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Comparison of the impact of cognitive rehabilitation and neurofeedback on attention, working memory, processing speed, and anxiety in dyslexia

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Original Article

Abstract

BACKGROUND: The aim of this study was to compare the effect of cognitive rehabilitation and neurofeedback (NFB) on attention, working memory, processing speed, and anxiety among dyslexic children.

METHODS: The method of the present study was quasi-experimental with a pretest- posttest, follow-up design and a control group. The statistical population of the study included all dyslexic students (boys and girls) of 7 to 10 years of age in Peiyk Enghelab School, District 2 of Karaj city, Iran, who were referred to Irana Counseling Center in 2018. The subjects were selected through available sampling method and were randomly divided in two groups of 15 people (Cognitive Rehabilitation and NFB). The educational content included cognitive rehabilitation sessions and NFB training. The data collection tools included the Integrated Visual and Auditory (IVA) function test, Wechsler Memory Scale, Clinical evaluation of Q, and the Spence Children's Anxiety Scale (SCAS). Multivariate analysis of covariance (MANCOVA) was used in SPSS software to compare the effectiveness of cognitive rehabilitation and NFB on attention, working memory, processing speed, and anxiety in dyslexic children.

RESULTS: The findings showed a greater increase in attention, memory, and processing speed scores in the NFB group, compared to the cognitive rehabilitation group, and in contrast, a greater decrease in anxiety scores in this group in the follow-up phase. Moreover, the continuation of the results of neurofeedback treatment compared to cognitive rehabilitation was observed.

CONCLUSION: Based on the findings, it can be concluded that NFB can be used to increase attention, working memory, and processing speed, as well as reduce the anxiety of dyslexic children. The results of such studies can help psychiatrists, psychologists, and counselors provide useful treatments.

KEYWORDS: Rehabilitation; Neurofeedback; Attention; Working Memory; Processing Speed; Anxiety

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Introduction

One of the most important and common childhood disorders is learning disabilities. Although the disorder was previously defined as a separate category in valid classifications such as the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) with the 3 subgroups of reading disorder, writing disorder, and math disorder, in the DSM-V classification it has been renamed as a specific learning disability.[1] Sustained attention refers to the maintenance of attention

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over time, which is the most basic and simplest level of attention and other types of attention need it. For this reason, a possible defect in it can indicate a defect in other types of attention.[2]

Moreover, working memory is a part of the high-level cognitive actions that are responsible for selecting, actively manipulating, and temporarily storing information input in the cognitive system using processing systems.[3-6] In a meta-analysis of 36 studies involving 665 children with learning disabilities and 1,049 normal children, they showed that working memory in children with learning disabilities is impaired in all groups of the disorder.[7]

Another factor that seems to be a major obstacle to learning for children with learning disabilities is anxiety.[5,8] Anxiety has many negative effects on children. One of these effects is that working memory function decreases in children with high anxiety. As children with learning disabilities have poor learning skills and working memory function, the level of anxiety in these children is likely higher than in children without learning disabilities.[9-11]

Among the different types of special learning disabilities, reading disorder is one of the most common, especially in elementary schools. Attentional function, working memory, processing speed, and anxiety are important elements that seem to have a critical role in reducing educational problems. Notably, most of the problems of these students can be easily resolved through the careful evaluation of these elements. One of the relatively new methods in this field is neurofeedback (NFB) treatment.[12,13] This treatment was first proposed by Lubar. This approach is presented as a non-pharmacological treatment strategy and a new self-regulatory approach that serves to increase self-control and self-regulation. NFT is a type of operant conditioning that teaches a person to increase or decrease their brain activity. In recent decades, significant progress has been made in the field of cognitive sciences. Theoretically, cognitive rehabilitation is a treatment method with the main goal of improving the patient's cognitive function defects such as memory, executive function, social perception, focus, and attention.[14] In the research by Wang and Hsieh[15] on the effect of NFB on attention and working memory, the results showed that in the educational group, attention scores increased significantly, and in the experimental group, NFB increased working memory performance.

