

Investigation of the Impact of QEEG-Based Biofeedback on Attention and Behavioral Features in Young Male Adolescents with ADHD

Nader Alirezaloo¹, Ali S. Hosseini¹, Ebrahim Pishyareh^{1*},
Masoud Nosratabadi², Hojjatollah Haghgoo¹, Akbar Biglarian³

¹Department of Occupational Therapy, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran

²Paarand Specialized Center for Human Enhancement, Tehran, Iran

³Department of Biostatistics, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran

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Abstract

*Corresponding author:
Ebrahim Pishyareh,
Department of Occupational
Therapy, University of Social
Welfare and Rehabilitation
Sciences, Tehran, Iran.
ebipishyareh@yahoo.com

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Introduction: Attention Deficit/Hyperactivity Disorder (ADHD) is a disorder of neurobiological behavioral system. This disorder includes features such as attention deficit, impulsivity, and chronic, disproportionate-with-growth hyperactivity which reduce the child's ability to regulate, control, organize his behavior and cause attention deficit in activity of daily living (ADL). ADHD is one of the most common childhood disorders. The aim of this study was to investigate the effect of QEEG-based biofeedback on behavioral and attention factors of 7 to 14 year-old boys diagnosed with ADHD. **Method:** 40 boys diagnosed with ADHD were randomly assigned into the experimental and control groups. Integrated Visual and Auditory (IVA) test and Children's Behavioral Check List (CBCL) were used before the treatment and after 8 intervening weeks of treatment in both groups. Moreover, the brain mapping (QEEG) of the experimental group was used to design a treatment protocol. The experimental group received 24 sessions of neurofeedback therapy three times a week. The acquired data was analyzed using the Analysis of Covariance (ACNOVA). **Results:** Our findings demonstrated a significant difference in test results between the experimental and control groups upon IVA and CBCL tests following the neurofeedback intervention. Moreover, there was a significant difference between pre- and post-tests in the neurofeedback group. Interaction effect was insignificant at the time. **Conclusion:** Results of the present study showed that neurofeedback can bring significant improvements in attention factors especially, sustained attention and children's externalizing behaviors. As such, neurofeedback may be considered as one of the therapeutic modalities used along with core therapies and medication, though, more research is needed to compare the clinical effects of different treatment protocols with one another.

Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a neurobiological behavioral disorder, which includes features such as attention deficit, impulsivity, chronic disproportionate-with-growth

hyperactivity, which reduce the child's ability to regulate, control, organize his behavior and causes attention deficit in activities of daily living(1). What distinguishes ADHD, is that the level and scope of activity, agitation, restlessness and impulsive behavior of children is inconsistent with the

developmental and evolutionary level of individuals. This would cause impairment in normal functions such as performance at home and school as well as social functions(2).

In a recent classification of childhood disorders, two general categories of externalizing- and Internalizing problems have been determined(3). Externalizing problems include impulsivity, hyperactivity, aggression and criminal behaviors which cause some problems, such as fighting, disobedience, drug abuse, etc; the problems that are annoying for the children themselves but are problematic for parents or teachers. On the other hand, internalizing problems include emotional behaviors such as crying, anxiety and isolation that are more annoying for the children themselves(4).

According to DSM-5, Depending on which of the above symptoms manifest more, the ADHD disorder is classified into four categories. These include: 1- ADHD with predominant pattern of attention deficit, 2-ADHD with predominant pattern of impulsivity/hyperactivity, 3- ADHD with the compound symptoms of inattention and impulsivity/hyperactivity and 4- attention deficit with unknown hyperactivity disorder(5).

Many studies have been conducted on the etiology of this disorder while no single factor has been identified as the cause of all or even most cases of ADHD. However, various research findings indicate that nutritional factors(6) , genetic(7), parenting style(8) and dysfunction of brain structures contribute to the development of this predicament (9). Among these factors, genetic and dysfunctioning of brain structures has attracted most attention (10,11) .

