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Effectiveness of Brain Training Exercises on Visual and Auditory Memory in Students with Dyslexia

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Abstract

Background: Dyslexia, a learning disorder characterized by reading difficulties, can also impair memory function in students.

Objectives: This study aimed to address the gap in knowledge regarding the effectiveness of brain training exercises in enhancing memory function in this population. We investigated whether such interventions could improve academic success for students with dyslexia.

Methods: A quasi-experimental design was utilized, incorporating pre-test, post-test, and 45-day follow-up measurements, with a control group for comparison. The target population comprised elementary school students diagnosed with dyslexia at learning disability centers in Tehran, Iran, during the 2022 - 2023 academic year. Using convenience sampling, 30 participants were selected and then randomly assigned to either the experimental (brain training) or control group through simple random assignment. Visual memory and digit-letter sequencing abilities were assessed using validated tools: The Visual Memory Questionnaire and the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) Digit-Letter Sequencing subtest, respectively. The experimental group participated in eight brain training sessions, each lasting 60 minutes, while the control group received no intervention during the study period. Data analysis was performed using SPSS version 27.0. Repeated measures ANOVA with Bonferroni post-hoc tests were employed for data analysis.

Results: Post-test visual memory scores were significantly higher in the brain training exercises group (M = 8.73, SD = 1.60) compared to the control group (M = 5.30, SD = 1.25). Auditory memory scores demonstrated a similar trend, with the brain training group outperforming the control group (M = 10.80, SD=1.78 vs. M = 6.86, SD = 1.99). The brain training program produced significant improvements in visual and auditory memory among students with dyslexia, as evidenced by post-test results ($P < 0.001$).

Conclusions: This finding suggests a robust positive effect of the intervention on memory function. These results suggest that brain training exercises can be a promising intervention for enhancing memory function in students with dyslexia.

Keywords: Brain Training, Visual Memory, Auditory Memory, Dyslexia, Students

1. Background

Learning disabilities (LDs) are a heterogeneous group of neurodevelopmental disorders marked by persistent deficits in acquiring, organizing, or applying specific academic skills, such as reading, writing, and mathematics (1). Despite having average or above-average intellectual abilities, individuals with LDs face significant challenges in these areas, often impacting their academic progress and overall well-being (2). Reading disabilities, commonly referred to as dyslexia, represent one of the most prevalent LDs, affecting an estimated 5 - 15% of school-aged children across diverse linguistic and cultural contexts (3). These difficulties arise from impairments in both word recognition and comprehension processes. Emerging research highlights the complex interplay between auditory processing, language abilities, and word-reading skills in the neuropsychological underpinnings of reading disabilities (4). Individuals with dyslexia frequently encounter challenges in tasks involving phonological awareness, rapid auditory processing, and orthographic processing, all of which contribute to their reading difficulties (5).

Dyslexia is characterized by persistent deficits in reading accuracy and fluency, often accompanied by challenges in comprehending written text relative to an individual's age, educational level, and overall intellectual abilities (5). Research has identified several neuropsychological factors contributing to dyslexia, including visual perception impairments that hinder the recognition and decoding of written words, auditory processing difficulties that impede the segmentation of spoken sounds and their linkage to corresponding written symbols, and motor memory deficits that affect the ability to smoothly and efficiently produce written letters and words (6). These combined challenges can significantly impact an individual's ability to learn and succeed in an academic setting.

Memory impairments in students with LDs can significantly affect academic performance. For instance, auditory memory deficits may impair the ability to recall letter sounds and blend them to form words, leading to difficulties with word recognition and decoding. Similarly, a child with visual memory deficits may struggle to recognize specific letters and words, impeding accurate reading and spelling (7). Additionally, Khan and Lal (8) report that students with LDs show impairments in both visual and auditory memory. While visual memory deficits are commonly observed among these students, there is considerable individual variation; some students with LDs experience substantial visual memory challenges, while others may have relatively intact visual memory skills (9). Conversely, many students with LDs face challenges in phonological awareness, phonological coding, orthographic coding, short-term auditory memory, and rapid naming (10). Weaknesses in auditory memory can contribute to difficulties with reading and spelling words (11).