Abbariki et al.[16] and Narimani et al.[17] found that computer-based cognitive rehabilitation therapy could be used as a suitable method to reduce children's cognitive deficits. In the research by Yarmohammadian et al.,[18] it was shown that teaching cognitive strategies for reading performance, information processing speed, verbal memory, and visual memory can be an effective therapeutic approach for dyslexic students.

Learning disability is a developmental neurological disorder and the existence of this disorder disrupts the learning process and educational process of children, and affects other aspects of their lives. Moreover, pointing out certain studies in the field of NFB, some researchers concluded that the weak points of the methodology of previous studies make it difficult to decisively deduce the usefulness and precision of these methods. Although the field of dyslexia will have the profit of administering a non-medical therapeutic method, it is not advisable empirical data on NFB in the clinical field.

However, some researchers believe that the presentation of NFB and cognitive rehabilitation in the form of a multi-faceted therapeutic program can lead to behavior normalization, increased educational and social performance, and adjustment of dyslexic children in their everyday life. It is worth mentioning that, mixed therapy of NFB and

cognitive rehabilitation can modify both cortical and arousal functions in dyslexic children. Considering the abovementioned facts, this research was carried out to determine the effectiveness of NFB and cognitive rehabilitation on attention, working memory, process speed, and anxiety in dyslexic children.

Methods

Procedure and study setting: The present research was a quasi-experimental study of unbalanced control groups with a pretest-posttest design and follow-up. The statistical population of the study included all dyslexic students (boys and girls) of 7 to 10 years of age of Peiyk Enghelab School, District 2 of Karaj city, Iran, who were referred to Irana Counseling Center in 2018.

The subjects were selected using available sampling method and were randomly divided into 2 groups of 15 people (Cognitive Rehabilitation and NFB) based on the diagnosis and referral of psychiatrists and according to the inclusion criteria.

The students' intelligence and desire to participate in the research were among the confounding variables that seem to have affected the results of the research and could not be controlled. To avoid the effect of sample loss on the research results, a larger number of samples were selected.

Determination of sample size: By referring to Cohen's table, and considering the number of groups (u = 2), a confidence interval (CI) of 95%, test power of 0.8, and effect size of 0.4, the number of samples was calculated to be 12 subjects in each group. Considering a possible sample loss of 20%, this was increased to 15 participants in each group.

Integrated Visual and Auditory Function Test: The Integrated Visual and Auditory (IVA) function test + PLUS test is based on the DSM-IV and distinguishes between attention deficit hyperactivity disorder (ADHD) types including the predominantly inattentive type (ADHD-I), the predominantly hyperactive-impulsive type (ADHD-H) is the combined type (ADHD-C). This test is applicable in children of 6 years of age and older and adults. The duration of this test [with the training section] is about 20 minutes. The test task includes answering or not answering [inhibiting the answer] 500 test stimuli. Each stimulus is presented for only one and a half seconds. Therefore, the test requires maintaining attention. The results of previous studies show that IVA + PLUS test has sufficient sensitivity (92%) and predictive power (89%) to correctly diagnose ADHD in children. The validity of the test in the open test method shows that the 22 scales of the IVA have a direct and positive relationship with each other (88%-46%).[19]

Wechsler Memory Scale: This software was designed by Wechsler in 2003 based on the Wechsler memory subtest which measures general verbal comprehension, perceptual reasoning, working memory and processing speed, and overall IQ, and can be used to assess children's memory. The internal reliability coefficient of the Wechsler Memory Scale (WMS) is very high and its validity coefficient is higher than 90.[20,21] In Iran, Abedi et al. reported test-retest coefficients in the range of 0.65 to 0.94 for this tool.[22]

Clinical evaluation of Q: This is a method of evaluating and determining the treatment protocol for NFB. This method is not weaker than the 19-channel QEEG. The Clinical Q is used to make the NFB treatment process more effective, and using this method reduces the number of NFB sessions.[17]

Spence Children's Anxiety Scale: The Spence Children's Anxiety Scale (SCAS) contains 45 items, which are scored on a scale ranging from 0 to 3 (never, occasionally, often, and always). Thus, the maximum and minimum scores of the SCAS are 114 and 0, respectively. The internal consistency of this questionnaire

is 95% and it has good concurrent justifiability.