According to the two main characteristics of ADHD, i.e. the disorder in attention and motor control; most of neuroanatomical studies are concentrated on brain centers involved in attention (anterior cingulate gyrus, the right frontal cortex and anterior and posterior corpus callosum) and motor control (basal ganglia and cerebellum)(12,13) .

Various methods such as PET, SPECT and fMRI are used to study brain function. In addition to high costs, these methods sometimes subject to side effects, such as injection of radioactive agent or placement in a powerful magnetic field(14).

In the meantime, using electroencephalography (EEG), which records the electrical activity of the brain, is considered a preferred method owing to its low cost and safety (15).

Based on quantitative electroencephalography (QEEG), it seems that, there are also differences in the function of brain waves in the brains of people with ADHD compared to healthy subjects (16). QEEG in contrast to EEG, has been developed to study the brain function (not the brain structure), therefore, it can be used in the detection and diagnosis of brain dysfunctions resulted from ADHD (17).

Nowadays, by comparing the patient's QEEG with the existing QEEG databases (QEEG analysis of healthy individuals) brain function's abnormalities can be identified and by comparing it with the existing patterns, the type of disorder can be specified (16-19). Findings from QEEG analyses suggest that the function of the frontal lobe, particularly the prefrontal are changed in ADHD (10).

Frontal lobe is responsible for control, adjustment and integration of cognitive abilities such as working memory, problem solving, cognitive flexibility, planning and self-monitoring, reasoning and response inhibition(6). The damage in each of these functions may result in significant consequences in the social, educational and emotional functioning which is known to be the case among ADHD suffers (20).

To investigate the relationship between EEG of the cerebral cortex and the underlying thalamo-cortical mechanisms of the brain a considerable body of neurophysiological research has shown that volatility and changes in rhythm and frequency of brain waves using neurofeedback can provide changes in the initial symptoms of ADHD (21).

Therefore, in terms of neuropathology, through biofeedback training based on brain waves, abnormal rhythms and frequencies can potentially convert to normal or near-normal rhythms and frequencies(22).

According to what mentioned, the relatively high prevalence of ADHD, lack of studies which consider all three factors of the functions of brain waves (brain map), attention components and educational and behavioral performance simultaneously, there seem to exist some unmet needs in the field of ADHD's applied research particularly in our local context.

Over and above this, the inconsistencies of results in extant body of research on the impact of biofeedback on brainwaves in ADHD, prompted us to investigate the effect of QEEG-based neurofeedback on externalizing behavioral components as well as sustained attention.

Materials

-QEEG

Brain waves were recorded from 19 points using a Medicom channel EEG19 (Russia) using a special helmet on the head references. The duration of QEEG was one hour, with a sampling rate of 256 Hz. Brain waves were recorded at three positions of closed eyes, open eyes and performing a cognitive task (reading) each for at least three minutes.

In this method, the brain waves derived from the activity of the cerebral cortex were recorded and entered into a computer. Using a series of mathematical operations these waves were converted to the numbers and the numbers into the charts or colored-coded brain. By comparing the patient's QEEG with the existing QEEG databases (QEEG analysis of normal subjects) possible brain wave abnormalities were identified.

-Child Behavior Checklist (CBCL)

The Achenbach System of Experience-Based Assessment consists of a set of forms to assess the competence, adaptive functioning and emotional-behavioral problems. Using these forms, normative data can easily be obtained in relation to a wide range of competences, adaptive functioning and emotional-behavioral problems.

Unlike many standardized tests, this measurement system uses open-ended and multiple choice questions to obtain and report information about the major characteristics and weaknesses in child's behavioral profile (23).

This measurement system has three reporting forms including forms for parents (Child Behavior Checklist [CBCL]), Teacher's Report Form (TRF) and Youth Self-Report (YSR).

Due to the fact that children in this study aged 7 to 14 years old, the CBCL was used to assess the emotional and behavioral problems of subjects.

Test-retest reliability between interviewers in CBCL scores was between 0.93 and 1 for scores obtained by different interviewers and reports of parents with an interval of 7 days. This reliability for the scales of competence, functioning and symptoms of emotional and behavioral adjustment in CBCL is equal to 0.90 (24).

