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The Effectiveness of a Cognitive Rehabilitation Program on the Cognitive Performance of Elementary School Students with Mathematical Learning Disabilities

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ABSTRACT

The present study aimed to investigate the effectiveness of a cognitive rehabilitation program on the cognitive performance of elementary school students in the second cycle who have been diagnosed with mathematical learning disabilities. This study was applied in purpose and used a quasi-experimental method with a pretest-posttest control group design. The sampling method was convenience sampling. In this process, the researcher referred to the Hafez Educational and Rehabilitation Center for Special Learning Disorders in Shiraz and identified second-cycle elementary students who had been diagnosed with mathematical learning disabilities based on diagnostic interviews and existing documentation in their clinical files. Based on the diagnoses made by specialists at the counseling center, a total of 30 students who met the inclusion criteria were selected to participate in the study. Data collection was conducted using the Cognitive Abilities Questionnaire developed by Nejati (2013). Data analysis was performed using SPSS software through both descriptive and inferential statistics. The findings demonstrated that the cognitive rehabilitation program had a statistically significant impact on the cognitive performance of elementary students with mathematical learning disabilities.

Keywords: Cognitive rehabilitation, Cognitive performance, Mathematical learning disability.

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Introduction

A learning disorder is a neurological problem that impairs the brain's ability to receive, transmit, and process information properly (1). These children are not necessarily of low intelligence and may even be intellectually gifted, but struggle with academic skills (2). Although this disorder is not completely curable, various interventions can support these children (3).

Mathematical learning disability is a type of learning disorder that disrupts an individual's ability to process numbers and perform calculations, affecting more than six percent of students (4). These individuals may also struggle to relate numbers and symbols to quantity and direction, count money, or read a clock

(Haberstroh & Schulte-Körne, 2022). Given the widespread application of mathematics in daily life, its learning and instruction have become global educational priorities for students and teachers alike (2). It is essential to identify the causes and contributing factors of this disorder and pave the way for effective interventions. These students often experience cognitive dysfunction and disruption across multiple dimensions, including cognitive performance (5).

Cognitive performance refers to an individual's capacity to process thoughts, which should function optimally in a healthy individual. It is defined as the ability to perform various mental activities, particularly those related to learning and problem-solving (6). Poor cognitive performance is linked to inefficient learning of demanding tasks, limited short-term memory, reduced alertness, and impaired attention (7). In a study by Khan and Al-Jahadali (2023), it was found that individuals with cognitive deficits possess limited memory focus (8). Achieving optimal academic performance necessitates strong cognitive capabilities; hence, any disruption in students' cognitive abilities significantly impairs their learning (9). Specifically, students with poor cognitive functioning face difficulties in learning, as they struggle to maintain focus and demonstrate weak analytical skills, resulting in lower academic output compared to their peers (7). Therefore, it is essential to implement effective programs aimed at enhancing cognitive performance in this population.

Various programs have been introduced and confirmed to improve students' cognitive performance (10), including cognitive-behavioral therapy, self-monitoring training, motor and rhythmic interventions, and self-regulation training. Cognitive rehabilitation is another effective intervention for this population.

Cognitive rehabilitation refers to treatments and recovery strategies for cognitive impairments. It involves providing therapeutic services aimed at strengthening damaged areas or introducing new compensatory patterns, with the primary goal of improving cognitive deficiencies and functions such as memory, executive functioning, social cognition, concentration, and attention (11). This therapeutic method is based on the principles of brain neuroplasticity and includes targeted exercises to enhance various cognitive domains such as attention, memory, language, and executive functions (12). The objective of cognitive rehabilitation, grounded in cognitive sciences, is to improve or increase the efficiency of cognitive functions such as auditory discrimination, attention, visuospatial perception, accuracy, and especially working memory—highlighting the brain's adaptability (13). The cognitive rehabilitation program aims to reduce attention and learning difficulties in students with learning disorders and thus promote their academic progress (14).

Studies indicated that the tasks and exercises involved in cognitive rehabilitation stimulate auditory and visual senses, generate inter-neuronal messengers, activate cognition and memory, and induce adaptations in the central nervous system—particularly the hippocampus—resulting in improved memory, cognitive function, and academic performance in students with learning disorders (10, 13, 15).

In light of the above, the impact of cognitive rehabilitation on multiple cognitive domains and the enhancement of cognitive and academic performance in students becomes evident. This study aims to evaluate the effectiveness of the cognitive rehabilitation program on the cognitive performance of elementary school students with mathematical learning disabilities. In fact, this research seeks to answer the question: Does the cognitive rehabilitation program affect the cognitive performance of second-cycle elementary school students with mathematical learning disabilities?