Mousavi et al. distributed the Beck Depression Inventory Second Edition (BDI-II), Beck Anxiety Inventory (BAI), Thought Control Questionnaire (TCQ), and Anxious Thoughts Inventory among 767 students of Qazvin University.[23] From among these students, 528 individuals participated in the test-retest process with a 2-week interval. Using exploratory factor analysis, the 5 interpretable factors of distraction, worry, social control, punishment, and re-evaluation were identified for the TCQ. As a result, the internal consistency of the questionnaire factors and the reliability of their retest were found to be satisfactory.[23]

In a study conducted by Amiralsadat Hafshejani et al.,[24] factor analysis showed that this scale has 5 components (market panic, generalized anxiety, specific phobia, social anxiety, and separation anxiety) with desirable fitness indices. Moreover, the value of Cronbach's alpha was 0.939for the whole scale, and 0.812, 0.894, 0.803, 0.709, and 0.801, respectively, for the dimensions of market panic, generalized anxiety, specific phobia, social anxiety, and separation anxiety. The most appropriate cut-off point of this scale was 24.5.

Method of implementation and intervention: The inclusion criteria for the intervention program were receiving a diagnosis of dyslexic disorder, no history of psychosis and confusion according to the psychiatrist, age range of 7 to 10 years, not receiving medication or other psychological treatment at the time of diagnosis, no acute psychiatric disorder and other comorbid disorders, consent and declaration of conscious and voluntary willingness to participate in the research. The study exclusion criteria were addiction and dependence on drugs or alcohol, drug poisoning, or drug withdrawal. Cognitive rehabilitation and NFB sessions were conducted by the researcher under the supervision of professors. After the sessions, the posttest and follow-up were implemented by the researcher.

The content of the cognitive rehabilitation and neurofeedback sessions are presented in table 1.

Neurofeedback training: In NFB, sensors called electrodes are placed on the patient's scalp. These sensors record the electrical activity of a person's brain and show it in the form of brain waves [often simulated in the form of a computer game or video]. In this case, playing a movie or directing a computer game is done without the use of hands and only with a person's brain waves.

Multivariate analysis of covariance (MANCOVA) was used in SPSS software (version 24, IBM Corp., Armonk, NY, USA) to compare the effectiveness of cognitive rehabilitation and NFB on attention, working memory, processing speed, and anxiety in dyslexic children.

The study was approved with the ethical code of IR.kiau.REC.1399.776.

Results

First, the distribution of data related to research variables at a significance level of 0.05 have been investigated, the results of which are shown in table 2.

Based on the results presented in table 2, the level of significance of the calculated statistic for all variables is greater than 0.05, so the assumption of normal distribution of scores is accepted. In order to compare the effectiveness of cognitive rehabilitation and NFB on attention, working memory, processing speed, and anxiety in dyslexic children, MANCOVA was used. The results of this test along with its hypotheses are presented below.

As can be seen in table 3, the significance level of the Box's M test in the posttest phase is equal to 0.095 and in the follow-up phase is equal to 0.615.

