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Investigating the Effectiveness of Cognitive Rehabilitation on the Executive Functions of Students with Specific Learning Disorder

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ABSTRACT

The present study was conducted to investigate the effectiveness of cognitive rehabilitation on the executive functions (behavioral and cognitive regulation) of students with specific learning disorder. The research method was experimental with a pre-test-post-test design and a control group. The statistical population of the research was made up of all the students with specific learning disorder who referred to the learning disorders center of Ardabil in the academic year of 2021-2022, from which 40 students were selected using the available sampling method. Then, they were randomly replaced in the experimental group (20 participants) and the control group (20 participants). The experimental group was exposed to cognitive rehabilitation intervention for 11 sessions. To collect data, the behavioral rating questionnaire of Gioia et al. (2000) was used. The data were analyzed through the analysis of covariance statistical test. The findings showed that cognitive rehabilitation intervention improved executive functions (behavioral and cognitive regulation) in students with specific learning disorder of the experimental group ($P<0.01$). Considering the effect of cognitive rehabilitation intervention in students with special learning disorder, schools and counseling centers can use this type of treatment in working with these children to improve their executive functions (behavioral and cognitive regulation).

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Introduction

Among childhood developmental disorders, specific learning disorder is one of the most common (Robertson et al., 2019) refering to defects in which the affected child is at a lower level in terms of acquiring the expected skills of reading, writing, speaking, or mathematics than children of the same age and with appropriate intellectual capacity.

Up to now, several definitions of learning disorders have been provided (Maleki Aghjehkandi et al., 2021). According to the fifth diagnostic and statistical manual of mental disorders, a learning disorder is diagnosed when a person has a deficit for at least six months in one of the following cases (incorrect or slow reading of words, understanding the meaning of what is read, spelling, written expression, calculation, and mathematical reasoning). The person has a problem and these abilities are much lower than what is expected from a person according to their chronological age and significantly interfere with the daily life activities and educational progress of the person (Georgan et al., 2023). In fact, learning disabilities is a general term for a heterogeneous group of disorders that manifest through obvious problems in acquiring and using listening, speaking, reading, writing and reasoning skills or mathematical skills. A learning disability is a disorder in one or more basic psychological processes that causes difficulty in understanding or using spoken or written language and may be in the form of an incomplete ability to listen, think, speak, read, write, spell words, or it might appear in mathematical calculations (Mattison et al, 2023).

There is evidence that shows children with learning disabilities have deficits in executive functions (Crisci et al., 2023). In fact, one of the neurocognitive problems in which children with learning disabilities are weak is executive functions (El Wafa et al., 2020). During the last decade, increasing attention has been paid to the field of executive functions in children. Executive functions have traditionally been defined as an umbrella term for functions such as planning, working memory, impulse control, inhibition, attention shifting, as well as initiation and organization of action. Historically, these functions are related to the frontal structures of the brain and specifically to the prefrontal cortex (Machado et al., 2021). Executive functions are a set of abilities that are necessary to implement and control efficient, purposeful and forward-looking behavior in an environment with continuous changes (Serpell & Esposito, 2016). This term includes the control and coordination of cognitive operations and has a vital meaning in today's neuropsychology. The concept of executive functions refers to high-level control processes used to guide behavior in various environments (Sosic-Vasic et al., 2017).

Cognitive rehabilitation is one of the effective solutions in improving the symptoms of specific learning disorder (Aghaei Sabet et al., 2020;Ahn & Hwang,2017). Cognitive rehabilitation intervention refers to all training based on the integration of the findings of cognitive neuroscience and information technology on the basis of the principle of neural flexibility (Irazoki et al., 2020). It is used to improve mental abilities in the field of cognitive functions including perception, attention, alertness, memory, etc. (Owen et al., 2010). Cognitive rehabilitation intervention is a special and unique treatment focusing solely and mainly on cognitive abilities (Balea et al., 2018). There are two basic methods of cognitive rehabilitation: restorative rehabilitation method (in which mental deficits are repaired by various repeated exercises) and compensatory method (in which adaptive strategies and tools are used to modify the environment despite the progressing deficits and to compensate for the functions). These two techniques can be used together and can be elements of a comprehensive multidisciplinary rehabilitation program that includes other types of psychosocial treatment and rehabilitation (Hayes, 2015).