Methods and Materials

Study Design and Participants

This study was applied in purpose and employed a quasi-experimental research design using a pretest-posttest structure with a control group. The statistical population consisted of second-cycle elementary school students in Shiraz who had been referred to the Hafez Educational and Rehabilitation Center for Special Learning Disorders.

Regarding sample selection, based on the recommendation by Delavar (2006), a sample size of 15 participants per group is sufficient to yield statistically valid results in quasi-experimental research. Therefore, the sampling method used in this study was convenience sampling. The researcher visited the Hafez Educational and Rehabilitation Center for Special Learning Disorders in Shiraz and identified second-cycle elementary students diagnosed with mathematical learning disabilities based on clinical interviews and the documentation in their medical files. Based on expert diagnosis from the counseling center, 30 students who met the inclusion criteria were selected to participate in the study. These students were then randomly assigned to an experimental group (n = 15) and a control group (n = 15).

The inclusion criteria were: informed consent for participation in the study, diagnosis of mathematical learning disability, and enrollment in the second cycle of elementary school. The exclusion criteria were: missing more than one session of the intervention, incomplete or inaccurate responses to the distributed questionnaires, and lack of cooperation with the trainer or failure to complete the assigned tasks.

A formal letter from the Islamic Azad University, Marvdasht Branch, was submitted to the Hafez Educational and Rehabilitation Center for Special Learning Disorders in Shiraz. Upon obtaining permission, the researcher proceeded to identify second-cycle elementary students who had been diagnosed with mathematical learning disabilities. Thirty students were selected through convenience sampling and randomly assigned to the experimental group (n = 15) and the control group (n = 15). The Cognitive Abilities Test (CAT-2013) by Nejati was administered to both groups during the pretest phase. Subsequently, the cognitive rehabilitation intervention was implemented for the experimental group over the course of 10 sessions. Each session lasted between 90 and 120 minutes and was held once per week. Upon completion of the intervention, the questionnaire was re-administered to both the experimental and control groups as a posttest.

Data Collection

Cognitive Abilities Test (CAT): The Cognitive Abilities Test developed and validated by Nejati (2013) consists of 30 items designed to assess individuals' cognitive abilities. This questionnaire includes seven subscales: memory, selective attention and inhibitory control, decision-making, planning, sustained attention, social cognition, and cognitive flexibility. Responses are based on a five-point Likert scale ranging from "almost always" to "almost never," scored from 1 to 5. Nejati (2013) reported the reliability of the instrument with a Cronbach's alpha coefficient of 0.83 and confirmed its face and content validity (16).

Intervention

The ARAM cognitive rehabilitation program, developed by the Institute for Cognitive Science Studies at Shahid Beheshti University and adapted from the study by Alipanah et al. (2022), consists of ten structured computerized sessions designed to strengthen various cognitive abilities in children with mathematical learning disabilities (4). Each session targets specific cognitive domains through engaging and progressively challenging tasks. In session 1 ("Colorful House"), sustained and selective attention are trained by identifying target houses among distractors. Session 2 ("Faces") enhances multiple attention functions by matching facial features under time constraints. Sessions 3 to 5 focus on visuospatial working memory through interactive memory grids, image recognition, and visual reconstruction tasks. Session 6 ("Acronym Formation") trains phonological span and inhibitory control by prompting participants to select words based on displayed acronyms. Sessions 7 to 9 focus on updating ability through color sequence recall, tracking animal movement in a grid based on directional arrows, and detecting repeated images. Finally, session 10 ("Word Matching") strengthens phonological span and inhibitory control by comparing the ending letter of one word to the beginning letter of the next. Each task is presented in a gamified format, with adaptive difficulty to ensure continuous cognitive engagement and development.

Data analysis

For data analysis, descriptive statistics including mean, standard deviation, frequency, and percentage were used to report research findings. For inferential statistics, analysis of covariance (ANCOVA) was applied using SPSS version 26.

Findings and Results

Table 1 presents the descriptive statistics, including mean and standard deviation of cognitive performance scores, separately for the experimental and control groups across the two measurement stages (pretest and posttest). As observed, in the control group, the mean scores show little variation between the pretest and posttest stages. However, in the experimental group, a considerable increase in scores is observed in the posttest compared to the pretest.