Table 1. Summary of session content

Session	Content
1	The purpose of this session was to screen and evaluate the children individually and to create a safe environment for them. In this initial assessment session, the history of each child was obtained from his/her psychiatric record.
2	The purpose of the second session was to establish a therapeutic alliance, familiarize the children with the educational program, and provide game instructions.
3	In this session, training was provided and the children played games related to selective attention and attention and focus, including providing a network of images that change at intervals or appear with different shapes, sizes, and colors.
4	In this session, in addition to repeating the exercises of the previous session, incentive games such as "Finding Lost Objects" and "Be Quick" are played with the aim of improving working memory.
5	This session included training and playing games related to sustainable attention, including viewing a grid of targets and agility in selecting each visually changing target.
6	In this session, in addition to repeating the exercises of the previous session, incentive games such as "Target Exercises", "Clever Detective", and "Happy Hunter" were performed aiming to promote selective, focused and sustained attention to improve compensation for poor performance in games with different subjects.
7	This session included training and performing games related to short-term visual-spatial memory, including finding and matching objects and numbers in a network simultaneously, and related to comprehensive and regular visual-spatial associations and classification, visual imaging, and shear focus, including presenting a network of letters, numbers, or symbols, and finding a goal based on the rules of the game.
8	In this session, in addition to repeating the exercises of the previous session, incentive games such as "Happy Hunter" and "Finding hidden objects" were played in order to improve poor performance, selective attention, and visual-spatial memory for each subject.
9	This session included teaching and performing games related to stable attention and recognizing memory, including providing a number of different buttons or images depending on the level of difficulty and remembering these items in terms of shape, color, location, order, etc.
10	In this session, in addition to repeating the exercises of the previous session, incentive games such as "powerful puzzle" were performed with the aim of improving working memory, recognition and reasoning, and in order to improve compensation for poor performance in games with different subjects.
11	This session included training and performing games related to speed and movement control, including presenting a number of different images, and depending on the specific level, remembering the shape, color, location, and order, and then, finding items in the middle of the screen or sorting a set of items and recognizing in the audio-visual-spatial memory including presenting a set of clothes, letters, sounds, and other items, and placing items in the squares that have already been presented.
12	In this session, in addition to repeating the exercises of the previous session, incentive games such as "puzzle game" and "pop not zop" were played with the aim of improving motor memory control and speed, and the "Do not be late" game was played with the aim of improving auditory and visual memory to improve compensation of poor game performance for each subject.
13	This session included training and performing games related to numerical skills, including classification, including calculating the target stimuli set on the screen, classifying the target shapes according to the set rules, and finding pattern objects in the boxes.
14	In this session, the games related to numerical skills were performed again.
15	This session included teaching and performing games related to numerical discrimination and numerical distribution, including presenting boxes consisting of pictures and numbers and finding the desired box, or following the rules set at each stage of the game.
16	In this session, in addition to repeating the exercises of the previous session, incentive games such as "countdown" were performed with the aim of promoting conceptual reasoning and classification and visual-spatial arrangement, working memory, and attention in order to compensate for poor game performance for each subject.

Since this value is greater than the significance level (0.05) required for the rejection of the null hypothesis, the null hypothesis is confirmed based on the homogeneity matrix of covariances.

As shown in table 4, Levene's test results are not significant in any of the variables. Therefore, the null hypothesis for homogeneity of variance of variables is confirmed.

Table 2. Results of Kolmogorov-Smirnov test to check the normality of score distribution

Variable	Pretest		Posttest		Follow-up	
	Z Kolmogorov-Smirnov	P	Z Kolmogorov-Smirnov	P	Z Kolmogorov-Smirnov	P
Attention	0.135	0.351	0.099	0.730	0.141	0.303
Working memory	0.102	0.694	0.135	0.354	0.143	0.287
Processing speed	0.087	0.856	0.131	0.391	0.113	0.569
Anxiety	0.089	0.835	0.136	0.341	0.118	0.523

Table 3. Result of covariance matrix homogeneity test [box]

Level	Box's M	F	df_1	df_2	P
Posttest	19.186	1.619	10	3748.207	0.095
Follow-up	9.648	0.814	10	3748.207	0.619

df: Degree of freedom

According to the results presented in table 5, the significance level of all four relevant multivariate statistical tests, Pillai's trace, Wilkes' lambda, Hotelling's Trace, and Roy's largest root, was less than 0.01 ($P < 0.01$) in posttest and follow-up stages.