This checklist was completed by a parent or person who has custody of the child based on the child's condition in the last 6 months. The list has two parts where the first part is related to the child's competence in various fields such as the activities,

social and school relations, and the second part is related to the emotional-behavioral problems which can be studied in two ways. First, it can be examined using profiles which are set according DSM-5 disorders. The orientation based on DSM involves emotional and physical problems, anxiety, and hyperactivity with attention deficit, oppositional behavior and conduct problems.

Moreover, the emotional-behavioral problems can be evaluated based on the scale of the syndrome which is experience-based. Syndrome is a set of problems and symptoms that tend to occur at the same time. To detect the syndrome in the CBCL, factor analysis methods would be used. Based on those factors or symptoms, anxiety/depression, withdrawal/depression, somatic complaints, social problems, thought problems, attention problems, rule-breaking behavior, and aggressive behavior will be investigated. The first 3 factors constitute the internalizing problems and the last two form the externalizing problems and the scores related to these two scales can be achieved of the total syndromes at such scales(25).

- Integrated Visual and Auditory Performance Test (IVA)

IVA is a 13-minute audio-visual continuous testing battery to evaluate two main factors including impulse control and attention. IVA test has been developed based on the Diagnostic and Statistical Manual of Mental Disorders DSM-IV and deals with identifying and distinguishing different types of ADHD including the type of attention deficit, hyperactivity (impulsivity), combined and not otherwise specified (NOS) types (26). Other than being one of the most accurate tests for the diagnosis of ADHD, this test precisely distinguishes 5 types of attention including focused attention, sustained attention, selective attention, divided attention and attention movement both in the auditory and visual domains. This test is applicable for subjects 6 years and older, including adults(27).

Method

In this study, 40 ADHD children referring to Paarand Enhancement Center were randomly selected according to the inclusion criteria and informed about the study protocol. After completing the informed consent form, a demographic questionnaire, CBCL questionnaire by the parents or guardians and the integrated visual auditory test

(IVA) by the child, subjects eventually underwent the brain map (QEEG) assessment.

In fact, QEEG was used to determine the local or general dysfunction of the brain, which was similarly used in this study to determine brain dysfunction of the children with ADHD as well as precise treatment protocols tailored to each individual in the phase of QEEG-based biofeedback intervention. Then, the participants were assigned to two groups (n=20 each) based on the statistical methods and the results obtained from the tests and brain maps

following criteria matching. Later, the intervention group received 24 sessions of QEEG-based biofeedback, and following the intervention both groups received the IVA test and CBCL in the post-test phase.

Results

In this study, 40 enrolled children were divided into two groups (i.e., the intervention and the control group each including 20 subjects) based on matching criteria. Participants were between 7 and 14 years old. The participants in both groups were male. The mean, standard deviation, minimum and maximum age of subjects in the two groups are presented in Table 1.

Since the age was considered as a defining criteria, as shown in Table 1, the mean age of both groups managed to be roughly equal.

Analysis of Covariance (ANCOVA) was used to analyze the data and to control the pretest effect.

In this case, externalizing behavior scale test scores as the dependent variable, the group variable (with two levels) as the independent variable and externalizing behavior scale pre-test scores as a covariate were considered in the covariance equation.

Before performing the covariance analysis, in order to verify the homogeneity of variance in values, externalizing behaviors and internalizing behaviors, Levene's Test for Equality of Variances was employed.

Table 1. Descriptive characteristics of participants' age

Group	No	Mean	Std. D	Min	Max
Intervention	20	9.45	2.038	7	14
Control	20	9.90	2.075	7	14
Total	20	9.68	2.043		

Table 2. Analysis of homogeneity of variances (Levene's test) for the subscales of CBCL

Variable	df	F	degree of Significant
Internalizing behavior	1.38	0.538	0.54

Table3. The results of analysis of covariance for the externalizing behavior in intervention and control groups

	Total squares	df	Mean of Squares	F	p-value
Externalizing Behavior	3278.097	1	3278.097	236.131	<0. 001
Group	297.003	1	297.003	21.394	<0. 001
Error	513.653	37	13.883		
Total	11755.00	40			

As shown in Table 2, Levene's test was not statistically significant in any of the variables. Therefore, the assumption of homogeneity (equality) of variances was approved enabling us to use multivariate analysis of variance. As summarized in Table 3, the results of changes in externalizing behaviors scale was reported with high significance level ($p < 0.001$, $F = 21.394$). This significant level suggests that biofeedback therapy based on brain waves used in the study reduces externalizing behavior scale scores in the intervention group, in other words, the intervention improved externalizing behaviors of the subjects in the test group. Meanwhile, this scale had no significant change in the control group.

