delayed post-test (follow-up) with a control group. The population consisted of all female students in district two of Kerman city, totaling 6,515 individuals. The sample included 60 ten-year-old female students selected through multi-stage cluster sampling. Within each cluster, individuals were chosen using simple random sampling. Each group - the control group, the brain-based learning group, and the self-regulatory training group - consisted of 20 students and received 16 sessions of 45 minutes each, focusing on executive functions. At the end of the training, an immediate test and a follow-up test two months later were conducted to assess the sustainability of the intervention. The measurement tools of this research included the fourth-grade reading book, Stroop Test (2006), Wisconsin Card Sorting Test (1948), Continuous Performance Test (1956), and N-Back Test. The data were analyzed using repeated measures test within the framework of multivariate analysis of covariance (MANCOVA) using SPSS-V.24 software. **Results:** The results indicated a difference in the effectiveness of brain-based learning and self-regulatory training on executive functions of students with reading learning disorders. Specifically, the improvement in the brain-based learning group was more significant than that in the self-regulatory training group ($P < 0.05$). **Conclusion:** Therefore, it can be concluded that educational interventions, especially brain-based learning, can be effective and efficient strategies to enhance the performance and skills of students, particularly those with reading disorders.

How to Cite This Article:
Garusiyan Shad, N., Tavakolizadeh, J., Dastjerdi, R., & Taheri, H. (2023). Comparing the effectiveness of brain-based learning training and self-regulation training on the executive functions of students with learning disabilities in reading. *jayps*, 4(10), 44-53.

Introduction

One of the most common and significant specific learning disorders in students is dyslexia (Ehtesabi et al., 2022). Reading, as a primary method of acquiring knowledge and information, is foundational in learning, particularly in primary education, and forms the basis of future academic success (Soleymani Davodli, Khorramayi, Jokar, & Hosseinchari, 2019). Dyslexia is characterized by difficulties in correctly recognizing words or reading fluently. It involves mistaking similar-looking words, guessing words based on their first and last letters, significant struggles in syllabifying words, difficulty in distinguishing parts from wholes, and an aversion to learning to read. Approximately 4 to 8 percent of school-aged children in the United States suffer from dyslexia, which includes various deficiencies in reading, spelling, and comprehension. Dyslexia is also observed in about 75 percent of children and adolescents with specific learning disorders, particularly those with reading deficits (Darabi et al., 2022).

Reading comprises two main components: decoding and comprehension (Ostadzadeh et al., 2022). Decoding is the mechanical aspect of converting printed letters into spoken language, while comprehension refers to the higher-level aspect of reading, where individuals infer meanings from the language. However, some students, despite having natural intelligence and appropriate educational opportunities, struggle with reading (Ejmandnia, Ghasemzadeh, Shafiee, & Mosbahipour, 2021). Dyslexia, a specific learning disorder, is characterized by apparent defects in word recognition and fluency, and it may also involve significant deficiencies in decoding or spelling words. Specific learning disorder in reading is one of the most commonly diagnosed neurodevelopmental disorders in childhood, leading to poor academic performance and accompanied by issues in word recognition, fluency, and comprehension (Mohammadi et al., 2022). These problems lead to deficiencies in cognitive abilities (Karavolas, 2018). Dyslexia involves challenges in one or more domains of reading, spelling, and writing. According to the Diagnostic and Statistical Manual of Mental Disorders, the prevalence rate of specific learning disorders in reading, writing, and mathematics is between 5 to 15 percent among elementary school children across different languages and cultures (Ganji, 2020).

