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Effectiveness of Neurofeedback on Executive Functions and Tendency Toward High-Risk Behaviors in Adolescents with Attention Deficit Hyperactivity Disorder

Roghieh Nooripour [1], Simin Hosseinian [2,*], Gholam Ali Afrouz [3] and Nour-Mohammad Bakhshani [4]

[1] PhD student of Counseling, Department of Counseling, Faculty of Educational Sciences and Psychology, Alzahra University, Tehran, Iran
[2] Professor, Department of Counseling, Faculty of Educational Sciences and Psychology, Alzahra University, Tehran, Iran
[3] Distinguished Professor, Department of Psychology and Education of Exceptional Children, Faculty of Education and Psychology, University of Tehran, Iran
[4] Professor, Department of Psychiatry and Clinical Psychology, Research Center for Health of Adolescents and Children, Zahedan University of Medical Sciences, Zahedan, Iran

[*] *Corresponding author*: Professor, Department of Counseling, Faculty of Educational Sciences and Psychology, Alzahra University, Tehran, Iran. Tel: +98-9125010156, Email: hosseinian@alzahra.ac.ir

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Abstract

Background: Attention deficit hyperactivity disorder (ADHD) is a major neuropsychiatric disorder diagnosis in children and adolescents.
Objectives: The current study aimed at evaluating the effectiveness of neurofeedback on executive functions and tendency towards high-risk behaviors in adolescents with ADHD.
Methods: The current quasi-experimental study with pretest-posttest, follow-up, and control group design was conducted on two experimental and control groups of eight ADHD adolescents referred to counseling clinics in Tehran, Iran, from 2016 to 2017. The age range of the participants (both the control and experiment groups) was 14 to 18 years. The control group did not receive any treatment and subjects just were given pre-test and post-test. The Conners adult ADHD rating scales-short self-report, Iranian adolescents risk-taking scale, and Wisconsin card sorting test (WCST) were used in the current study. The Levene, the Shapiro-Wilk, repeated measures, and Bonferroni tests were performed to analyze data with SPSS.
Results: Repeated measures showed that intervention had a significant effect on risky behaviors and executive functions of adolescents with ADHD ($P < 0.05$) and effects of neurofeedback sustained after one month.
Conclusions: In summary, the findings of the current study showed that neurofeedback can be used to treat the executive functions and tendency towards high-risk behaviors in adolescents with ADHD.

Keywords: Adolescents, ADHD, High-Risk Behaviors, Neurofeedback, Executive Functions

1. Background

Attention deficit hyperactivity disorder (ADHD) is a major neuropsychiatric disorder diagnosis in children, adolescents, and adults that can be chronic with beginning in childhood that frequently continues into adulthood. It is featured by the lack of attention, hyperactivity, and impulsivity symptom (1). Moreover, the signs cause significant stress and impedance and are comprehensive (i e, impairment is observed in numerous aspects of life, such as executive functions, social work, and occupational success). The two fundamental international symptomatic criteria utilized clinically are the international classification of diseases, the 10th revision (ICD-10) and the diagnostic and statistical manual of mental disorders (DSM), the 5th revision (2). The former is widely applied by European clinicians, while the latter is broadly utilized within the United States (US) and by a few European physicians. The ADHD frequency in children and adolescents is 5.3% to 5.9%, respectively, worldwide and 4.6% in Europe. Same countable rates around 5% were for adults with ADHD (3).

One of the most commonly investigated components now is executive functions (EF). An adolescent with ADHD shows the significant deficiency in a dimension of EF such as main memory, hindrance, and planning capacities. Adolescents with ADHD are long perceived to display executive function all through childhood and adolescence. Rich trial evidence demonstrates wide contrasts in executive function between samples of adolescents with and without ADHD (4). Investigation of the adolescent as particular populations is accessible, but rarely in comparison with younger children. The foremost consistent executive functions noticed in an adolescent with ADHD are

in main memory, inhibition, and planning/organization capacities. These particular capacities are constantly related to the deterioration perceived by an adolescent with ADHD, especially when evaluation for the impact of core ADHD symptoms. In addition, both ADHD symptoms and executive function regularly endure into adulthood. These findings closely adjust with numerous noticeable theories with respect to the etiology of ADHD, which nominate that the ADHD's signs are generally directed by shortages in executive function capabilities (5).

