

# Effect of Neurofeedback on Anxiety, Dyslexia, and Dysgraphia in Elementary Students Afflicted with Attention Deficit Hyperactivity Disorder- a Pilot Study

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## Abstract

**Background:** Neurofeedback as a behavioral technique has an important role in the attention on internal changes along with strengthening and increasing focus and attention of children in some fields.

**Objectives:** This study aimed to investigate the effect of neurofeedback on anxiety, dyslexia, and dysgraphia in elementary students afflicted with Attention Deficit Hyperactivity Disorder (ADHD).

**Methods:** In this pilot study, five elementary students with ADHD from Yazd, Iran were included. According to the electroencephalogram (EEG) pattern, brainwave training was accomplished with the neurofeedback method. Children received 30 sessions of neurofeedback treatment, 3 times per week (for 10 weeks). Before and after neurofeedback training, the children were evaluated and compared with tools of EEG, the Beck Anxiety Inventory (BAI), the Conner's Parent Rating Scale (CPRS) for ADHD, and the Conner's test for dyslexia and dysgraphia.

**Results:** Neurotherapy is effective on dyslexia and dysgraphia; in other words, the students' learning performance significantly improved after Neurotherapy ( $P=0.000$  and  $P=0.001$ , respectively). There was no significant difference regarding anxiety ( $P=0.178$ ) before and after neurofeedback.

**Conclusion:** Neurofeedback improves dyslexia and dysgraphia but does not affect anxiety in elementary students.

**Keywords:** Neurotherapy, Neurofeedback, Attention Deficit Hyperactivity Disorder (ADHD), Dyslexia, Dysgraphia.

## Introduction

Many experts believe that partial injury to the brain, as a part of the central nervous system, and biochemical and genetic factors are the major causes of learning disorders.<sup>1</sup> According to these studies, there is a specific role for the frontal lobe in learning disorders.

The frontal lobe has administrative functions in designing and organization of sources. Also, it has a critical role in intermediate preventive behaviors such as

controlling movement behaviors and prevention of concentration on irrelative and distracting stimuli.<sup>2</sup> Evidence shows that right frontal lobe dysfunction is the basis for attention deficit disorders.

Learning disorders initiate in preschool and lasts through adulthood.<sup>3</sup> Learning disorders are among the most common problems of students, among which dyslexia is the most important and is present in 75 % of children and adolescents with learning disorders.<sup>4</sup>

Dyslexia is characterized by disability in word recognition, slow incorrect reading, and poor understanding. Studies estimate a prevalence of 2 to 8% for dyslexia, and boys are three to four times more clinically referred than girls. However, accurate epidemiological studies have reported that the incidence of dyslexia is similar in boys and girls.<sup>5</sup>

<sup>7</sup> According to a meta-analysis, the prevalence of dyslexia is 4.58 % among Iranian students.<sup>3</sup>

Regarding this issue, performing psychological interventions can play an essential role in reducing children's fear and anxiety. One of these methods and treatments is neurofeedback. The neurofeedback method has been used for treating anxiety since 1970. Kamiya and Klitner and alpha training accompanied the initial works. Alpha waves are high and smooth voltage waves of 8 to 12 Hz, which could result in relaxation.<sup>5</sup> Neurofeedback makes the brain's electrical function conditional and causes an optimal level in any individual's function.<sup>6,7</sup>

The process of neurofeedback involves learning or teaching self-discipline of the brain's activity. The brain controls required blood through expansion or contraction of the blood vessels, and the blood flow in the brain is directed toward specific areas that have more activity in this self-discipline.<sup>8</sup>

The neurofeedback objective is to normalize abnormal neural frequencies by raising awareness over EEG patterns.<sup>9,10</sup> The neurofeedback provides us with computer information by recording the brain function and presenting the physiological information that has been emitted through brainwave.