As demonstrated in Figure 1, externalizing behavior scores in the intervention group has declined, suggesting that brain wave-based biofeedback therapy used in the study improved the externalizing behaviors of participants based on the CBCL test while it did not improve the same in the control group.

Test post-test scores of the sustained attention scale at the two levels of audio and visual as the dependent variable, group variable (with two levels) as the independent variable the pre-test scores of constant attention in any two levels of audio-visual scale (with two levels) a covariate were considered in the equation. The results of analysis of covariance is summarized in Table 4.

Figure1. Test scores in CBCL externalizing behaviors of pre-test and post-test accross groups

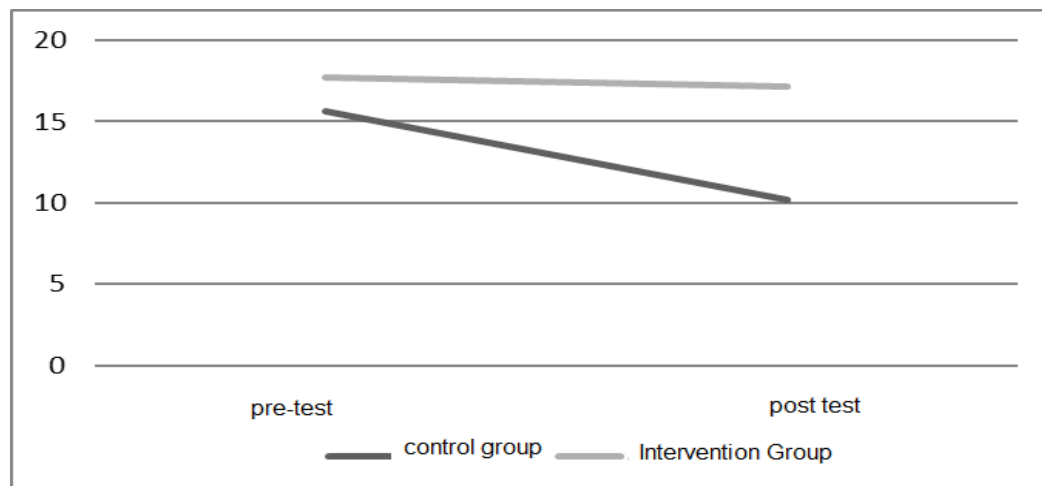
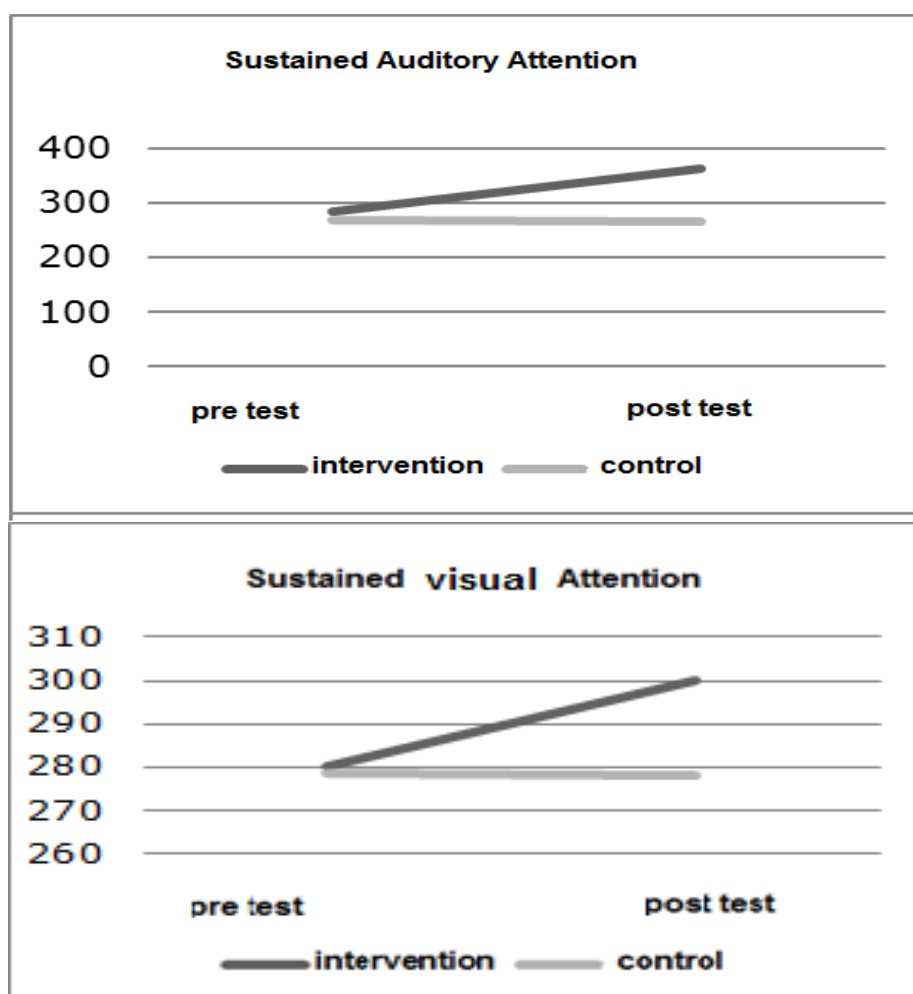