Yavari et al. (2022) in a research titled ‘Investigating the effectiveness of cognitive rehabilitation on the executive functions (response inhibition and planning) of children with attention deficit hyperactivity disorder’ came to the conclusion that this type of training affects response inhibition and planning of children with attention/hyperactivity deficit disorder. Javadzadeh et al. (2022) in a research entitled ‘Effectiveness of Baran's cognitive rehabilitation program on the executive functions of high-functioning children with autism’ investigated the effect of cognitive programs on executive functions and concluded that this type of training improves working memory, stable attention and cognitive flexibility of children. Sadeghi et al. (2017) in their research concluded that cognitive skills training was effective on executive functions and cognitive abilities of children with learning disabilities. Moreover, Krebs et al. (2021) in a research on the effects of cognitive training on healthy elderly people with low cognitive function found that brain stimulation in this way improves cognitive function. Wiest et al. (2020) in their study on the effectiveness of computer-based cognitive training on working memory in a school environment concluded that auditory working memory ability improved via this training program.

regarding the literature, it is necessary to carry out effective interventions to improve executive functions. However, the studies conducted in the field of executive

functions training have been done mostly among high school students and in a more limited way on middle school students. Considering the key role of these functions in students' future education, and the point that if they are not addressed, students will be at risk of adult illiteracy, it is necessary to examine this issue among elementary school students as well. Therefore, the present research was conducted to investigate whether cognitive rehabilitation intervention is effective on the executive functions (behavioral and cognitive regulation) of students with specific learning disorders.

Method

Design

The current research is practical in terms of its purpose, and in terms of method, it is experimental with a pre-/post-test design and a control group.

Participants

The statistical population of the current study included all elementary school students with specific learning disorders who referred to the learning disorders center in Ardabil in the academic year of 2021-2022. To select a sample from the statistical population, 40 students with specific learning disabilities were selected through available sampling. After that, these 40 students were randomly replaced in the experimental (20 participants) and the control (20 participants) groups. Gal et al. (2007) believed that for the validity and generalizability of an experimental research, the sample size should be at least 30 people in the two experimental and control groups. Of course, if there were a drop in the experimental group, the same number of people would be removed from the control group. In this study, all the students participating in the experimental group participated in the meetings due to ethical considerations and the consent with the researcher, and for this reason, there was no dropout. At the beginning of the study, the consent of all the participants to participate in the research was obtained. It should be noted that the participants in the experimental and the control groups were matched in terms of educational and family status. The criteria for entering the research included: being primary school students, having visited the learning disorders center and diagnosed as having learning disorders and having a file in this center, having the ability to regularly participate in the meetings, and they should not use psychiatric medication during the treatment (according to the parents' questions), passing at least six months from their psychotherapy and drug therapy (if they had it before), and having consent to participate in the sessions. The exclusion criteria were the participants' lack of satisfaction and inability to participate in the meetings.

Instruments

Gioia et al. (2000) Behavioral Rating Questionnaire of Executive Functions: Behavioral rating questionnaire of executive functions is the best checklist for measuring and screening executive functions in primary school children, which was compiled by Gioia et al. (2000) and has two dimensions. It has a teacher and parent form with 86 questions. The time required to complete this questionnaire is 10 to 15 minutes, and the parent or teacher should mark the option of never = zero, sometimes = 1 and always = 2 in response to the options related to the child. In this questionnaire, getting a high score means fewer executive functions and getting a low score means more executive functions. In order to interpret behavior, this questionnaire measures executive function: planning (15 questions), inhibition (14 questions), attention transfer (11 questions), working memory (11 questions), emotional control (10 questions), control (9 questions), organization of materials (8 questions) and initiation (8 questions). The results of these eight domains are summarized in two overlapping indicators: behavior regulation skills (inhibition, attention transfer, emotional control) and cognitive skills (planning, working memory, supervisory control, material organization, initiation). In Shahabi's research, the validity and reliability of the questionnaire was measured, and the test-retest reliability coefficient of the subscales of this questionnaire was: attention transfer: .81, emotional control: .91, initiation: .80, working memory: .71, planning: .81, material organization: .79, supervision control: .78, behavior adjustment index: .90, cognitive index: .87 and the overall score of executive functions was obtained to be .89. The internal consistency coefficient for this questionnaire was from .87 to .94, indicating the high internal consistency of all subscales of the questionnaire (Nodeei et al., 2015).