Brain training exercises, also known as Brain Gym or Educational Kinesiology, have emerged as a promising approach to enhance learning outcomes for children with LDs. Developed by Dennison and Dennison (12), brain training involves a series of coordinated movements designed to activate and integrate both hemispheres of the brain, thereby reducing stress associated with specific memories, situations, individuals, locations, or skills. The brain training protocol uses cross-lateral movements to promote neural repatterning, which in turn supports whole-brain learning, academic achievement, and behavioral regulation (13). These interventions are especially beneficial for children with developmental disabilities such as attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) (14, 15).

Several studies have explored the potential benefits of brain training exercises for children with LDs. Kordbacheh et al. (16) investigated the synergistic effects of brain training exercises and filial play therapy in preschoolers with LDs. Their findings suggest that brain training exercises can contribute to positive development in emotional regulation, social skills, empathy, and parent-child relationships. Asadi et al. (17) examined the efficacy of a combined intervention involving brain training exercises and a computerized cognitive rehabilitation program called Captain Log. Their study demonstrates that this approach effectively reduces cognitive avoidance and enhances executive function in students with LDs. Ardin and Nuraini (18) focused on the underlying neural mechanisms associated with brain training exercises. They propose that brain training exercises stimulate the vestibular system by activating both hemispheres of the brain through the motor and sensory cortices. This activation, they argue, leads to a reduction in the fight-or-flight response, ultimately improving learning performance. While previous research (12, 13) has explored the benefits of brain training for various cognitive functions, there is a need for further investigation into its impact on specific LDs, such as dyslexia.

2. Objectives

This study aims to investigate the effectiveness of brain training exercises on visual and auditory memory in students with dyslexia.

3. Methods

This study employed a quasi-experimental design with a pretest-posttest and follow-up structure, incorporating a control group to bolster the internal validity of the results. The target population included all primary school students in Tehran diagnosed with dyslexia at learning disability centers during the 2022 - 2023 academic year. To ensure participant homogeneity and to recruit a manageable sample size, a convenience sampling approach was used. Thirty participants were selected and randomly assigned to either the experimental (brain training) or control group (waiting list) using a simple random assignment procedure (n = 15 per group). Random assignment was conducted using a table of random numbers. A G*Power analysis revealed that 15 participants per group are needed for an effect size of 1.24, an alpha of 0.05, and a power of 0.95. Inclusion criteria required a current diagnosis of dyslexia based on the DSM-5, observable dyslexic symptoms reported by teachers or parents for at least one semester, and the absence of any coexisting neurodevelopmental disorders (such as ADHD, communication disorders, developmental coordination disorder, or ASD) or mental health conditions (including anxiety or depression). To preserve data integrity, participants taking medication that could influence the intervention or demonstrating noncompliance by missing two consecutive therapy sessions were excluded. Ethical considerations were carefully addressed throughout the study. Participants provided informed consent prior to participation, ensuring they understood the nature of the study, potential risks and benefits, and their right to withdraw at any time. Confidentiality was maintained through the use of anonymous data collection and secure storage of participant information.

3.1. Instruments

3.1.1. Visual Memory Questionnaire

The Visual Memory Questionnaire (VMQ) is a test designed to assess visual memory. It consists of a 20-cell cardboard sheet with a colored image in each cell, some of which share similarities in terms of color, shape, and orientation. There is also a blank 20-cell sheet and 20 cardboard pieces, each featuring one of the images from the main sheet. The VMQ is used in three stages to assess visual memory:

- Stage 1: The subject looks at the geometric figures for one minute and then recalls the orientation and location of the geometric figures.

- Stage 2: This is a repetition of Stage 1. The subject looks at the geometric figures for another minute and then recalls the orientation and location of the geometric figures.