The output gained by a computer is based on operant conditioning theory and positive and negative reinforcement. Neurotherapy prepares the electrical impulses, and their amplitude is attained via separate filtered frequency bands. Consequently, the client is provided with the information visually and audibly, and the use of a computer helps any individual moderate his brainwaves in bandwidth. In a neurofeedback training session, the client can learn to condition their brainwave patterns and increase the optimal level.<sup>11,12</sup>

The studies have suggested that the highest frequency of EEG abnormalities in children with learning disorder has

been related to an increase in theta's activity comparing to normal peers, and a reduction has been observed in alpha activity while in children with a learning disorder in rest. That is why they are fundamental for the proper functioning of mental tasks in the relevant areas in normal children and normal adults.

These facts strongly indicate that the strengthening of theta/alpha reduction for children with learning disorders who have EEG abnormalities may lead to the normalization of EEG and, consequently, improve their cognitive and behavioral abilities.<sup>11</sup>

The neurofeedback logic originated in neurophysiologic studies that have shown a relationship between EEG and infra-thalamocortical systems responsible for the rhythms and frequencies of EEG.

A neuronal injury can change EEG rhythms and frequencies, besides neurofeedback training can normalize these rhythms, resulting in sustained clinical effects. Along with this hypothesis, several studies have indicated that students with learning disorders, especially dyslexia, have low abnormal EEG. They have activity and reduction in alpha 12 of slow waves, particularly in the theta range of ratio 13 to their own normal peers. Researchers believe that neurofeedback is a technique that acts from the feedback of the brain's electrical activity during operant conditioning and modifying the disturbed brain wave patterns.<sup>11,13</sup>

In fact, neurofeedback through operant conditioning leads to a simultaneous increase in the client's sensorimotor rhythm or beta-brain waves in specific brain points with no suitable frequency. Such conditionality can decrease theta brain waves in the most common points, while SMR or beta frequency increases.<sup>11</sup> Comprehensive exercises such as Neurotherapy modify the cause of disorders.<sup>11,14</sup> Neurofeedback could be used to treat aggression,<sup>15</sup> anger,<sup>16</sup> depression, anxiety, and mood disorders.<sup>17,18</sup> Finally, considering that intensity of anxiety in children may be developed to the extent of disabling dimensions and a feeling of imminent helplessness affects them and their family. Regarding a limited number of studies conducted on the effects of the neurofeedback method on decreasing such anxiety, this study is absolutely crucial.

## Objectives

The purpose of this study was an aim to investigate the effectiveness of neurofeedback in anxious children with learning disorders.

## Methods

This pilot study was conducted on a single sample with a pretest-posttest design. The study sample consisted of 5 third grade elementary students with learning disorders in Yazd. A purposive convenience sampling was performed in this study; five subjects with learning disorders were selected from those children referred to the center. To observe the internal validity of the research, subjects were matched for age, intelligence, school grade, and lack of seizure, anemia, and other disorders. An EEG, a writing test, a reading test, and an anxiety inventory was obtained from all the subjects, and after diagnosis of learning disorders by the doctor present at that center, therapy was performed three sessions a week for ten weeks.

The therapeutic protocol was as follows: first, an EEG was obtained, and then due to the QEEG pattern in a specified location (based on 10-20 international system) and frequency spectrum, electrodes were placed to correct the abnormal brain waves. Each therapeutic session consisted of two 10-minute protocols. During the first protocol, the active electrode was connected to the Fcz site, and the ground and reference electrodes were connected to the ears. The training was done according to the frequency spectrum of the EEG and included a reduction in alpha (8-12 Hz) and theta band (4-7 Hz). In the second protocol, the active electrode was connected to the P4 or Pz site, and the other two electrodes were connected to the ears with the enhancement of the alpha band.