Procedure

After obtaining the necessary permits, the researcher appeared in person at the learning disorders center and selected 40 students who had been diagnosed with learning disorders and replaced them in the experimental and the control groups. After the pre-test, the experimental group received cognitive rehabilitation for 11 sessions and each session, they used working memory training software up to 60 minutes, but the control group did not receive any training and continued with their normal routine. At the end, a post-test was taken from both groups. The working memory training

software was prepared in 2019 under the supervision of psychology professors of Ferdowsi University of Mashhad and in cooperation with Sina Behavioral-Cognitive Sciences Research Institute. Also, based on the existing theories, modeling Robommo software (Klingberg et al., 2005) and adaptation to Iranian culture, its content validity was confirmed. This software offers the user exercises in the three parts of auditory, visual, and spatial memory (fixation) separately using numbers, letters, and shapes. The degree of difficulty in each exercise is classified from one to nine, and the user can choose the degree of difficulty s/he wants at the beginning of each exercise and start his exercise from that degree of difficulty. But after starting the training, the degree of difficulty is automatically increased and it provides the possibility of using the maximum memory capacity for more training and increasing the memory level. The level of difficulty of the tasks is designed in such a way that as the participants' skills improve, the tasks become progressively more difficult (the tasks are adjustable). On the left side of the screen, the point bar shows the amount of points earned as the feedback from the exercise for the user, and for each correct attempt, twenty points are added to their points, and for each wrong attempt, ten points are deducted, and if the participants obtains 100 points, the level of difficulty of the exercise increases by one degree (Hamzelou et al., 2013). The software affects the ability of a person's working memory by using the method of positive reinforcement, as well as repetition and practice and visual and auditory sensory stimulation. Over time, a person learns how to use his/her senses and mental space to keep more numbers and letters in their mind.

Table 1.
Summary of Cognitive Rehabilitation Sessions

1	Introducing and establishing a cordial relationship with the students, introducing the students to the computer and teaching them how to work with the mouse and explaining the different parts of the software.
2	Reinforcing forward visual memory up to three numbers and letters. In this way, the students saw a letter or number on the screen and after it disappeared or remembered the number or letter seen, they chose the previously seen letter or number from the nine houses. The students memorized this exercise up to three numbers and letters forward.
3	Reinforcing forward visual memory up to six numbers and letters. The assignments were the same as the second session, only the number of numbers and letters seen was up to six.
4	Reinforcing reverse visual memory up to three numbers and letters. In this way, the students saw a letter or number on the screen and after it disappeared, by remembering the number or letter seen, they chose the previously seen letter or number among the nine. The students remembered this exercise up to three numbers and letters in reverse.
5	Reinforcing reverse visual memory up to six numbers and letters was done. The assignments were the same as the fourth session, only the number of numbers and letters seen was up to six numbers or letters.
6	Reinforcing forward auditory memory up to three numbers and letters. In this way, the students heard a letter or number on the screen and after it disappeared by remembering the heard number or letter, they chose the previously heard letter or number from the nine parts. The students memorized this exercise up to three numbers and letters forward.
7	Enhancing auditory memory up to six letters and zeros. The assignments were the same as the sixth session, only the number of numbers and letters heard was up to six.
8	Reinforcing reverse auditory memory up to three numbers and letters. In this way, the students heard a letter or number from the computer, and after the sound stopped, by remembering the heard number or letter, they chose the previously heard letter or number from the nine houses. The students remembered this exercise up to three numbers and letters in reverse.
9	Reinforcing reverse auditory memory up to six letters and zeros. The assignments were the same as the eighth session, only the number of numbers and letters heard was up to six numbers and letters.
10	Consolidatingvisual and auditory memory in such a way that first the students saw a letter or number on the screen, then they remembered the correct location of the observed letter or number among the nine houses.
11	Consolidating reverse visual and auditory memory. The tasks were similar to the 10th session, with the difference that the students recalled the location of the seen and heard numbers and letters in a reverse order.

Findings

Table 2.
Descriptive Statistics of Executive Functions

Variable	Components	Level	Groups			
			Experiment		Control	
			M	SD	M	SD
Executive functions	**behavior regulation**	**pre-test**	60.50	1.70	60.45	1.88
		Post-test	56.30	2.75	60.35	2.48
	cognitive	**pre-test**	85.65	1.22	85.60	2.04
		Post-test	79.90	2.29	85.65	2.06
	Total	**pre-test**	146.15	2.08	146.05	1.88
		Post-test	136.20	3.36	146.00	2.77

As seen in Table 2, the mean and standard deviation of the components of executive functions for the students of the experimental and control groups are shown in the pre-test and post-test stages. Univariate covariance analysis was used to test the hypothesis regarding the total score of executive functions. Analysis of covariance is a statistical method used to adjust the initial differences of the participants. In this way, each of the scores in the pre-test is used as a covariate in the post-test scores. In covariance analysis, it is necessary to comply with some assumptions (such as the normality of data distribution, the homogeneity of the slope of the regression line, and the homogeneity of error variances). In this research, these assumptions were investigated first, and then since these assumptions (checking the normality of the data distribution with the Kolmogorov-Smirnov test: $P<0.05$, homogeneity of the slope of the regression line: $P<0.05$, $F=0.04$, and the homogeneity of error variances: $P < 0.05$, $F = 2.67$) were maintained, the univariate covariance analysis was used to compare the average scores of executive functions in the experimental and control groups, the results of which are shown in the following table.