In students with dyslexia, learning often remains at the knowledge level and does not advance to higher levels. These students struggle to connect the learned materials and find relationships between them. Additionally, many face difficulties in understanding concepts and connecting new concepts with previous knowledge, leading to challenges in forming logical connections (Mosraabadi & Alilou, 2016). Students with this disorder also face difficulties in word recognition, reading fluency and speed, spelling errors, and comprehension issues. This disorder involves mistaking similar words, guessing words based on their beginnings and endings, mirror reading, severe syllabification issues, disinterest in reading, and difficulties in distinguishing parts from wholes. Another problem in children with reading disorders is a weakness in their executive functions, which are closely linked to reading progress and difficulties (Brack, Purpora, Smith, & Storksen, 2022). Executive functions are directly related to the health of the frontal lobe of the brain. These functions act as intermediaries between complex neural circuits, facilitating distinct connections in the frontal lobe with other cortical and subcortical structures, and are positively associated with cognition and awareness (Chen & Gauvrit, 2021).

Executive functions are a general term encompassing a wide range of cognitive processes and behavioral abilities, including problem-solving, attention, working memory, impulse control, maintenance and transformation, verbal reasoning, planning, and organization. They relate to higher cognitive functions like volition, goal-oriented thoughts, planning, self-awareness, and self-regulated behavior (Reidy & Reid, 2018). These components play a crucial role in personal and social skill development in childhood and adulthood and are important in interpersonal abilities and emotional regulation. Various studies have shown the significance of these functions, which can be seen as skills that assist individuals in focusing on the essential aspects of a task and planning to complete it (Mori & Gray, 2016). Many dyslexic children, even without corrective assistance, acquire some information about printed language in the first two years of elementary school. By the end of

the first grade, some may have learned to read a few words, but without any remedial educational intervention, these children will struggle with reading. Thus, interventions to assist these students are crucial. This research considers two interventions: brain-based learning and study. Brain-based learning, introduced as a new approach to education and understanding of the brain's natural learning process since 1980, emphasizes how the brain learns and includes adopting rules about brain processes and organizing teaching for meaningful learning (Jafarpour & Zarei, 2019).
Brain-based learning, or cognitive science, is a concept related to learning that aims to understand the brain's rules and regulations for creating meaningful learning and organized instruction. The foundation of brain-based learning is that the brain is naturally programmed for meaningful learning. The principles of brain-based learning provide a theoretical framework for effective teaching processes and the best conditions for learning to occur in the brain. The most influential components of brain-based learning, each with its subcomponents, include: alertness combined with relaxation, immersive engagement in complex experiences, and active processing of information (Nozohoori Behrabad, Fathi Azar, Adib, & Bafandeh Qaramaleki, 2019). The second educational approach that plays a significant role in the executive functions of dyslexic students is self-regulation. Self-regulation is an integrated and new form of instruction, primarily based on the expansion of traditional cognitive therapy concepts and methods. It combines the principles and foundations of cognitive, attachment, object relations, Gestalt, and constructivist schools into a single educational and conceptual model (Li et al., 2019).
Self-regulatory strategies can be taught to students, allowing them to organize their cognitive, motivational, behavioral, and learning beliefs, ultimately enabling them to evaluate their behaviors and organize learning situations more effectively (Aryatabar, Khoeini, & Asadzadeh, 2021). Students' academic success largely depends on their ability to plan, organize, prioritize information, regulate attention, manipulate information in working memory, and monitor their progress. One of the major issues for students that disrupt the learning process and reduce their academic performance is the lack of attention. The extent of learners' attention to the subject matter is one of the main factors in teaching and learning; as Bandura emphasizes, the initial stage of any learning starts with attention, and if there is insufficient attention, the learning process will be impaired. Attention, concentration, and monitoring are among the most important higher mental activities and are solely significant aspects of the cognitive structure that play a crucial role in intelligence, memory, and perception. Attention deficit is one of the core deficiencies in learning disabilities (Emslander & Schirrer, 2021). Since education and development of executive functions are essential in enhancing academic, educational, and social capabilities, students with learning disabilities face challenges in achieving educational goals due to weaknesses in executive function components. Therefore, efforts are always made to improve executive functions in dyslexic students through effective training, such as implementing components related to self-regulated and brain-based learning (Mousavi, Eshayeri, Esteki, & Vakili, 2022). Given the findings of the presented studies, the significance and place of interventions in brain-based learning and self-regulated instruction are evident. However, no research to date has compared these two approaches, especially in relation to executive function components. It is necessary for research to compare different approaches in the field of learning disabilities in various aspects related to children to identify and recommend the most effective approaches to students. Therefore, this necessity led the researcher to compare the effectiveness of these two instructions in students with reading learning disorders to obtain more precise results regarding the efficiency of each of these packages.

