The Effectiveness of Neurofeedback Therapy on Sustained Attention of Dyslexic Students

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Abstract
This study aimed to evaluate the effectiveness of neurofeedback therapy on sustained attention of dyslexic students. The research method was quasi-experimental, pretest-posttest with a control group, and 1-month follow-up. The available sample selection method and the sample number of 30 students with dyslexia were selected and randomly divided into experimental and control groups. The experimental group received neurofeedback treatment in 8 sessions once a week. The research instruments used in this study were Karami, Nouri, and Moradi's (2005) reading performance questionnaire and sustained attention to continuous performance test (Rosvold, 1956). The results of repeated measures analysis of variance showed that neurofeedback treatment was effective on sustained attention ($P < 0.05$) .Therefore, it can be concluded that neurofeedback therapy can be used to increase sustained attention in dyslexic children.

Keywords: Neurofeedback treatment, sustained attention, dyslexia

Introduction

Among learning disorders, reading difficulties are one of the most common student disorders. The International Association of Dyslexia [1] identifies this problem as a special learning disorder of neuropsychological origin; Has defined. Dyslexia is a disorder in mispronouncing similar words, guessing words by considering the letters at the beginning and end, mirroring or reading words upside down, severe spelling problems, reluctance, and aversion to learning to read [2,11-18]. Approximately 80% of students with learning disabilities have difficulty reading. The prevalence of disability is reported to be 8.2% in male students and 2% in female students. Also in Iran, reading disorder in the second, third, fourth and fifth grades of elementary school respectively 10.8%, 5.9%, 8.2%, 6.9% in boys and 5.9%, 4.4%, 3.5%, 2.8% in girls reported [1].

Experts in the field of learning disabilities have listed a variety of reasons for the etiology of reading disorders. In general, the main causes of dyslexia are poor auditory perception, poor visual and auditory processing, inability to understand words, inability to pay attention to important aspects of words, sentences, and paragraphs, and inability to understand the unit of speech represented by letters. Researchers state that defects in temporal lobe processing are the cause of phonological disorders seen in dyslexic children, and the evaluation and judgment functions performed on the surface of this lobe are reported to be weaker than usual in this group [3,18-25].

Most abnormalities seen in the brain of dyslexics are concentrated in areas related to phonological processing. These areas are located in the left hemisphere of the brain. According to Arns et al. [4,5,26-32], dyslexic children have higher slow-wave activity (delta, theta) in the temporal and frontal regions of the brain. In a study, Walker and Norman [6,33-37] examined the difference between QEEG in dyslexic children and normal children and taught them EEG abnormalities with neurofeedback. This study was performed on 12 dyslexic children for 30 to 35 sessions. The researchers increased the activity of 18-16 Hz in the T3 region (left middle temporal region) and

proved that this method can improve the reading speed and comprehension of dyslexic children.Most current corrective strategies for children with reading disorders focus on direct instructions on the various components of reading.Many effective treatment programs begin with teaching how to communicate letters and sounds correctly. Neurofeedback is used to alter brain function by altering the pattern of brain waves; In fact, this method of factor conditioning is performed on the EEG, which ultimately affects the self-regulatory system and leads to lasting changes in brain function. Neurofibrillation refers to a form of active conditioning of the brain's electrical activity that rewards the brain's optimal activity and inhibits the brain's undesirable activity. Neurofeedback is believed to stimulate growth and alter brain cell levels, which in turn support brain function and cognitive-behavioral function [1,38-40]. In a study, Marinus [1] tried to reduce reading and spelling deficits in dyslexic children by neurofeedback training based on neuropsychological differences between subjects, The experimental group was intervened by the neurofeedback method. The intervention group made significant progress in spelling. The effect of neurofeedback on dyslexia has also been confirmed in Fernandez's study [7].
With the relatively high prevalence of this disorder in the country's schools and the problems caused by it, the need to study and be aware of the factors affecting reading, and ways to improve it, requires appropriate diagnosis and intervention. For this purpose, the present study focused on the effectiveness of neurofeedback therapy on the sustained attention of dyslexic students in the west of Tehran.