- Stage 3: The subject tries to fully recall the orientation and location of the learned geometric figures.

A score of 1 is given for correct orientation and location, and a score of 0.5 is given for correct location and incorrect orientation (19). In the present study, the reliability coefficient of this test was calculated to be 0.78 using Cronbach's alpha; values above 0.7 indicate good internal consistency.

3.1.2. Auditory Working Memory Index Subtest (Wechsler Memory Test)

The Auditory Working Memory Index is an adaptation of the Wechsler Memory test and comprises two subtests. One subtest is Digit-Letter Sequencing, which measures auditory working memory, while the other subtest, Spatial Span, is designed to assess spatial working memory. The Digit-Letter Sequencing subtest contains 7 questions, each with three trials. In this subtest, a scrambled set of numbers and letters is presented to the subject, who must first sort the numbers from smallest to largest and then arrange the letters alphabetically before repeating them back. The scoring method for this test awards 1 point for each correct trial and 0 points for each incorrect trial. Consequently, the subject's score on the auditory working memory subscale falls within a range of 0 to 21 (19). In the present study, the reliability coefficient of this test was calculated to be 0.75 using Cronbach's alpha.

3.2. Intervention

The experimental group received specialized brain exercise training sessions, while the control (waiting list) group received no intervention. The brain training intervention consisted of 8 sessions, each lasting 60 minutes, conducted once a week. The brain exercise training comprises 26 engaging and simple exercises aimed at improving skill learning through the use of both hemispheres of the brain. This method claims to enhance mental and physical development and is currently utilized in over 80 countries worldwide. Brain exercise is one of the activities that can increase working memory. This method can improve cognitive, psychological, and motor functions, such as self-confidence, self-esteem, coordination, communication, focus, memory, stress management, and goal achievement. Some of the most important brain exercise activities include drinking water, abdominal breathing, cross-crawling, the eighth alphabet, brain buttons, yawning energy, space buttons, positive points, and neck rotations. After the interventions, post-tests and follow-ups were conducted in both the experimental and control groups after 45 days.

3.3. Data Analysis

Descriptive statistics (means and standard deviations) were used to characterize the central tendency and variability of the collected data. To investigate the effectiveness of the brain training intervention in enhancing visual and auditory memory, a repeated-measures analysis of variance (ANOVA) was conducted with a significance level of $\alpha = 0.05$. Before conducting the ANOVA, the assumptions of normality, homogeneity of variances, and sphericity were verified. The Shapiro-Wilk test assessed normality, while Levene's test checked for homogeneity of variances. Mauchly's test was employed to evaluate sphericity. Additionally, post-hoc comparisons with Bonferroni correction were planned to identify any significant group differences in memory performance at each measurement point.

4. Results

A total of 30 elementary school students participated in this study, equally divided into an experimental group receiving brain training and a control group. The sample demographics reflected a balanced distribution across gender (15 girls and 15 boys) and grade levels (grades 2 through 6). The participants' ages ranged from 8 to 12 years (M = 10.28 years, SD = 2.62 years).

The results presented in Table 1 demonstrate significant improvements in both visual and auditory memory performance among students in the experimental group (brain training exercises) compared to the control group. Specifically, the experimental group exhibited a marked increase in memory scores from pre-test to post-test and follow-up assessments. In contrast, the control group displayed minimal changes in their memory performance across these time points. These findings suggest that the brain training intervention may be effective in enhancing visual and auditory memory in students with dyslexia. The mean scores for both the brain training exercises and control groups at the pre-test, post-test, and follow-up stages are visually represented in Figure 1.

Before conducting the repeated-measures ANOVA, the study ensured that the data met the key assumptions of the test. The normality of the dependent variables (visual and auditory memory) across all groups was verified using the Shapiro-Wilk test. Non-significant results confirmed that these variables were normally distributed within the sample. Furthermore, Levene's test for homogeneity of variances—a critical assumption for ANOVA—revealed no statistically significant differences in the variances of the research variables, thereby upholding this requirement. Lastly, Mauchly's test of sphericity was conducted. The non-significant results (implicit in the mention of sphericity being upheld) supported the assumption of sphericity, indicating that the variances of the differences between repeated measures were equal across all three measurement stages (pre-test, post-test, and follow-up). These verifications ensured the validity of using the repeated-measures ANOVA to analyze the intervention's impact on the dependent variables.