Method

The present study employs a quasi-experimental design, using a pre-test, immediate post-test, and delayed follow-up (tracking) design with a control group. The pre-test-post-test design with a control group consisted of two experimental groups and one equivalent control group. Each group was measured twice, the first measurement with a pre-test before the instruction, and the second after completing the required instruction. To form three groups, 20 subjects in the first group, 20 in the second, and another 20 in the control group were randomly assigned using a multi-stage sampling method. The statistical population used in this research consists of all fourth-grade female primary school students in public schools of District 2 of Tehran's Education Department in the year 2023, totaling 6,515 students.

Materials

1. Stroop Test: The Stroop Test, one of the most commonly used tests for selective or focused attention and response inhibition (Chan, Chun, & Law, 2006), is a laboratory model and a fundamental test for frontal lobe brain function. In the present study, a computerized version of the Stroop Test (Word/Color) was administered to subjects, consisting of three stages. This software-based test in this research is considered a measure of inhibition. It has been used in several studies to assess cognitive inhibition. The indices measured in this test include accuracy (number of correct responses) and speed (average reaction time of correct responses to stimuli in milliseconds). The test consists of 14 main cards. Each card contains a word in either green or red, displayed eight times, with the display method and color of these cards changing randomly each time. Each card is displayed for one-eighth of a second. Thus, the subject must try to identify the color of the cards as quickly as possible and indicate it using either a green or red key. Essentially, the shorter the time and the higher the number of correct responses (maximum of 112 correct answers), the higher the score obtained by the subject. The reliability of the Stroop Test, according to Lezak's (2004) research using the retest method, is reported to range from 0.80 to 0.91. Studies conducted on this test indicate its reliability and validity in adults (McLeod, 1991) and children (Barn, 2004). Also, Ghadiri and colleagues (2006; as cited by Ajilchi et al., 2013) reported the reliability of all three attempts of this test as 0.60, 0.83, and 0.97, respectively, using the retest method.

2. Wisconsin Card Sorting Test (WCST): The Wisconsin Card Sorting Test (WCST) is a neuropsychological test that measures abstract reasoning, cognitive flexibility, perseverance, problem-solving, concept formation, set shifting, hypothesis testing, and the use of error feedback, initiation and cessation of action, and attention maintenance. This test was designed to assess abstract reasoning and the ability to adapt cognitive strategies to environmental challenges. Therefore, it is believed that the WCST assesses a complex range of executive functions including planning, organizing, abstract reasoning, concept formation, maintaining cognitive rules, the ability to change, and inhibiting impulsive responses (Lezak, 2004). The original WCST consists of 60 response cards (or 64 response cards as in Grant and Berg, 1948) opposite 4 key stimulus cards. Stim (1977; as cited by Abdi et al., 2014), emphasizes that this test is used to assess cognitive flexibility. In the present study, a computerized version of the test was used, consisting of 64 distinct cards, and considered as an index for cognitive flexibility. The higher the number of correct responses, the better the performance of the individual. The maximum score is 64, and the minimum is zero. The Wisconsin Card Sorting Test is one of the most important psychological tests used to measure general intelligence and cognitive performance. This test is usually presented as a booklet of cards with various images, typically consisting of 60 to 70 cards. Each card in this test features a series of polygonal shapes, dots, lines, or other patterns categorized into four groups: shapes, colors, numbers, and patterns. In each group, cards are presented randomly, and the individual must categorize them according to a specific pattern. In this test, the individual must demonstrate the ability to quickly and accurately categorize cards with high precision. Scoring in this test is based on the number of cards accurately categorized within a limited time. The Wisconsin Card Sorting Test is one of the most important cognitive intelligence tests, measuring cognitive abilities, including attention, memory, concept understanding, abstract thinking, and logical judgment. Scoring in the Wisconsin Card Sorting Test is based on the number of cards accurately categorized within a limited time. Stim (1977; as cited by Abdi et al., 2014) obtained a reliability of over 0.86 for assessing cognitive deficits following brain injury. Additionally, the reliability of this test, according to the agreement coefficient of evaluators in the study by Sperin and Strauss, was reported as 0.83. Naderi in 1994 also mentioned the reliability of this test in the Iranian population as 0.85 using the retest method (Ajilchi et al., 2013).