Methods
The present study is a quasi-experimental study and its design is a pre-test-post-test with a control group and a follow-up period. The statistical population of the present study included all poor students in the fourth grade of the elementary school in west Tehran in 2020. Therefore, the sample size of this study included 50 dyslexics who were selected by the available sampling method and randomly assigned to two experimental groups (25 people) and a control (25 people). The inclusion of students in this study is that fourth-grade student who has been diagnosed with a reading disorder by a clinical specialist by DSM criteria. According to the latest changes made in 2013 for the DSM-5 criteria, students should have at least one of the following symptoms continuously for 6 months, despite the help of others:
1- They read the words slowly, difficultly, or incorrectly (they read the words hesitantly and slowly and guess them).
2. They have difficulty understanding the meaning of words and written texts.
Have trouble spelling words (delete or add letters)
3- They have difficulty in writing opinions and expressing their opinions in writing.
4- They have difficulty in recognizing numbers and geometric shapes (they have difficulty in understanding mathematics)
The neurofeedback course was performed for patients in the experimental group for 20 sessions of 45 minutes, and the control group spent this time on the waiting list. At first, all subjects were pre-tested. At the end of 7 training sessions, a post-test was taken again from the same subjects. Also, to follow the results, the test was taken again after 30 days.

Treatment method
In this study, two treatment protocols were used for treatment using neurofeedback therapy in dyslexic children. The first was the alpha/theta protocol in the Cz region and the aim was to increase the alpha by reducing theta. The second protocol, in regions C3 and C4, implemented the SMR protocol, in which the SMR beta was amplified from 12 to 15 Hz, and the 4 to 7 Hz theta and the 22 to 30 Hz beta were suppressed. These two protocols were repeated in all twenty training sessions. Subjects after the seventh session who had progressed somewhat. Received a cartoon CD as reinforcement. The subjects also received a cartoon CD (the subject's favorite cartoon) after the thirteenth and nineteenth sessions. Neurofeedback sessions were held three times a week until the twelfth session, but from the twelfth to the nineteenth session were held twice a week, and the last session was held for another two months (because neurofeedback therapy is gradually discontinued).

Tool
Sustainable Note: This test was developed in 1956 by Rosvold.The Persian version of the continuous performance test is a software test that is performed with the help of a computer.This test consists of two sets of stimuli (Persian numbers, or images), each of which consists of 150 stimuli.Of these, 30 stimuli (20% of the total stimuli) are the target stimuli that the subject is expected to respond to by observing them (pressing a key). The interval between the

presentation of two stimuli is 1000 milliseconds and the presentation time of each stimulus is 200 milliseconds. The variables obtained from performing this test are the number of non-response to the target stimulus (negligence error, omission error), the number of responses to the non-target stimulus (commit an error, respond), and reaction time in milliseconds [8].Hadianfar, Najarian, Shokreshkan, and Mehrabizadeh, the artist [9] in a 20-day retest showed validity of 0.59 to 0.93 for different parts of the test.Also, the validity of the recent test was evaluated by the criterion validation method based on the comparison of normal and attention-deficit/hyperactivity groups, and the results of its various variables showed a significant difference at a level less than 0.001 between the two groups [1].

Data analysis

Data were analyzed in the present study at both descriptive and inferential levels. Regarding the type of research variables at the level of descriptive statistics (frequency and characteristics of the studied variables along with the relevant graphs) and to explain the research hypotheses, repeated measures analysis of variance test was used with the assumption of homogeneity of variance within the group. Data were analyzed using spss22 software.

Results

The results related to the mean and standard deviation of the research variable are presented below.