The repeated-measures ANOVA, detailed in Table 2, investigated the impact of brain training exercises on visual and auditory memory. The analysis yielded significant main effects for both memory types across the pre-test, post-test, and follow-up assessments ($P < 0.001$). This indicates a statistically significant change in mean memory scores over time for all participants. Furthermore, significant interaction effects were observed between the intervention group (brain training) and the control group for both visual and auditory memory at each measurement point ($P < 0.01$). This suggests that the brain training intervention had a statistically significant positive effect on memory performance compared to the control group.

To further investigate the intervention's effectiveness within the brain training group, Bonferroni post-hoc comparisons were conducted (Table 3). The results revealed significant improvements in both visual and auditory memory performance from pre-test to post-test ($P < 0.001$). This suggests that the brain training intervention had a rapid and positive impact on memory within the group. Notably, the significant differences persisted between post-test and follow-up assessments, indicating that the intervention's effects were sustained over time. These findings provide further support for the effectiveness of brain training exercises in enhancing memory function.

5. Discussion

The present study aimed to investigate the effectiveness of brain training exercises on visual and auditory memory in students with dyslexia. The findings of this study provide compelling evidence for the effectiveness of brain training exercises in enhancing visual and auditory memory among students with dyslexia. These results align with the findings of previous studies conducted by Kordbacheh et al. (16), Tai and Lau (20), and Thakre et al. (21).

Individuals with dyslexia often exhibit impairments in visual memory compared to their neurotypical peers (22). These challenges manifest as difficulties with visual-motor perception and visual memory tasks. Visual memory plays a crucial role in processing and retaining information related to written objects, letters, words, and sentences. Deficiencies in visual memory can hinder the storage and comprehension of such information (23). Brain training exercises, which incorporate engaging and simple movements aimed at enhancing learning skills through the utilization of both brain hemispheres, have gained widespread popularity, with applications in over eighty countries worldwide. These exercises are purported to promote cognitive and physical development. Brain training, particularly those targeting working memory, has a well-established history of improving focus, attention, and memory (16).

Table 1. Means and Standard Deviations of Visual and Auditory Memory in Brain [a]

Variables and Phases	Brain Training Exercises Group	Control Group
Visual memory		
Pre-test	5.36 ± 1.31	5.20 ± 1.30
Post-test	8.73 ± 1.60	5.30 ± 1.25
Follow-up	9.00 ± 1.60	5.40 ± 1.24
Auditory memory		
Pre-test	6.20 ± 1.42	6.73 ± 1.90
Post-test	10.80 ± 1.78	6.86 ± 1.99
Follow-up	11.13 ± 1.92	7.00 ± 2.17

[a] Values are expressed as mean ± SD.

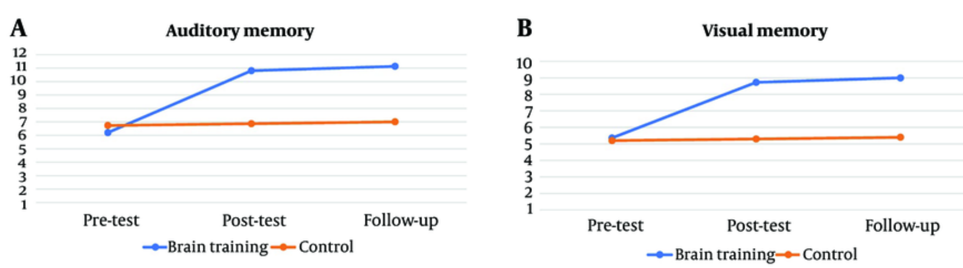

Figure 1. Comparative analysis of visual and auditory memory scores between groups across three evaluation phases