3. Continuous Performance Test (CPT): The Continuous Performance Test (CPT) was designed in 1956 by Rosvold et al. and has since been a common and powerful tool in assessing patients with attention deficits and hyperactivity. This test requires the suppression of unwanted responses and continuous monitoring of target responses. In this test, the individual must perform an action (pressing a button) in response to a target stimulus in a series of target and non-target stimuli presented. Outputs of this test include correct responses to the target stimulus, average reaction time for correct responses, incorrect responses to non-target stimuli, and failure to respond to the target stimulus (errors of omission). In the test used for this research, two numbers appear on both sides of the display screen, and the individual is asked to press the space bar on the keyboard as accurately and quickly as possible if the two numbers displayed are the same. This task allows for continuous monitoring of stimuli while repeatedly changing the target stimulus (Llewelyn, 2008). In this test, 150 numbers are presented as stimuli, with 30 stimuli (20%) as target stimuli and the remaining 80% as non-target stimuli. Each stimulus is displayed for 200 milliseconds, and the interval between two stimuli is one second. The total duration of the test, including a practice phase for better comprehension by the subject before the main phase, is 200 seconds. In this test, two types of errors are counted by the computer program. Additionally, the number of correct responses (up to 150 responses) and the reaction time of the subject to the stimulus are also calculated. Hasani and Hadianfar in 2007 reported the reliability of this test through retesting for different parts ranging from 0.59 to 0.93 (Ajilchi et al., 2013).

4. N-Back Test: The N-Back Test was first designed by Kirchner in 1958 as a cognitive performance task related to executive functions. This test, requiring both the retention and manipulation of information, is deemed very suitable for assessing working memory. In this test, several visual stimuli are serially presented on a screen, and participants must respond in two conditions with different working memory loads. In low-load conditions, participants must press a target key if a stimulus matches the previous one. In high-load conditions, they must compare each stimulus with the two preceding ones and press the corresponding key if they match. The output of this test includes the number of correct and incorrect responses. Data from this test consist of the number of correct responses, incorrect responses, unanswered items, and the average reaction time of correct responses. The total score is considered the number of correct responses. A higher number of correct responses, fewer incorrect responses, and shorter response times indicate a desirable working memory state. In domestic and international research, the reliability of this test ranges from 0.54 to 0.84, and its validity is also reported as acceptable (Bozorgmehr & Bozorgmehr, 2014).

Implementation

60 fourth-grade female students from five schools in Tehran's district two were selected, with two students with reading disorders and one regular student from each of the 20 fourth-grade classes, totaling 40 students with reading disorders and 20 regular students. These students were selected for simultaneous placement in the brain-based learning group, self-regulatory training group, and control group, each comprising 20 students. An orientation session was also conducted by teachers and researchers to explain that these groups should receive training according to these methods and be tested afterward. The female students in these groups received equal training in brain-based learning and self-regulatory training, focusing on executive functions. The control group continued their usual daily activities without receiving any training in brain-based learning and self-regulatory training regarding executive functions. After the training sessions were completed in February 2023, both groups were immediately post-tested under the same conditions. Two months later, the children were again administered the executive functions questionnaires as a delayed post-test. The collected pre-test and post-test data were analyzed using appropriate statistical tests and compared across the groups. Descriptive statistics such as mean and standard deviation and inferential statistics, including multivariate analysis of covariance, were used to control the pre-test variable. SPSS version 24 was the data analysis software.