Generally, the detailed predominance of executive function in ADHD samples changes broadly, depending on the sample and definition of the executive function (i.e. Biederman et al. (6), 33% and Lambek et al. (7), 54%). When Nigg et al. (8) utilized a limit of defective activity on each of the seven neuropsychological issues to characterize the nearness of the executive function; they still concluded that around 79% of the participants had the executive function criterion. Whereas this proposes that executive functions are predominant in ADHD, a notable part of adolescents with ADHD do not appear to have clinically remarkable deficits. These results lead to substituting theories about the association between ADHD and executive functions that even though executive functions are associated with ADHD symptoms, they are not the essential root of the disorder (9). Critically, they moreover recommend that the observed diversity in executive functions may be inferable to natural variables other than the seriousness of the essence of ADHD symptoms.

On the other hand, adolescents with ADHD are at a risk for concurrent problem behaviors such as substance abuse and delinquency, cognitive issues, mood and anxiety problems, and psychiatric disorders. Impairments related to ADHD are multi-faceted, with results such as high-risk behaviors, and interpersonal relationship challenges (10).

ADHD during adolescence is regularly related to expanded utilization in different particular high-risk behaviors (11) including smoking and drug abuse (12-14), unsafe driving (15), gambling (16), and vulnerable sex (17). Within the clinical and theoretical literature, risk-taking behaviors are characterized as careful engagement in behaviors related to a few probabilities of unpleasant results (18). In fact, higher scores on a scale containing different risk-taking behaviors should be recorded in the adolescents with ADHD (19).

Nowadays, both stimulant medicine and behavior treatments are the foremost frequently practiced and accepted medications for ADHD. Nevertheless, current massive investigations and reviews illustrated the limitations of these treatments. For instance, limited extended impacts of stimulus medicine (possibly the result of an up-adjustment of the dopamine transporter (DAT) (20) and behavior therapy are demonstrated). It, hence, becomes clear that there is a requirement for new treatments for ADHD with superior permanent impacts that moreover clarify the later investigation intrigued in neurofeedback as a therapy for ADHD.

Neurocognitive impairment related to ADHD basically appears to enhance with the application of stimulant medication (21). A recent survey shows that remittance of ADHD symptoms is not mostly related to progressed neurocognitive functions: adolescents with transmitted ADHD still experience decreased neurocognitive function. It demonstrates that ADHD symptomatology and neurocognitive functions should be considered as separate treatment result measures (22).

In addition, even though stimulant medication seems effective in decreasing ADHD symptoms (23) and developing neurocognitive functions, most of the adolescents over the years suspend stimulant medication use in spite of the diligent course of the disorder. Subsequently, additional interventions to the current treatment as usual (TAU) are justified to advance and diminish ADHD symptoms enduringly, and simultaneously develop neurocognitive functions. In this regard, neurofeedback, which is considered as a possibly effective intervention to decrease ADHD symptoms in ADHD and autism spectrum disorders, might as well be able to improve neurocognitive functions (24).

One of the possible treatments is neurofeedback that trains the brain by means of operant conditioning to progress regulating itself by giving real-time video/audio data approximately, and its electrical action is measured by scalp electrodes. The hypothetical establishment for neurofeedback treatment of ADHD is based on the idea that brain waves can be deliberately altered (25); investigations showed the excessive electroencephalogram (EEG) theta activity (characterized by a drowsy/inattentive state) and diminished beta activity (characterized by an awake/attentive state) in patients with ADHD compared with the control group (26); researches based on neuroimaging, positron emanation tomography (PET), and single proton emanation computed tomography (SPECT) showed a neurophysiological basic of ADHD (27), and investigations on EEG and slow cortical potential dysfunctions and their relationship with basic thalamocortical mechanisms (28) and EEG changes related to a positive medication reaction (29).

Neurofeedback is based on the fundamental of operant conditioning and points to modify brain function by giving real-time feedback of EEG action to the patient. Adolescents with ADHD appear to have an increased theta activity and decreased beta activity compared with ordinarily developing adolescents. Appropriately, the foremost frequently utilized neurofeedback protocol is the theta/beta training, which points to reduce theta (4 - 7 Hz) and increment sensorimotor rhythm (12 - 15 Hz) or beta (12 - 20 Hz). Theta/beta training in one investigation found changes in brain function as reflected in a decrease

of posterior-midline theta activity (30). Also, the decrease in theta activity was related to the activity of ADHD symptoms as shown by parents. Two other types of research released similar changes in attention on behavioral surveys over time for an adolescent with ADHD treated with neurofeedback, stimulant medication, or both. Hence, a few randomized controlled trials (RCTs) appeared to have enhancements in ADHD symptomatology, as detailed by parents. Symptoms and developing neurocognitive functions indicate that most of the adolescents over 15 years suspend stimulant medication use in spite of the diligent course of the disorder. Subsequently, additional interventions to the current treatment as usual (TAU) are justified to advance and diminish ADHD symptoms enduringly and simultaneously develop neurocognitive functions (31, 32).