Notably, Pz and P4 sites were used interchangeably every other session. If a subject had long beta waves in the sites mentioned above, they were inhibited simultaneously in the occipital and frontal regions or as an additional protocol; therefore, therapeutic sessions could take 20 to 30 minutes. A positive point was given to a subject who could maintain a reduced alpha (8-12 Hz) and theta wave (4-7 Hz) lower than the defined threshold for half a second (0.5 seconds). This positive point was visually

demonstrated in an open page on a computer display and vocally expressed to the subject as feedback. This process continued till the end of the therapeutic session.

## Data analysis

Data analysis was performed in two statistical levels, namely descriptive statistics (mean value and standard deviation) and inferential statistics (paired t-test) by means of SPSS software version 20. Data from electroencephalography was inserted into the NeuroGuide software, and the wave differences were calculated.

## Ethical considerations

This article is extracted from a student's thesis for obtaining a master's degree at the Islamic Azad University, Yazd Branch, that proposal has been registered in the Research Council under No. 920144491.

The neurofeedback is generally recognized as a safe intervention for improving electroneurological flexibility but some people report side effects (Fatigue, Depression, Dizziness, Headaches, Head pressure, Low energy, Muscle tension, Social anxiety, Tiredness).

Before starting the intervention, we explained about possible side effects. Written informed consent was obtained from parents. Also, the principles outlined in the Declaration of Helsinki were performed.

## Results

Five children were recruited for this pilot study from elementary school students with dyslexia and dysgraphia comorbid with ADHD aged 10 years old. sample was absolutely male (100%) and had a mean age of 10.0 years.

Assess the neurotherapy effectiveness in anxiety show that According to the below table, the significance level of the paired t-test ( $P=0.178$ ) is greater than 0.05, and there is no significant difference between pretest and post-test regarding the anxiety inventory. Thus, rejected the efficacy of neurotherapy.

Based on this table, the mean values of the anxiety variable (RQ) were 14.2 and 14.6 for pretest and post-test, respectively. Therefore, the mean value of the subjects' reading quality did not increase significantly in the post-test regarding descriptive statistics. Can consider the

Neurotherapy is effective on dyslexia and dysgraphia in children with reading disorders.

According to the above table, the mean value of reading quality (RQ) pretest and post-test were respectively 20.2 and 40. Thus, the mean value of the subjects' reading quality did not increase significantly in the post-test regarding descriptive statistics.

Based on this table, the mean value of writing quality pretest and post-test were respectively 25.8 and 48.8. Thus,

the mean value of the subjects' writing quality significantly increased in the post-test regarding descriptive statistics.

This study's descriptive findings show that the mean value of the reading quality pretest was 20.2, and it increased in reading quality post-test to 40. Additionally, the mean value of writing quality in students with learning disorders was 25.8 in the pretest and 47.8 in the post-test. Furthermore, inferential results are as follows:

**Table-1.** The results of paired t-test (dependent t-test) on the mean value difference between pretest and post-test of subjects' anxiety

Mean value	Standard deviation	Standard error of the mean	95 % confidence level		T	Degree of freedom	Significance level
			Lower limit	Upper limit			
-1.633	4	0.178	-1.08009	0.28009	-1.633	4	0.178

**Table-2.** Descriptive statistics to compare pretest of anxiety inventory with its post-test

Test	Mean value	Number of subjects	Standard deviation	Standard error of the mean
ADHD pretest	14.2000	5	4.65833	2.08327
ADHD posttest	14.6000	5	4.77493	5.13542

**Table-3.** Descriptive statistics to compare pretest of reading disorder with its post-test on the subjects

Test	Mean value	Number of subjects	Standard deviation	Standard error of the mean
Reading quality pretest	20.2	5	6.42	2.87
Reading quality posttest	40	5	5.15	2.30

**Table-4.** Descriptive statistics to compare pretest of writing disorder with its post-test on the subjects

Test	Mean value	Number of subjects	Standard deviation	Standard error of the mean
Writing disorder pretest	25.8	5	5.40	2.42
Writing disorder posttest	47.8	5	5.98	2.67