The brain-based learning group was conducted in person once a week to evaluate the executive performance and efficiency of students with reading disorders. The teaching method involved presenting educational content by the teacher, with student participation. Tools used included the fourth-grade reading book, smartboards, whiteboards, and tests related to evaluating executive function and student efficiency variables.

The teaching method in brain-based learning involved the teacher playing a primary role in presenting lesson content to the students. The teacher aimed to integrate all elements and techniques of this teaching method, involving students in classroom exercises and their experiences in line with narratives, in a calm manner to improve skills related to executive function and efficiency in students with reading disorders. This included enhancing subcomponents of executive function such as presentation time, number and accuracy of responses, cognitive flexibility, concept formation, attention maintenance and improvement, and reading speed.

The self-regulatory learning group was similarly taught in person once a week, focusing on the executive performance and efficiency of students with reading disorders. The teacher led the teaching process, encouraging students to delay immediate impulses, focus attention, think about the potential consequences of their behavior, and replace it with appropriate behavior. This aimed to improve skills related to executive function and efficiency in students with reading disorders, enhancing subcomponents like response time, cognitive flexibility, concept formation, attention retention, and improvement, and increasing reading speed and comprehension.

At the end of the teaching phase using both brain-based learning and self-regulatory methods, the outcomes of the two teaching methods were evaluated and compared with each other and with the control group through immediate and delayed post-tests.

Results

In this study, participants were matched based on age and gender, with 60 female students (10 years old) from the fourth grade being selected and divided into three groups of 15. The first group received brain-based learning, the second group self-regulatory learning, and the third served as the control group. The outcomes of the groups were compared with each other and with the control group at the end. Since pre-test, immediate post-test, and delayed post-test (follow-up) phases were conducted with these participants, a repeated measures design was used to examine the research hypotheses.

Table 1. Mean and standard deviation of variables

Group	Variable	Index	Pre-test	Post-test	Follow-up
Brain-based	Continuous attention	Mean	83.70	102.50	103.10
		SD	10.84	10.28	8.98
Self-regulation	Continuous attention	Mean	81.90	97.40	102.50
		SD	8.77	10.46	9.90
Control	Continuous attention	Mean	80.90	81.70	82.05
		SD	8.47	12.30	10.73
Brain-based	Focused attention	Mean	78.60	98.40	96.20
		SD	9.47	9.30	10.01
Self-regulation	Focused attention	Mean	82.00	90.60	90.00
		SD	11.86	7.49	9.75
Control	Focused attention	Mean	80.40	80.00	83.60
		SD	11.60	16.82	16.87
Brain-based	Active memory	Mean	21.70	27.60	27.70
		SD	4.60	3.59	3.96
Self-regulation	Active memory	Mean	2.60	22.70	27.90
		SD	1.40	3.80	3.64
Control	Active memory	Mean	20.90	19.50	20.40
		SD	3.81	5.02	5.05
Brain-based	Cognitive flexibility	Mean	42.20	56.40	54.20
		SD	8.24	8.73	7.00

Self-regulation	Cognitive flexibility	Mean	40.40	53.00	55.20
		SD	5.99	6.62	5.87
Control	Cognitive flexibility	Mean	41.80	38.00	39.60
		SD	6.52	8.55	8.92

It was observed that the mean scores in the two experimental groups showed an increase in the sub-scales of executive functions in the post-test compared to the pre-test. According to the results presented in the table, it can be inferred that brain-based learning and self-regulatory training have improved executive functions. Before using parametric statistical methods, the assumptions of the test must be confirmed to use the desired test; therefore, the assumptions of repeated measures analysis of variance along with the between-group effect ("independence of observations, normal distribution of the dependent variable, homogeneity of variances, and Sphericity test") were examined in the different groups.