Table 4. Levene's test results for homogeneity of variance

Level	Variable	F	df_1	df_2	P
Posttest	Attention	0.220	1	28	0.643
	Working memory	2.260	1	28	0.144
	Processing speed	0.181	1	28	0.674
	Anxiety	0.923	1	28	0.345
Follow-up	Attention	0.281	1	28	0.600
	Working memory	0.061	1	28	0.807
	Processing speed	0684	1	28	0.415
	Anxiety	2.010	1	28	0.167

df: Degree of freedom

Thus, the statistically zero hypothesis is rejected and a significant difference was observed between the scores of attention, working memory, processing speed, and anxiety in the cognitive rehabilitation and NFB groups in the posttest and follow-up stages.

Table 5 shows the results of the inter-subject effects test in the comparison of attention, working memory, processing speed, and anxiety in the cognitive rehabilitation and NFB groups in the posttest and follow-up stages. According to the results presented in table 6, the value of F obtained for all variables is significant at the level of 0.05 ($P < 0.05$).

Discussion

The aim of this study was to compare the effect of cognitive rehabilitation and NFB on attention, working memory, processing speed, and anxiety among dyslexic children.

The findings showed a significant difference between the cognitive rehabilitation and NFB groups in terms of the scores of attention, working memory, processing speed, and anxiety in the posttest and follow-up stages. Moreover, in the NFB group, compared to the cognitive rehabilitation group, a greater increase was observed in attention, memory, and processing speed scores, and in contrast, a greater decrease in anxiety scores, which indicated more effectiveness of neurofeedback.

Table 5. Results of multivariate analysis of covariance in the comparison of attention, working memory, processing speed, and anxiety between treatment groups

Level	Variable	Amounts	F	Degree of freedom of effect	Degree of error freedom	P	Effect size
Posttest	Pillai's trace	0.468	4.618	4	21	0.008	0.468
	Wilks' Lambda	0.523	4.618	4	21	0.008	0.468
	Hotelling's Trace	0.880	4.618	4	21	0.008	0.468
	Roy's Largest Root	0.880	4.618	4	21	0.008	0.468
Follow-up	Pillai's trace	0.551	6.543	4	21	0.002	0.551
	Wilks' Lambda	0.551	6.543	4	21	0.002	0.551
	Hotelling's Trace	0.551	6.543	4	21	0.002	0.551
	Roy's Largest Root	0.551	6.543	4	21	0.002	0.551

Table 6. Comparison of attention, working memory, processing speed, and anxiety between the treatment groups in the posttest

Level	Variable	Source	Total squares	df	Average squares	F	P	Effect size
Posttest	Attention	Intergroup	10.672	10	10.672	8.689	0.007	0.266
		error	29.728	24	1.239			
	Working memory	Intergroup	76.164	1	76.164	6.813	0.015	0.221
		error	268.314	24	11.180			
	Processing speed	Intergroup	4.784	1	4.784	6.550	0.017	0.214
		error	17.527	24	0.730			
	Anxiety	Intergroup	9.610	1	9.610	4.408	0.046	0.155
		error	52.318	24	2.180			
Follow-up	Attention	Intergroup	7.093	1	7.093	7.392	0.012	0.235
		error	23.028	24	0.959			
	Working memory	Intergroup	120.442	1	120.442	10.368	0.004	0.302
		error	278.792	24	11.616			
	Processing speed	Intergroup	10.025	1	10.025	7.728	0.012	0.244
		error	31.131	24	1.297			
	Anxiety	Intergroup	8.888	1	8.888	6.392	0.018	0.210
		error	33.368	24	1.390			

These results are consistent with some prior studies such as that by Ramirez et al.[8] They showed that NFB had a significant effect on the performance of American students. Moreover, Soleimani et al.[21] believe that processing speed could be more improved with cognitive rehabilitation and NFB. Furthermore, Shiran and Breznitz[25] have shown rehabilitation and NFB to be highly effective in Swedish individuals with brain disability,[8,21,25] which is inconsistent with other studies such as that by Parsons and Faubert.[4] These researchers investigated enhancing learning in a perceptual-cognitive training paradigm using EEG-NFB in Canadian people.[4] Their results showed that NFB had no significant effect on perceptual-cognitive ability. In addition, Zuppardo et al.[10] investigated anxiety, self-esteem, and behavioral problems in American children and adolescents with dyslexia. The results showed that NFB had a minor effect compared to other treatment methods.[4,7,10,20,26,27]