To summarize, although neurofeedback is considered as a possibly effective treatment to reduce ADHD symptoms in adolescents (33), information about the neurocognitive effects of neurofeedback is limited. Therefore, the current study aimed at evaluating the effectiveness of neurofeedback on executive functions and tendency towards high-risk behaviors in adolescents with ADHD.

2. Methods

The current quasi-experimental study with pretest-posttest, follow-up, and control group design was conducted on all adolescents with AHDH referred to counseling clinics in Tehran, Iran, from 2016 to 2017. The participants consisted of two experimental and control groups of ADHD adolescents (n = 8 each group). The age range of the subjects was 14 - 18 years. The participants in the control group did not receive any treatment and were only given pretest and posttest.

Inclusion criteria were age 15 - 18 years, middle socioeconomic status, no serious physical illnesses such as heart disease or multiple sclerosis, no drug abuse and drug dependence, no use of psychoactive drugs, no psychosis illnesses such as schizophrenia or related disorders, no brain injury, no grief experiences in the last six months such as divorce and close relatives death, and not participating in any psychological training parallel to the current study. Exclusion criteria were missing two sessions of the provided treatment, facing extreme stressful events or getting sick and individual opt-out.

The current study employed the Conners adult ADHD rating scales-short self-report developed by Conners et al. (34) with 26 items scored 0 to 3 in five subscales. Subscales include attention-memory problems, restlessness/hyperactivity, emotional instability/shakiness, problems with the individuals' overall self-image, and low-interest hyperactivity index. The raw scores of each subscale, using the appropriate normative table for that area, show the likelihood of an outbreak or exaggeration in the symptoms (34). This questionnaire was standardized in Iran by Davari-Ashtiani et al. (35), and cut down to 38. The reliability of this questionnaire was confirmed by Cronbach's alpha of 0.72.

Iranian adolescents' risk-taking scale was used in the current study. By reviewing valid and promising tools in the field of risk management such as the risk assessment questionnaire for adolescents (36) and the risk management system for young people (YRBSS), and considering the cultural conditions and social constraints of the Iranian society, Zadeh Mohammadi et al. (37) adopted 38 items. It assesses seven subscales of high-risk behaviors including dangerous driving, violence, cigarette smoking, substance abuse, alcohol consumption, sexual behavior, and relationship with opposite sex and the current study used their total scores. Respondents completed this scale by agreement or disagreement on a five-point Likert scale from completely agree (score 5) to completely disagree (score 1). Cronbach's alpha of this instrument for total score was 0.94 (37).

Wisconsin card sorting test (WCST) was performed in the current study. In the WCST a pack of cards are shown to the participants and they are instructed to sort the cards on the base of rules formerly provided and proceed until all the cards are sorted (38). The obtained score of each participant shows the level of executive function, number of rectified categories (number of categories ordered with 10 successive right reactions), perseverative errors (all wrong responses that contained a coordinate to the preceding sorting category), and perseveration of the preceding reaction (correct repetitions of the straightforward preceding incorrect response). The standardized form validated for the Iranian samples was utilized and the psychometric properties were satisfactory in the Iranian population (39).

The experimental group attended 30 sessions each lasting for 30 minutes three times a week. Follow-up was performed after 30 days in the experimental and control groups. Alpha/theta protocol was utilized in the current study.

The Levene, Shapiro-Wilk, and repeated measures, and Bonferroni tests were performed to analyze data.

3. Results

Covariance examination was utilized to assess data normality, covariance, and homogeneity of pretest scores between the two groups. To evaluate the normality of data, the Shapiro-Wilk test was utilized. The Levene test was performed to assess the homogeneity of variance within groups. According to Tables 1 and 2, the findings were not significant ($\alpha = 0.05$).

Tables 3 and 4 show the result of analysis of variance for repeated measures performed to evaluate effectiveness of neurofeedback.

Table 1. Results of Shapiro-Wilk Test to Evaluate the Normality of Data

Variable	Shapiro-Wilk Test		
	Sig.	df	F
Risky behaviors			
Experimental	0.324	8	0.450
Control	0.407	8	0.625
Number of error			
Experimental	0.265	8	0.542
Control	0.183	8	0.428
Number of category completed			
Experimental	0.360	8	0.357
Control	0.215	8	0415
Perseveration response			
Experimental	0.143	8	0.927
Control	0.096	8	0.889

Table 2. Result of Levene Test for Homogeneity of Intergroup Variance of Data

Variable	Levene Test			
	F	df 1	df 2	Sig.
Risky behaviors	3.383	1	14	0.156
Number of error	3. 417	1	14	0.778
Number of category completed	2.39	1	14	0.101
Perseveration response	2.685	1	14	0.210

Table 3. Intergroup Comparisons for Risky Behaviors and Executive Functions Based on Repeated Measures Analysis

Variable	Sig.[a]	Chi-Square	df	The Mauchly
Risky behaviors	0.811	1.865	2	0.17
Number of error	0.507	1.173	2	0.37
Number of category completed	0.124	1.094	2	0.89
Perseveration response	0.162	1.016	2	0.60

[a] Sig. (0.5)

Table 4 shows homogeneity of covariance confirmed by the Mauchly test.