Table 1. Descriptive Statistics of Cognitive Performance Scores

Group	Variable	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD
Control	Memory	6.20	2.651	6.60	2.947
	Selective Attention & Inhibitory Control	7.47	2.900	7.93	2.658
	Decision-Making	8.24	3.140	8.09	2.435
	Planning	6.13	3.021	6.44	2.960
	Sustained Attention	7.11	2.386	7.67	2.320
	Social Cognition	5.32	1.646	5.21	1.472
	Cognitive Flexibility	6.67	1.877	6.10	2.193
	Cognitive Performance (Total)	47.14	8.914	48.04	7.752
Experimental	Memory	6.93	2.987	9.16	2.949
	Selective Attention & Inhibitory Control	7.67	3.498	10.27	3.283
	Decision-Making	7.11	3.812	9.86	2.854
	Planning	6.73	2.604	8.31	2.987
	Sustained Attention	7.27	2.549	9.03	2.588
	Social Cognition	5.90	1.775	8.16	2.129
	Cognitive Flexibility	6.13	1.922	9.13	2.386
	Cognitive Performance (Total)	47.74	9.056	63.92	8.390

To examine the effect of the cognitive rehabilitation program on the cognitive performance of second-cycle elementary students with mathematical learning disabilities, multivariate analysis of covariance (MANCOVA) was used. The results of this analysis are presented below. It is worth noting that all assumptions of covariance analysis were confirmed, allowing for the use of MANCOVA.

Table 2. MANCOVA Results Comparing Cognitive Performance Between Experimental and Control Groups

Effect	Test Statistic	Value	F	df Effect	df Error	Sig. Level	Effect Size
Group	Pillai's Trace	0.734	5.903	8	16	0.002	0.734
	Wilks' Lambda	0.266	5.903	8	16	0.002	0.734
	Hotelling's Trace	2.755	5.903	8	16	0.002	0.734
	Roy's Largest Root	2.755	5.903	8	16	0.002	0.734

As shown, the significance levels for all four multivariate statistics—Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root—are less than 0.01 ($p < .01$). Thus, the null hypothesis is rejected, indicating a significant difference in cognitive performance between the experimental and control groups in the posttest stage. This supports the conclusion that the cognitive rehabilitation program was effective.

To examine differences between the experimental and control groups for each component of cognitive performance, between-subjects effects tests were used. The results are shown below.

Table 3. Between-Subjects Effects Test Comparing Cognitive Performance Components in the Posttest

Variable	Source	SS	df	MS	F	Sig. Level	Effect Size
Memory	Between	55.678	1	55.678	10.736	0.004	0.338
	Error	108.905	21	5.186			
Selective Attention & Inhibitory Control	Between	46.988	1	46.988	9.040	0.007	0.301
	Error	109.149	21	5.198			
Decision-Making	Between	13.657	1	13.657	5.840	0.025	0.218
	Error	49.114	21	2.339			
Planning	Between	50.738	1	50.738	6.664	0.017	0.241
	Error	159.881	21	7.613			
Sustained Attention	Between	61.222	1	61.222	11.818	0.002	0.360
	Error	108.789	21	5.180			
Social Cognition	Between	39.846	1	39.846	12.898	0.002	0.380
	Error	64.874	21	3.089			
Cognitive Flexibility	Between	52.372	1	52.372	10.686	0.004	0.337
	Error	102.918	21	4.901			
Total Cognitive Performance	Between	197.992	1	197.992	13.143	0.001	0.336
	Error	391.683	26	15.065			

Table 3 presents the results of the between-subjects effects test for comparing the components of cognitive performance between the experimental and control groups during the posttest phase. As the results indicate, the obtained F-values for all components are statistically significant at the 0.05 alpha level ($p < .05$). Therefore, the null hypothesis is rejected, and the research hypothesis is supported. Given the higher mean scores of the experimental group in the posttest compared to the control group, it is concluded that the cognitive rehabilitation program was effective and led to an improvement in cognitive performance among second-cycle elementary school students with mathematical learning disabilities.

Discussion and Conclusion

Findings indicate that the cognitive rehabilitation program had a statistically significant effect on cognitive performance in second-cycle elementary school students with mathematical learning disabilities. Specifically, the results demonstrated that participants experienced a considerable and significant improvement in their cognitive functioning following the implementation of the cognitive rehabilitation program.

Regarding the significance of the cognitive rehabilitation program's impact on cognitive performance among students with mathematical learning disabilities, research evidence supports these results. The findings align with prior findings (7, 9, 12-14, 17-19).