Table4. The results of analysis of covariance to compare continuous attention in test IVA between intervention and control groups

Visual	25644.644	1	25644.644	39.873	<0.001
Group	4292.549	1	4292.549	6.674	<0.05
Error	23796.856	37	643.158		
Total	54237.600	39			

Figure2. The mean scores of sustained attention at pre-test and post-test at two different levels of auditory and visual scale via IVA test in both intervention and control groups



As shown in Table 4, the extent of changes were notable in the constant attention scale of the IVA, both in audio and visual tests with a high confidence levels and statistical significance ($p < 0.001$, $F = 21.900$ and $p < 0.005$, $F = 6.674$; respectively). The effect of pre-test scores as a covariate in the variable was removed whereby the independent variable again has created differences between the groups.

In other words, the brain map-based biofeedback treatment (independent variable) used in the study could notably improve the sustained attention scale both at visual and the audio levels.

Also, according to Table 4 and Figure 2, the mean scores of sustained attention in both auditory and visual level in the post-test has dramatically increased while this scale in the control group had no significant change.

Discussion

In this study, first attempts were made to treat children with ADHD using QEEG-based neurofeedback and then, the impact of the treatment on behavioral and attention components were compared to the control group receiving no treatment.

High confidence levels in our findings corroborated the significance of intervention where the mean scores of the externalizing behavior subscales in the intervention group at the post-test were significantly lower than the pre-test. These findings may suggest the effectiveness of brain map-based biofeedback on alleviating symptoms of externalizing behaviors in ADHD. As mentioned before, some of the symptoms of externalizing behaviors include impulsivity and hyperactivity, aggression and disobedience.

This is consistent with some earlier reports in the field. Results from Linden et al., (1996) study showed that after 40 sessions of neurofeedback, parent reports of children's externalizing behaviors such as hyperactivity, aggression, impulsivity and lack of compliance was improved (28).

Different studies have used different scales for parent reports. In Lubar et al (1995) ADDES scale were filled by parents in order to assess children's behaviors. Parent reports on this scales indicated improvements in the symptoms of hyperactivity and impulsivity in these children. However, the results of QEEG in the pre-test and post-test of this study did not show significant changes in children mandating more discussion in this regard (14).