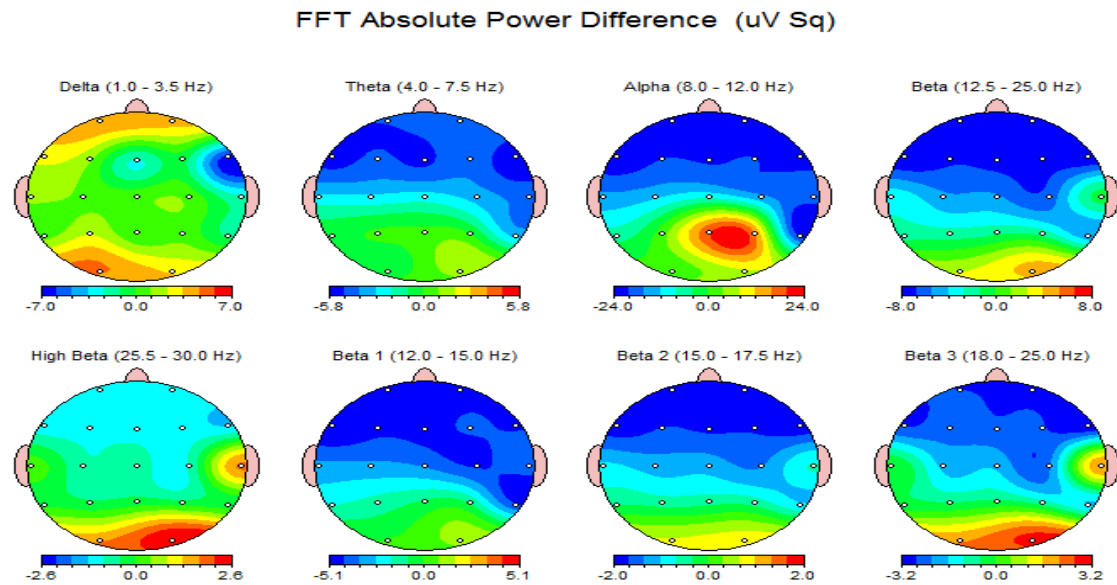
As has been shown, there is an increase in previously enhanced occipital alpha waves. Likewise, frontal alpha waves, corresponding to ADHD, show a significant reduction. Therefore, we can expect that with subjects' better concentration on the reading disorder test, their performance in the reading post-test will improve. As a result Neurotherapy is effective on anxiety in children with learning disorders.

According to the above table, the significance level of the paired t-test ( $P=0.178$ ) is greater than 0.05, and there is no significant difference between pretest and post-test

regarding the anxiety inventory. Neurotherapy is effective on dyslexia and dysgraphia in children with reading disorders.

According to this table, the significance level of the paired t-test ( $P=0.000$ ) is less than 0.05, and therefore, we can conclude that students' reading quality has significantly improved after Neurotherapy.

Based on the above table, the significance level of the paired t-test ( $P=0.001$ ) is less than 0.05, and as a result, we can state that the writing quality of students has significantly improved after Neurotherapy.



**Figure-1.** Analysis of data from EEGs and wave differences in pretest and post-test performed by NeuroGuide software

**Table-5.** The results of paired t-test (dependent t-test) on the mean value difference between pretest and post-test of subjects' anxiety

Mean value	Standard deviation	Standard error of the mean	95 % confidence level		T	Degree of freedom	Significance level
			Lower limit	Upper limit			
-1.633	4	0.178	-1.08009	0.28009	-1.633	4	0.178

**Table-6.** The results of paired t-test (dependent t-test) on the improvement of reading disorder in children with learning disorders

Mean value	Standard deviation	Standard error of the mean	95 % confidence level		T	Degree of freedom	Significance level
			Lower limit	Upper limit			
-19.8	3.49	1.56	-24.14	-15.46	-12.68	4	0.000

**Table-7.** The results of paired t-test (dependent t-test) on the improvement of writing disorder in children with learning disorders

Mean value	Standard deviation	Standard error of the mean	95 % confidence level		T	Degree of freedom	Significance level
			Lower limit	Upper limit			
-22	6.04	2.70	-29.50	-14.50	8.14	4	0.001

## Discussion

The present research is characterized by awaken the interest of other scientists in the field biofeedback to conduct similar research studies to reveal the importance of this method for the treatment of not only learning disorders but also to other psychiatric disorders. The main aim of the study was to measure the effectiveness of biofeedback in the treatment of psychiatric disorders, especially on learning disorder.