Table 2. Repeated-Measures Analysis of Variance Results for Visual and Auditory Memory

Variables and Source	SS	df	MS	F	P	η^2
Visual memory						
Time	123.58	1.26	97.99	526.64	0.001	0.92
Time × group	58.56	1.52	38.52	124.78	0.001	0.85
Group	132.50	1	132.50	12.177	0.006	0.36
Auditory memory						
Time	229.39	1.29	176.57	365.55	0.001	0.89
Time × group	108.91	1.59	68.49	86.78	0.001	0.80
Group	143.21	1	143.21	8.19	0.001	0.28

Brain training exercises can serve as an effective tool for strengthening cognitive abilities in children with various developmental disabilities, including LDs, due to the alterations they induce in the brain and nervous system. These exercises promote coordination between both hemispheres of the brain, stimulating the vestibular system by activating both motor and sensory cortices (17). This stimulation, coupled with a reduction in the fight-or-flight response, enhances students' performance in the learning process. Additionally, brain training exercises can augment blood flow and oxygen supply to the brain, leading to improvements in memory, focus, energy levels, blood pressure regulation, visual acuity, physical balance, and coordination. This cognitive training can be characterized as a process of educating both the mind and body, facilitating effective learning across a wide range of skills (16).

Impairments in visual and auditory memory significantly hinder individuals' abilities to read and spell words. Memory function is a crucial aspect of

Table 3. Bonferroni Post-hoc Comparisons for the Brain Training Group at Pre-test, Post-test, and Follow-up

Variables	Phases		Mean Difference	SE	P
Visual memory	Post-test	Pre-test	3.36	1.04	0.001
	Follow-up	Pre-test	3.63	1.11	0.001
	Follow-up	Post-test	0.26	0.84	0.534
Auditory memory	Posttest	Pre-test	4.60	0.92	0.001
	Follow-up	Pre-test	4.93	0.85	0.001
	Follow-up	Post-test	0.33	0.78	0.760

human cognitive processing, playing a pivotal role in learning and overall development (24). Brain training exercises can effectively strengthen neural pathways in the brain through the implementation of physical movements. These exercises can lead to improvements in various cognitive, psychological, and motor functions, including cognitive flexibility, self-confidence, self-esteem, coordination, communication, focus, memory, stress management, and goal attainment (16). Exercise triggers the release of neurotrophins, which play a key role in increasing hippocampal volume. Neurotrophins promote the survival and regeneration of neurons, stimulating and facilitating their growth (25). These essential substances are crucial for memory formation and retention. Consequently, enhancing neurotrophin levels through exercise leads to improvements in visual and auditory memory.

This study had several limitations. The small sample size may have limited the generalizability of the findings. Additionally, the use of convenience sampling, while practical, may have introduced potential biases into the study, as participants were not randomly selected from the larger population.

5.1. Conclusions

This study investigated the effectiveness of a brain training program in enhancing memory function among students with dyslexia. Our findings revealed statistically significant improvements in both visual and auditory memory on post-tests compared to baseline measures. These results suggest that the brain training program positively impacts these cognitive functions in this population. Future research is necessary to explore the long-term sustainability of these memory gains. Additionally, investigating the underlying mechanisms by which the program exerts its effects would provide valuable insights into the neurocognitive processes involved. Finally, comparing the efficacy of this program with other interventions for improving memory in dyslexia, such as cognitive-behavioral therapy or educational interventions, would be beneficial for establishing best practices in supporting this population.

Footnotes

Authors' Contribution: A. V. K: Study concept and design, acquisition of data, analysis and interpretation of data, and statistical analysis; F. S. M., Z. D. B: Administrative, technical, and material support, study supervision; F. H: Critical revision of the manuscript for important intellectual content.

Conflict of Interests Statement: The authors declare that they have no conflict of interests.

Data Availability: All data generated or analyzed during this study will be available from the corresponding author upon reasonable request.

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