To explain these consistent results, it must be acknowledged that the human brain is able to heal itself, that is, the ability to learn or relearn self-regulating mechanisms of brain waves that play a key role in normal brain function. Thus, NFB training actually strengthens the underlying self-regulatory mechanisms for effective functioning 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, therefore, it improves the brain and strengthens proper activity. As a result, the brain is asked to manipulate different brain waves by producing more of some waves and producing less of others.[5] The underlying mechanism of this change may be explained by the theory of operant conditioning; if a change in the stimulus (amplitude of the brainwaves) based on a predetermined contract is accompanied by the desired outcome [motion of video images or sound production], it will lead to learning, and this learning will be more effective when it uses simpler stimuli [such as NFB training] that lead to reinforcement. To explain the present findings, it can be said that neurofeedback training changes the frontal lobe and affects three parts of the motor cortex, sensorimotor, and cingulate. The action of the motor-sensory cortex is not limited to guiding the motor-sensory functions; it also helps to encode the cognitive and physical activities of the cerebral cortex.

Therefore, people who have difficulty with cognitive tasks can benefit from the effects of NFB on the left motor sensory cortex.[5,28] Neuropsychological research has shown that people with ADHD show deficiencies in the development of synapses and neural connections. Therefore, correct stimulation of the brain can help them to expand their synapses, establish normal activities, and improve their cognitive functions.[27,29] The results of another study showed that in clients with more severe social anxiety disorder, who probably had high resistance to performing techniques and coping with situations that can cause anxiety, NFB changed the expectation of clients and caused them to face these situations, and reduced their anxiety symptoms.[13]

To explain inconsistent results, it must be noted that EEG biofeedback may not be fully effective due to the influence of different variables. Moreover, NFB is generally not channelized, covers a wide range of disorders, and may not have specifically covered the disorder in question in this study. Notably, various studies have reported conflicting results; some studies reported high effectiveness and other studies report poor results. Moreover, cognitive rehabilitation requires consideration of the specific conditions of the disease or the disability of individuals. Conflicting studies may not have been able to consider the general conditions of individuals. People with dyslexia often experience other problems at the same time, and dyslexia may not be treated along with other problems. Finally, cognitive rehabilitation is an up-to-date method and requires updating of treatment content and technical methods. Conflicting studies may not have used up-to-date methods.

This study has valuable results. Nonetheless, there were some limitations, that is, lack of a placebo-controlled trial. Moreover, the generalization power of this study is week. These limitations should be addressed in future studies. Thus, more rigorous evaluations of patients during the process of treatment can be conducted through randomized placebo-controlled trials. Given the role of executive functions, attention, and information processing in the creation, persistence, and exacerbation of dyslexia, it is recommended that children be examined in terms of these factors before entering school. Furthermore, due to the effectiveness of NFB therapies and cognitive rehabilitation in the treatment of dyslexia, it is suggested that the centers for the treatment of learning disorders with NFB and cognitive rehabilitation employ counselors and trainers in this field, and place the use of these therapies on their agenda. Attention to other groups of learning disabilities is suggested in future research.

Conclusion

The cognitive rehabilitation program used in this study mainly focused on cognitive deficits of attention, memory, and executive function; therefore, generalizing the results to other cognitive deficits such as reasoning and spatial perception requires further research. The use of cognitive rehabilitation method is recommended to promote other cognitive functions such as logical reasoning, problem solving ability, visual and auditory processing speed, types of attention, and memory in dyslexic children, children with special learning disorders, and patients with dementia and Alzheimer's disease, multiple sclerosis (MS), Parkinson's disease, and epilepsy.

Conflict of Interests

Authors have no conflict of interests.

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