Table 1. Mean and standard deviation of stable attention

	Variable	Group	N	Pre-test		Post-test		Follow up	
				Mean	SD	Mean	SD	Mean	SD
Sustained attention	Omission error	Intervention	25	6/8	0/78	5/73	0/46	5/46	0/75
		Control	25	6/73	0/80	6/73	0/80	6/6	0/51
	Commission error	Intervention	25	6	0/76	5/73	0/46	3/6	0/51
		Control	25	6	0/85	3/73	0/46	5/73	0/71
	Response time	Intervention	25	158/33	3/29	117/41	2/11	117/46	1/85
		Control	25	160/93	3/11	160/73	2/97	160/8	2/96

Table 1 summarizes the descriptive data, ie the mean and standard deviation of the dimensions of sustained attention in the pre-test, post-test, and follow-up stages in the experimental group and the control group. As can be seen, the average dimensions of sustained attention in the post-test and follow-up phase decreased compared to the pre-test stage in the experimental group, which means improved sustained attention, but in the control group in the post-test and follow-up phase compared to the pre-test. has not been done.

One of the presuppositions of using parametric tests is the assumption of the normal distribution of scores of the sample group or groups in the community. The normality of normality is rejected if the probability of random difference between the distribution of sample groups and the distribution of normalcy scores in the population is less than 0.05. According to the obtained results, it is observed that the default normal distribution of scores of research variables in the experimental group and the control group is confirmed ($P < 0.05$).

Another assumption that needs to be used to use parametric tests is the assumption of the equality of variance. The basis of this assumption is that it is assumed that the variances of the scores of the two groups in society are equal and do not differ significantly. Levin test is used to test this hypothesis. The results of this test also showed that the null hypothesis for the equal variance of the scores of the two groups of research variables in the post-test and follow-up is confirmed.

Table 2. Results of Machley test for covariance equals

	Variable	Mauchly's	$\chi 2$	df	P
Sustained attention	Omission error	0/910	2/843	2	0/244
	Commission error	0/731	8/620	2	0/015
	Response time	0/422	23/601	2	0/000

The results of Table 2 show that Machley's assumption that the covariances are equal in the omission error dimension is confirmed and rejected in the other dimensions, so we must use the Greenhouse-Geiser tests in strict order to reject the null hypothesis. But if the probability level in the first row is close to zero, it is not necessary to follow Machley's default. Given that the probability level is close to zero, it is clear that the observance of these assumptions had no effect.

Table 3. Results of analysis of covariance with repeated measures for stable attention

	Variable	Source	Sum of Squares	df	Mean Squares	F	Sig.	Effect sizes	Observed Power
Sustained attention	Omission error	levels	9/068	1	9/068	15/541	0/000	0/357	0/967
		Levels* Group	6/4	1	6/4	10/404	0/003	0/271	0/899
		Error	15/535	28	0/519				
	Commission error	levels	27/669	1	27/669	43/243	0/000	0/607	1/000
		Levels* Group	18/068	1	18/068	27/676	0/000	0/497	0/999
		Error	18/268	28	0/617		0/000		
	Response time	levels	6304/76	1	6304/76	1989/162	0/000	0/986	1/000
		Levels* Group	6223/018	1	6223/018	1963/371	0/000	0/986	1/000
		Error	89/734	28	3/169				

According to (P = 0.000) in Table 3, it can be seen that there is a significant difference between the control and experimental groups in the dimensions of stable attention. Also, according to (P = 0.000) the effect of group membership on the scores of the dimensions of sustainable attention is significant and it can be concluded that there is a difference between the pre-test and post-test of the experimental group in the dimensions of sustainable attention, ieneurofeedback treatment has been effective.

Table 4. Results of analysis of covariance with repeated measures of sustained attention among subjects (between pre-test, post-test, and follow-up stages)

	Variable	Source	Sum of Squares	df	Mean Squares	F	Sig.	Effect sizes	Observed Power
Sustained attention	Omission error	The effect of pre-test	2572/729	1	2572/729	4412/88	0/000	0/994	1/000
		Group	12/273	1	12/273	18/33	0/000	0/396	0/985
		Error	16/728	28	0/585		0/000		
	Commission error	The effect of pre-test	1539/7	1	1539/7	3683/224	0/000	0/992	1/000
		Group	44/273	1	44/273	103/312	0/000	0/785	1/000
		Error	12/183	28	0/628		0/000		
	Response time	The effect of pre-test	1890808/483	1	1890808/483	101026/561	0/000	1/000	1/000