On the other hand, in a study by Linz et al (2007), parents and teachers reported greater improvement in these children after neurofeedback. The difference between these two studies is that in comparison to Lobar et al.'s (1995) study, in this study significant changes were shown in theta and beta brain waves in QEEG (13).

In the case of findings, it should be noted that the scales of assessment in these studies were parent reports and parents usually tend to exaggerate upon showing the effects of treatment.

In a same vein, Carmody et al (2001), reported that regardless of the parents' reports of children who received neurofeedback, these children showed less impulsivity and oppositional behaviors lower than the control group based on teacher report form (TRF) even up to one year of follow-up (29).

In the present study, the neurofeedback focus was on strengthening alpha and beta waves, which are assumed to affect the externalized behaviors. In this regard, Amer et al (2010) investigated whether EEG changes show the externalization in children's behavior or not. It was shown in this study that the alpha waves reduction in the frontal cortex is entirely consistent with Conners' Parent Rating Scale scores in children's externalizing behaviors in ADHD. Also, the higher the ratio of theta / beta in children was, the parents' reported more externalized behaviors (30).

Based on the existing body of evidence, increased activity in the left prefrontal and reduced activity in the right prefrontal cortex leads to aggression (31). Therefore, the impact of neurofeedback on aggression is at least partly due to the impact of reduced activity in the left prefrontal cortex and increased activity in the right prefrontal cortex. Cannon et al (2009) and Egner et al (2004) showed that neurofeedback training is effective on the activities of the prefrontal cortex. Thus, its effect on externalizing behaviors such as aggression is explained by its effect on the prefrontal cortex (32,33).

Also, the effect on aggression can be described by reduced impulsivity. As noted before, in this study impulsivity behaviors have also decreased. Many studies, including Apter et al (1990) showed that reduction in the aggressive behavior in children, reduced the impulsivity (34).

Another important finding of this study is the effect of QEEG-based neurofeedback on sustained or continuous attention. The main hypothesis was that the right frontal cortex dysfunction results in

hyperactivity and some studies have shown that treatments which are shown to be effective in patients with frontal injury and improve sustained attention are also effective in improving sustained attention in hyperactive children.

In this study, the significance of the post-test scores in the intervention group can be reflected to the effectiveness of brain map-based biofeedback on the beta and theta waves band as well as the SMR upon intervention. This improves the function and patterns of brain waves in the mentioned areas and contributes to the effectiveness of neurofeedback on sustained attention.

This finding is in line with the findings of Lobar and Shouse (1979) study. In their study, the neurofeedback was based on sensory integration rhythm and ultimately resulted in improved sustained attention in children with ADHD (35,36).

Pishyareh et al (2011), investigated the impact of computerized cognitive rehabilitation therapies on factors such as sustained attention in students. Their study showed that neurofeedback training in left and right temporo-parietal areas (C3 and C4) leads to favorable change in students' scores on the variables like sustained attention, working memory, and reduce design time and nervous reaction time as well as educational performance measures and problem solving skills (37).

Some research in other areas other than hyperactivity and attention deficit also showed the effects of neurofeedback on sustained attention. For instance, Yaghoub et al (2008) showed that neurofeedback is effective on brain injury patients' sustained attention. In this study, to assess attention (DAUF) and (QEEG) tests were used. The results of the analysis showed that the intervention group compared with the control group, at the end of the period, significantly manifested greater improvement in the number of correct responses and the time to react(38).

In the brain waves model, central and parietal alpha, central and frontal theta, frontal beta, central beta and parietal beta, frontal SMR and central SMR had significant changes in comparison to the beginning. So, it can be inferred that neurofeedback treatment possibly results in improvement of cognitive outcomes in patients with brain injury.

Conclusion

One of the strengths of this research was the use of qualitative electroencephalography (QEEG) as the aid component, along with other factors such as age, behavior and attention scores in stratifying the participants in two groups of intervention and

control with statistical matching in the pre-test phase. Moreover, the effect of neurofeedback on symptoms of externalized behaviors in ADHD was examined where significant effects were documented. More research in this area could yield more definitive conclusions and treatment strategies in this regard.

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