Table 3.
Covariance Analysis to Compare the Average Scores of Executive Functions of the Experimental and Control Groups

Source of changes	SS	df	MS	F	sig	ES
Pre-test	167.83	1	167.83	32.11	0.001	0.46
Group	980.62	1	980.62	187.63	0.001	0.83
Error	193.370	37	5.23			

As shown in Table 3 ($p<0.01$, $F=187.63$), after adjusting the pre-test scores, the difference between the experimental and control groups is significant at the alpha level of 0.01; therefore, the hypothesis of the research is confirmed revealing the effectiveness of cognitive rehabilitation on the executive functions of students with specific learning disorders and the difference between the experimental and control groups in terms of the amount of executive functions in the post-test.

Moreover, the multivariate covariance analysis was used to test the hypothesis regarding the components of executive functions. In multivariate covariance analysis, it is necessary to observe some assumptions (normality of score distribution, homogeneity of error variances, homogeneity of variance-covariance matrices). In this research, these assumptions were investigated first. In checking the normality of the distribution of scores, the results of the Kolmogorov-Smirnov test showed that the distribution of the scores of the research variables in the pre-test and post-test stages is normal. In order to check the homogeneity of error variances, Levin's test was used, the results of which (behavior regulation: $F=1.65$, $Sig=0.21$, cognitive: $F=1.35$, $Sig=0.25$) showed the homogeneity of error variances. . Also, in order to check the hypothesis of homogeneity of variance-covariance matrices, M-box test was used ($Box=0.77$, $F=0.24$, $Sig=0.87$) whose significance level is greater than 0.05 and hence, the hypothesis of homogeneity of variance matrices was confirmed. Therefore, multivariate covariance analysis was used to investigate the research hypotheses, the results of which are presented in the following tables.

Table 4.
Multivariate Covariance Analysis to Compare the Average Scores of the Components of Executive Functions (Behavioral and Cognitive Regulations) of the Experimental and the Control Groups

Tests	Amounts	F	df hypothesis	df error	SL	ES
Pillai's Trace	0.84	90.72	2	35	0.001	0.84
Wilks Lambda	0.16	90.72	2	35	0.001	0.84
Hoteling's Trace	5.18	90.72	2	35	0.001	0.84
Roy's Largest Root	5.18	90.72	2	35	0.001	0.84

As the Table shows, the result of multivariate covariance analysis indicates that all four statistics, Pillai's effect (P<0.01, F=90.72), Wilks's lambda (P<0.01, F=90.72), Hotelling's effect (P<0.01, F=90.72) and the Roy largest root (P<0.01, F=90.72) are significant. In this way, it is clear that the linear combination of the dependent variables, after adjusting the initial differences, are affected by the independent variable. In other words, the results of multivariate covariance analysis show that cognitive rehabilitation has been effective on the linear combination of dependent variables and there is a significant difference between the groups. Therefore, using univariate covariance analysis, the research hypotheses were examined to find out where the difference observed in the linear combination is related.

Table 5.
Covariance Analysis to Compare the Average Scores of the Behavioral and Cognitive Adjustment Components of the Experimental and Control Groups

Components	Source of changes	SS	Df	MS	F	sig	ES
behavior regulation	**Pre-test**	175.37	1	175.37	87.01	0.001	0.71
	Group	169.67	1	169.67	84.18	0.001	0.70
	Error	72.56	36	2.02			
cognitive	**Pre-test**	60.45	1	60.45	21.20	0.001	0.37
	Group	334.36	1	334.36	117.25	0.001	0.76
	Error	102.66	36	2.85			

As can be seen in Table 5, there is a significant difference between the experimental and control groups in the behavior regulation component (F=18.84; P<0.01) and the cognitive component (F=117.25; P<0.01). Therefore, the research hypotheses are confirmed ponting to the effectiveness of cognitive rehabilitation on the components of behavioral and cognitive regulation of executive functions of students with specific learning disorders and the difference between the experimental and control groups in terms of the components of executive functions.