The aims of this paper were to determine the effect of neurofeedback treatment on dyslexia, spelling disorder, intelligence quotient level of patient and both symptoms attention deficit and anxiety degree in patents with learning disorder. The difference in pre-test and post-test scores and t-test result showed that neurofeedback caused reducing severity of the dyslexia and spelling disorder disorders.in addition neurofeedback had effect on increasing of intelligence quotient level of patient and



decreasing of attention deficit symptom of patient but had not significant effect on anxiety of learning disorder patient. Our result was opposite with other the implemented research in line with the effectiveness of neurofeedback on anxiety has demonstrated that any individuals will be assisted through conditionalization to improve psychosocial responses and obtain anxiety control skills, did not show this effect. All studies on this matter suggest that neurofeedback can decrease anxiety and mood disorder by conditioning brain waves in different age groups. In this way, an individual can decrease their anxiety by concentrating on the given animation in a specific condition, and they could also increase their relaxation time by repeating the sessions. It is possible to observe through effective anxiety-reduction protocols that people roughly experience relaxation after 5 minutes. By the use of practice and repetition, an anxious person can enhance relaxation after knowing his or her own physiological and nervous changes. The suggested method is safe and absolutely painless. Additionally, no harm has been reported so far about it. The anxious person consciously and voluntarily learns how to diminish his anxiety without any types of chemicals. Finally, it is noteworthy to mention that neurofeedback can aid a person to control his psychological status safely and to achieve an approach for coping with anxiety thoughts during everyday life Hammond et al.<sup>18</sup> The results of our research indicate that neurofeedback did not effect on the participants' anxiety. But results of different protocols have controversy our hypothesis Jahanian et al.<sup>19</sup> Conducted a research entitled "to study the effect of neurofeedback training on anxiety reduction in clients who came in psychological clinics in Isfahan". The sample contained 18 males with a mean of 34 years old which were selected based on convenience sampling method. The criteria for selecting individuals were anxiety scores above 35 in scale. Subjects underwent 15 neurofeedback sessions which each session lasted 30 minutes. The variable of age and gender has been entered in the research project as the moderator variable. Then, they were randomly divided into two groups, control group and experimental group. The participants were under went pharmacotherapy and by the end of the

treatment, the intake dosage was not stopped or decreased in both groups. The treatment protocol was as follows: the FP1 site was used as bipolar and CZ site was used as monopolar. These sites were measured and selected based on the international 10-20 system.<sup>20</sup>

The method to be used was as follows: EEGZ active electrode sensor was placed on the T3 site, and Flex proactive electrode sensor was placed on the FP1 site. The reference electrode of both sensors was also located on the left ear, and two ground electrodes were located on the right one. Then, the person's excitatory frequency was first obtained. In other words, the given frequency was suppressed in the range of 1 to 9 Hz, and the frequency of 10 -13 Hz was amplified, and the frequency of 14 to 20 Hz was suppressed for eight sessions. Besides, the frequency range of 1 to 11 Hz was suppressed for seven sessions at the CZ site, the frequency range of 12-15 Hz was amplified, and the frequency range of 21-30 was suppressed in a monopolar style. After the end of 15 training sessions, Cattell's anxiety post-test was administered on the same subjects. The results of the present research indicated that neurofeedback significantly reduces participants' anxiety. This research is consistent with the findings of the researches made by Heidari<sup>21</sup> and Moore.<sup>22</sup>