In explaining the impact of cognitive rehabilitation on the cognitive performance of students with mathematical learning disabilities, it can be stated that Sun et al. (2023) emphasized that any improvement in the learning of such students depends on enhancing their cognitive functions—especially attention, memory, analysis, and reasoning. This improvement can be facilitated through structured interventions like cognitive rehabilitation (9). This therapeutic approach is based on the principles of neuroplasticity, incorporating targeted exercises to enhance various cognitive domains such as attention, memory, language, and executive functioning. These processes ultimately lead to improved cognitive performance and deeper learning outcomes for students (12).

Haberstroh and Schulte-Körne (2022), in their study on the cognitive functioning of students with mathematical learning disabilities, reported that cognitive impairment in these students is more pronounced, significantly diminishing their learning capacity. They asserted that designing and implementing programs such as cognitive rehabilitation enhances the cognitive abilities of students with learning disorders (19). This not only improves their academic learning but also makes school participation and homework completion more enjoyable. The program enhances children's cognitive functioning by improving the retention of symbols and signs, boosting numerical calculation skills, and facilitating better retrieval and analysis of information from active sensory and short-term memory. This leads to the resolution of cognitive processing limitations in reading, writing, and arithmetic (18).

Milow et al. (2022) also examined cognitive performance and its relationship to learning in students with learning disabilities, confirming the necessity of improving cognitive functioning in order to enhance learning outcomes. They demonstrated that programs focusing on strengthening the neural and cognitive systems—such as cognitive rehabilitation—not only improve cognitive performance but also increase both the quantity and quality of learning.

This intervention engages all of the individual’s senses during the learning process and reinforces cognitive functions such as attention and reasoning, thereby supporting improvements in executive functions including memory and overall cognitive performance (13). The cognitive-neurological nature of the program strengthens cognitive functions in children with learning disabilities, enhancing their focus and concentration and allowing for better depth and quality of learning. Thus, the positive effect of cognitive rehabilitation on strengthening cognitive performance and learning ability is supported by empirical evidence. Fouladvand et al. (2023), in another study, found that students with poor cognitive functioning face significant learning difficulties. These students struggle with attention, concentration, and analysis, which results in lower academic performance compared to their peers (7). The researchers concluded that specific educational and therapeutic programs, such as cognitive rehabilitation, can improve cognitive functioning and thereby enhance academic achievement.

The primary focus of cognitive rehabilitation is to treat or compensate for cognitive impairments. The foundation for improving these deficits lies in the brain's neuroplasticity. According to this principle, cognitive rehabilitation enhances synaptic connectivity between neurons and restores impaired cognitive functions (4). Cognitive rehabilitation approaches target a range of deficits, including attention control, working memory, spatial ability, and inhibitory control. Such interventions are often computer-based and employ adaptive procedures whereby task difficulty automatically increases throughout the treatment sessions, continuously challenging the individual's performance. On the other hand, cognitive rehabilitation can restore impaired cognitive performance in individuals with mathematical disabilities through repetition and practice-based learning strategies (9).

Cognitive rehabilitation is essentially a structured set of educational practices grounded in cognitive functioning, with a strong emphasis on improving attention and enhancing the ability to recall daily activities (17). Since all learning and instructional processes necessary for mathematical problem-solving are inherently linked to cognitive skills, it appears that cognitive rehabilitation can effectively improve cognitive performance in this population. Cognitive training affects both cognition and behavior because it focuses on the underlying mental processes and strengthens the foundational abilities necessary for subsequent learning. Their findings demonstrated that the continuation and consistency of cognitive rehabilitation improve the mental capabilities of individuals with mathematical disabilities, and those with cognitive impairments benefit from cognitive rehabilitation interventions.

This study was conducted exclusively in the city of Shiraz, which limits the generalizability of the findings to other cultural and geographical contexts. Additionally, the research sample included only second-cycle elementary school children, making it difficult to extend the results to students of other educational levels and age groups. Moreover, the study focused solely on students with mathematical learning disabilities, thereby restricting its applicability to individuals with other types of learning disorders. Another limitation concerns the lack of gender segregation; although both boys and girls participated, the absence of control over gender as a potential confounding variable may have affected the internal and external validity of the findings.

Future research is encouraged to explore the effectiveness of the cognitive rehabilitation program on cognitive performance and academic engagement among students with mathematical learning disabilities in different cultural and educational contexts. Studies could also examine this program across all primary school grades, including sixth grade and lower and upper secondary levels. From a practical standpoint, it is recommended that school counselors and therapists working with students with cognitive and academic impairments apply this rehabilitation protocol to enhance academic achievement and functional role fulfillment. Furthermore, training parents to implement the program at home through structured play could facilitate consistent intervention, improve children’s functioning in daily life, and reduce parental challenges in managing cognitive-behavioral difficulties.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. Written consent was obtained from all participants in the study.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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