Table 2. Levene nd Mauchly test

	Group	Levene		Mauchly		
index.Variable		F	P	Mauchly's W	df	Sig
Continuous attention	Brain-based	2.68	0.11	0.77	2.00	0.01
	Self-regulation	0.14	0.71	0.84	2.00	0.04
Focused attention	Brain-based	0.43	0.52	0.20	2.00	0.001
	Self-regulation	1.58	0.22	0.66	2.00	0.001
Active memory	Brain-based	0.88	0.36	0.48	2.00	0.001
	Self-regulation	0.10	0.75	0.75	2.00	0.005
Cognitive flexibility	Brain-based	0.42	0.52	0.64	2.00	0.001
	Self-regulation	0.08	0.77	0.78	2.00	0.001

As observed, the assumption of equality of variances is met ($p>0.05$). The variance difference between all combinations related to the groups (sphericity) must be equal. To examine this assumption, Mauchly's test was used, the results of which are presented in Table 4. As observed, the sphericity assumption is not met ($p<0.05$). Accordingly, Greenhouse-Geisser correction is used in hypothesis testing to obtain a more accurate approximation (Hooman, 2001), and within-group variance analysis results are calculated considering the non-fulfillment of the sphericity assumption. The summary of mixed ANOVA results for within-group and between-group factors is presented in Tables 3 and 4. Also, to examine the significant difference between the means of executive function components in the two groups across the three stages of training, the assumptions of homogeneity of variances and sphericity were checked. As observed, the assumption of equality of variances is met ($p>0.05$), and the sphericity assumption is not met ($p<0.05$).

Table 3. Analysis of variance with Greenhouse-Geisser

Variable	Index Factor	SS	df	MS	F	Sig	Eta^2
Continuous attention	Within-group	2691.22	1.63	1652.71	21.00	0.001	0.36
	Interction	2190.42	1.63	1345.16	17.09	0.001	0.31
	Between-group	6645.41	1.00	6645.41	34.45	0.001	0.48
Focused attention	Within-group	2703.20	1.11	2430.39	30.26	0.001	0.44
	Interction	2163.47	1.11	1945.12	24.22	0.001	0.39
	Between-group	2842.13	1.00	2842.13	7.11	0.01	0.16
Active memory	Within-group	171.67	1.31	130.63	13.41	0.001	0.26

	Interction	320.60	1.31	243.95	25.05	0.001	0.40
	Between-group	80.874	1.00	874.80	19.57	0.001	0.34
Cognitive flexibility	Within-group	681.87	1.47	464.55	8.17	0.001	0.18
	Interction	1800.27	1.47	1226.51	21.56	0.001	0.36
	Between-group	3718.53	1.00	3718.53	33.58	0.001	0.47

Table 3 results show that the calculated F-value for the effect of stages (pre-test, post-test, and follow-up) is significant at the 0.05 level for all four components ($p<0.05$). Therefore, there is a significant difference between the mean scores of executive function components in the three stages of pre-test, post-test, and follow-up training. Bonferroni post hoc test results indicate significant differences between the scores of executive function components in the pre-test compared to the post-test and pre-test compared to the follow-up. However, there is no significant difference between the scores of executive function components in the post-test compared to the follow-up stage, indicating that the scores of executive function components in the follow-up stage did not significantly change compared to the post-test stage.