Isotani et al<sup>23</sup> stated that the simultaneous increase in the client's sensorimotor rhythm or beta brain waves in certain brain sites that have no suitable frequency is not effective. Such conditionalization leads to a reduction in theta brain waves in these sites while enhancing the frequency of SMR or beta waves. The whole research in this regard illustrates that neurofeedback can reduce the incidence of anxiety and mood disorders through conditioning brain waves in different age groups. Like this, people will reduce their anxiety by concentrating on the animation given in certain conditions and increasing the duration of their relaxation by repeating the sessions. In protocols that effectively reduce anxiety, it is possible to see that any individual can experience relaxation after about 5 minutes of relaxation exercise. The anxious person can enhance his or her relaxation through exercises after knowing his physiological and nervous changes. Our research has proved an opposite hypothesis,

and it could be due to the fact that our protocol based on reduction of alpha and theta in front of the head and on the increase of alpha at the back part of the head is not suitable to treat anxiety.

Based on the analysis performed on the data from the post-test and the subjects' EEG, we found that frontal alpha waves causing ADHD were reduced and enhancement of occipital alpha waves improved their concentration. Furthermore, reduction of frontal alpha waves and increase in occipital alpha waves will probably improve memory functions of the subjects. As a result, they can concentrate better on reading and writing tests and may perform more successfully in the post-test. In conclusion, we can say that neurotherapy can be used as a strategy to improve dysgraphia in students with learning disorders. Also, our results suggested that neurotherapy is effective on dyslexia in children with learning disorders and these results were in accordance with the results of the studies performed by Othmer et al <sup>24</sup> and Fatollahpour et al <sup>25</sup> and Mousavi et al <sup>26</sup>.

On the contrary, our study results suggest that the protocol of frontal alpha and theta reduction and occipital alpha enhancement is not appropriate for treating anxiety. These results were contradictory to the findings of Heidari<sup>21</sup> and Moore.<sup>22</sup>

This research is different from Hammond et al <sup>18</sup> and Heidari <sup>21</sup> and Moore <sup>22</sup> research. Also, this study shows that our hypothesis is effective in learning disorders. Besides testing small samples is often unavoidable in studies on neurodevelopmental disorders, including randomized controlled trials assessing treatment efficacy in learning disorders. Unfortunately, plausible effect sizes in this field are also small. This is true not only because the real effect sizes in psychology are generally limited, but also this small samples may lead to an increased risk of overestimating the effect sizes. This means that leads to low statistical power. It is hoped that this article as a Guide for future research with larger examples and encourage further application of the training neurofeedback as an effective tool for improving cognitive abilities and nerve system dysfunctions. Limitations and suggestions  
Limitations: Making use of convenience sampling and The low number of subjects.

## Conclusions

This study's results depict that our protocol of frontal alpha and theta reduction and occipital alpha enhancement is not appropriate for treating anxiety.

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## Competing interests

The authors of this manuscript have no invested interests in products described or used in this article. The authors have no conflicts of interest.

## Abbreviations

Attention Deficit Hyperactivity Disorder: ADHD;  
Electroencephalogram: EEG;  
Beck Anxiety Inventory: BAI;  
Conner's Parent Rating Scale: CPRS.

## Authors' contributions

ZJN and HM were responsible for study concept and design and also they Led data collection and analysis and interpretation of data. ZJN, HM, MY, RB, EH, AJ, ASH and SAG Wrote the first draft. RB, ASH, MY, SAG and AJ Contributed to the writing of the second and third draft drafts. All authors read and approved the final manuscript. All authors take responsibility for the integrity of the data and the accuracy of the data analysis.

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## Availability of data and materials

The data used in this study are available from the corresponding author on request.

## Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki. Institutional Review Board approval was obtained.

## Consent for publication

By submitting this document, the authors declare their consent for the final accepted version of the manuscript to be considered for publication.

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