Discussion

The results of the study showed that there was a significant difference between the adjusted averages of the students with specific learning disorders of the experimental and control groups in terms of executive functions (behavioral and cognitive regulation). In this way, cognitive rehabilitation intervention caused a significant increase in the executive functions (behavioral and cognitive regulation) of the students with specific learning disorder in the experimental group. Therefore, the research hypotheses were confirmed.The findings of the present research are consistent with the findings of Barhaq Talab et al. (2022), Javadzadeh et al. (2022), Sadeghi et al. (2017) and Wiest et al. (2020).

In explaining these findings, it can be stated that the main focus of cognitive rehabilitation is on the treatment or compensation of cognitive disabilities. The basis of improving cognitive defects through cognitive rehabilitation is the brain's neuroplasticity. Based on this feature, cognitive rehabilitation intervention increases the synaptic connections between neurons and improves the lost cognitive function. Cognitive rehabilitation approaches have targeted domains of deficits (attention control, working memory, spatial ability and inhibitory control). Such training is generally conducted via computers using adaptive procedures whereby task difficulty is automatically increased throughout therapy

sessions and clients' performance is continually challenged. On the other hand, the cognitive rehabilitation program can restore the damaged functions through repetition and practice training strategies (Abaziri et al., 2018).

In fact, cognitive rehabilitation is a structured set of educational measures based on memory skills and cognitive functions that emphasize on strengthening attention and the ability to remember everyday activities. Since all the processes related to teaching and learning that are necessary in performing tasks requiring cognitive skills, it seems that the use of cognitive rehabilitation can be effective. According to the results obtained in this research, it can be said that despite the fact that executive functions have a biological and neuropsychological basis and are generally related to the prefrontal cortex of the brain, education and learning can be effective in improving them which shows the flexibility of executive functions. It is also a significant role that these functions play in academic progress. The functions considered in this research, especially attention and active memory, are among the most important effective factors in learning; thus, by improving them as a result of teaching executive functions, we can expect academic improvement (Azizian et al., 2016).

Conclusions

Cognitive rehabilitation is actually a kind of learning experience aimed at restoring brain functions that have problems and improving performance in real life. Cognitive rehabilitation is a treatment method whose main goal is to improve cognitive function and defects such as memory, executive functions, social understanding, concentration and attention. Cognitive rehabilitation therapy is a special and unique type of therapy in that it focuses solely and mainly on cognitive abilities (Wood & Fossey, 2018).

Since the cognitive ability of students with a specific learning disorder is damaged, cognitive rehabilitation can play an effective role in its improvement and promotion (Radfar et al., 2016). During the cognitive rehabilitation intervention, cognitive trainings are provided, which based on the principle of brain flexibility, directly target the cognitive deficits of these children. Moreover, in the intervention sessions, exercises related to strengthening executive functions such as attention, concentration and memory skills, and exercises to strengthen the skills Verbal and time-chaining manipulative skills, which led to the improvement of executive functions of children with learning disabilities. Cognitive rehabilitation intervention is based on the principle of neuroplasticity (Troll et al., 2008), used to improve mental abilities in the field of cognitive functions, including perception, attention, alertness, memory, etc. (Owen et al., 2010).

These abilities are also an important part of executive functions. Therefore, cognitive rehabilitation is effective in improving executive functions by improving mental and cognitive abilities. In general, cognitive rehabilitation improves executive functions, which include various abilities such as working memory, response inhibition, planning, and mental organization, enabling decoding, fluency reading, and understanding (Merrick et al., 2015). Different studies show that students with learning disabilities have impaired executive functions compared to students without learning disabilities (Yousfi et al., 2016).

Executive functions are the processes that control, direct and coordinate other cognitive processes. These functions include all the complex cognitive processes necessary to perform difficult or novel purposeful tasks. Therefore, considering the importance of executive functions and its key role in learning reading skills, it can be expected that effective interventions on executive functions will affect the learning progress of students with specific learning disorders. Overall, the results of this study showed that the intervention of cognitive rehabilitation in children with specific learning disorder is associated with the improvement of executive functions.

This research suffered from some limitations such as the fact that data collection was done based on self-reporting scale, whose reports are susceptible to distortion due to unconscious defenses, response bias and personal introduction methods. In this research, the effect of cognitive rehabilitation in a follow-up period has not been determined, and therefore, there is no information about the continuity of the change on the executive functions of the students with specific learning disorders. Therefore, it is suggested to use other data collection methods such as interviews in future researches. The follow-up phase should be included in the next studies to ensure the certainty of the effectiveness of the cognitive rehabilitation program in a long period of time. It is suggested that such interventions and trainings be taught to parents of students with learning disabilities so that they can be used in their practices.

Conflicts of Interest

No conflicts of interest declared.

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