Therefore, there is a significant difference between the mean scores of executive function components in the three stages of pre-test, post-test, and follow-up training. The results of the Bonferroni post hoc test, calculated to examine the differences between the means in the training stages, showed significant differences between the scores of executive function components in the pre-test compared to the post-test and pre-test compared to the follow-up. Additionally, there was no significant difference between the scores of executive function components in the post-test compared to the follow-up stage, indicating that the scores of executive function components in the follow-up stage did not significantly change compared to the post-test stage. With regard to the results in Table 8, regarding the interaction of stage and group factors, the calculated F-value for the effect of stages (pre-test, post-test, and follow-up) between the two groups of self-regulatory learning and control is significant at the 0.05 level for executive function components ($p<0.05$). Based on the results in Table 8, the calculated F-value for the between-group factor is significant at the 0.05 level for executive functions ($p<0.05$). Thus, there is a significant difference between the overall mean scores of executive functions in the two groups of self-regulatory learning and control. Overall, it can be concluded that the self-regulatory training method has had an impact on the scores of executive functions, such that the experimental group (self-regulatory learning) has led to an increase in executive function scores compared to the control group. Since the increase in executive function scores in the follow-up stage compared to the pre-test was also significant, the trend of increasing executive function scores in the follow-up stage compared to the pre-test stage continued and was significantly different, indicating the sustainability of the training (self-regulatory learning) on executive function scores. Mixed ANOVA was used to examine the effect of brain-based learning and self-regulatory learning on the scores of executive function components in the pre-test, post-test, and follow-up stages. The three stages of pre-test, post-test, and follow-up were considered as the within-subjects factor, and the grouping of participants into two groups as the between-subjects factor.

Conclusion

The current research aimed to compare the effectiveness of brain-based learning and self-regulatory training on the efficiency of female primary school students with reading disorders in District 2 of Tehran during the 2022-2023 academic year. It achieved results that could be utilized to enhance and advance the individual and social educational systems for all learners involved in education and training.

The statistical analysis of the data indicated that both brain-based learning and self-regulatory training methods had a significant impact on executive function scores. The experimental group showed higher executive function scores compared to the control group. Furthermore, there was a significant increase in executive function scores in the follow-up phase compared to the pre-test phase, demonstrating the sustainability of brain-based learning and self-regulatory training on executive function scores. Additionally, the increase in the focused attention variable was more pronounced in the brain-based learning group than in the self-regulatory training group. This finding suggests that students must first be able to decode words correctly before expanding their reading comprehension skills, as decoding is a stage of brain information processing. Therefore, brain-based learning, which focuses on brain function (including processing, interpreting, storing, and encoding information) and utilizes the entire brain system, is expected to be more effective in improving reading performance, accuracy, comprehension, phonological awareness, and efficiency of students with reading disorders compared to self-regulatory training (Kadivar, 2022).

This finding emphasizes that educational methods should consider the limitations of self-regulatory learning and emphasize that teaching techniques should be designed in line with the practical principles of the cognitive system and to enhance the skills of students with reading disorders, particularly in their efficiency. Designing educational environments based on brain-based learning, optimized for active learning, helps students understand the value of learning and gain confidence in their abilities, realizing that they can learn and progress through acceptable efforts (Sowller, 2010).

Furthermore, considering the importance of reading as a subject, especially in strengthening the skills of students with reading disorders, teachers and learners should strive to enhance reading skills in students with reading disorders, aligning with modern teaching methods and employing various skills to enhance efficiency. Teachers should guide students in this process by teaching correct techniques and rules and addressing their weaknesses. Students should also actively cooperate with their teachers, requesting assistance in improving their skills through brain-based learning (Hosseini Nejad, 2010).

A limitation of the study was the potential for inaccuracies, impatience, or personal perceptions of the participants, as the only tool used in this research was a questionnaire. Also, since the statistical population of this study consisted only of fourth-grade primary school girls in a specific and limited timeframe, the generalization of findings to other members of society and educational levels should be done cautiously and conservatively. Therefore, it is suggested to design and produce multimedia software and programs related to the reading subject, considering the content of the programs, objectives of the textbooks, and components of executive functions. Longitudinal research for more precise results, the use of brain-based learning in centers for specific learning disorders, especially reading disorders, can help reduce reading problems and increase attention in students with specific learning disorders. Equipping teachers' work programs with a brain-based learning approach and transferring necessary scientific information through booklets and brochures to students, especially those with reading disorders, can be very effective.

Conflict of Interest

According to the authors, this article has no financial sponsor or conflict of interest.

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