Group	19922/344	1	19922/344	1064/409	0/000	0/974	1/000
Error	524/044	28	18/716				

The results of the table above show that sustained attention is significant at the significance level of P 05 0.05, ie the observed difference between the mean scores of post-test and follow-up in the experimental and control groups is significant. In other words, neurofeedback has been able to affect the sustained attention of dyslexic students. Therefore, neurofeedback therapy has been effective in sustainingthe attention of dyslexic elementary students in post-test and follow-up.
Bonferroni post hoc test was used to follow the results and compare them in pairs within the time group variable. The results related to each dimension are presented separately.

Table 5. Results of Bonferroni post hoc test for sustained attention

	Variable			**Mean Different**	Standard Error		**Sig.**
Sustained attention	Omission error	Pre-test	Post-test	0/535	0/179		0/018
			Follow up	0/735	0/186		0/001
		Post-test	Follow up	0/202	0/141		0/500
	Commission error	Pre-test	Post-test	1/269	0/137		0/000
			Follow up	1/335	0/203		0/000
		Post-test	Follow up	0/069	0/145		1/000
	Response time	Pre-test	Post-test	20/569	0/413		0/000
			Follow up	20/502	0/460	0/000	
		Post-test	Follow up	-0/069	0/189	1/000	

The results of the Bonferroni post hoc test show that there is a significant difference between pre-test and post-test, and between pre-test and follow-up. On the other hand, there is a significant difference between post-test and follow-up that it can be said that the scores of the dimensions of sustainable attention of the intervention group decreased from pre-test to post-test and this decrease continued until the follow-up stage. Therefore, lowering the scores means improving the dimensions of sustainable attention in the intervention group.

Discussion and conclusion

According to (P = 0.000) it can be observed that there is a significant difference between the control and experimental groups in the dimensions of stable attention. Also, according to (P = 0.000), the effect of group membership on the scores of the dimensions of sustainable attention is significant and it can be concluded that there is a difference between the pre-test and post-test of the dimensions of sustainable attention, ieneurofeedback therapy has been effective on sustainable attention. Therefore, the research hypothesis is confirmed and neurofeedback treatment has been effective in sustained attention of dyslexic elementary students in post-test and follow-up. The results of this research are in line with the research of Rajabi, Narimani, and Abolghasemi [1].
Studies have shown that dyslexic students are poor in attentional skills [41], [42], [43], [44], [45]. From the research, it is inferred that there is a mental defect in dyslexic children and that is the inability to focus attention and attention on the subject in question. Also, children with special learning disabilities have delayed or interrupted their developmental process of gaining normal attention. These children perform the worst in tasks where there are distractions, and most teachers rate them as people who are significantly less attentive than their normal peers. Children's attention is quickly diverted from the task by the reading disorder. Attention is grouped under the heading of basic abilities. Because attention seems to interact in principle with the psychological operations of individuals when they are disturbed, it affects thinking and oral language and reading [5].
Explaining this finding, it should be said that the human brain can change and modify itself, ie the ability to learn or re-learn the self-regulatory mechanisms of brain waves that play a key role in the normal design and function of the brain [6]. Therefore, neurofeedback training actually strengthens the underlying self-regulatory mechanisms required for effective functioning. This training system encourages the brain to correct, adjust, and maintain proper activity by giving feedback to the brain about what the person has done in the past few seconds and what the normal

bioelectrical rhythms of the brain were. As a result, the brain is asked to manipulate different brain waves by producing more of some waves and producing less of others [43].
The underlying mechanism of this change may be explained by the theory of factor conditioning so that if the change of stimulus (amplitude of brain waves) based on a predetermined contract is accompanied by the desired outcome (motion of video images or sound production) and be strengthened will lead to learning, and this learning will be more effective when simpler stimuli such as (neurofeedback training) are used that lead to receiving reinforcement. Overall, it can be concluded that neurofeedback can help children with dyslexia regulate the activity of their brain waves and thereby, improve their attention and reading problems [41].

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