Repeated measures in Table 4 showed that the intervention had significant effects on risky behaviors and executive functions of adolescents with ADHD. It can be argued that the independent variable caused significant difference between the experimental and control groups.

In Table 5, the results of the post hoc test in different stages of the test in the experimental group indicated mean differences in three stages: pre-test, post-test, and follow-up. Therefore, the effects of neurofeedback sustained after one month.

4. Discussion

The findings of the current study and previous researches expanded the understanding about neurofeedback and its effectiveness on executive functions and tendency towards high-risk behaviors in adolescents with ADHD.

Table 4. Intragroup Comparisons for Risky Behaviors and Executive Functions Based on Repeated Measures Analysis

Variable	F (1, 14)	Eta Squared
Risky behaviors	5.70[a]	0.17
Number of error	8.36[b]	0.23
Perseveration response	7.06[a]	0.20
Number of category completed	6.75[a]	0.20

[a] P < 0.05
[b] P < 0.01

Table 5. Bonferroni Test for Neurofeedback on Risky Behaviors and Executive Functions of Adolescents with ADHD

J I	Mean Difference (I - J)	P Value	SD
Pre-test			
Post-test	-2.836[a]	0.002	1.038
Follow-up	-2.147[a]	0.005	1.514
Post-test			
Pre-test	2.836[a]	0.002	1.038
Follow-up	-0.089	0.526	1.346
Follow-up			
Pre-test	-2.147	0.005	1.514
Post-test	0.089	0.526	1.346

[a] P < 0.05
[b] P < 0.01

In common, neurofeedback decreases essential symptoms of ADHD and ADHD related practical impairment to a level close to the pharmacological treatment. All things considered, the study sample was limited (40), making it impractical to achieve that neurofeedback and medicine are comparable medications for ADHD. According to the follow-up appraisal, it was realized that adolescents received neurofeedback to sustain the accomplished advancements one month after completing the treatment.

Findings of the current study revealed that neurofeedback medication was effective on executive functions and tendency towards high-risk behaviors in adolescents with ADHD. Consistent with the current study results, adolescents of the experimental group made huge enhancements in conducting a spectrum of executive functions after neurofeedback treatment, while no such impacts were established; these results demonstrated more maintenance of the impairment of executive functions in ADHD and emphasized the current neurobiological perspective on ADHD, which recommended irregular executive functions. Moreover, the current study results provided more evidence to confirm the perspective that neurofeedback may dominate specific worth to treat adolescents with ADHD. At a neurophysiological level, neurofeedback intervention effectively diminished theta control (4 - 7 Hz) and essentially expanded low-beta (12 - 15 Hz) in all of the eight subjects in the experimental group. In contrast, it was consistent with the current study objectives that neurofeedback protocols, which target adolescents' theta/beta proportion basically work because they decrease theta control, attenuation of theta control was more reliable than enhancement of control during that treatment period (25).

According to the consistent enhancement of executive function, no basic changes in neurofeedback intercession was observed between post-test and follow-up stages and this finding was inconsistent with the findings of Kropotov et al. (41), that concluded no imminent changes in quantitative EEG power range of children with ADHD after neurofeedback treatment, in spite of the fact that neurofeedback was perceived to influence the sufficiency of event-related possible factors. Basically, these results showed a conceivable mechanism through which the association between theta power and executive functions can be perceived. The improvement of theta that is reliably supported throughout cognitive burdensome assignments such as utilization of memory (42), mental mathematics (43), error monitoring (44), and sentence comprehension (45) to permit actuation in task dimension supporting and the processing of external objectives. To explain more about the impacts of neurofeedback on ADHD, Monastra et al. (46) showed that the individuals with neurofeedback intervention demonstrated more attention and less hyperactive/violent behaviors compared with the ones receiving pharmaceutical treatment, especially Ritalin. According to the above results, it is clear that neurofeedback is an efficacious intervention for ADHD and a practical choice to utilize the psychostimulant medication, and it is expressed as the sort of intervention with supported advancement of core ADHD symptoms in the absence of stimulant treatment (46, 47). Additionally, neurofeedback is thought to be selected where medication is inadequate, only partly impressive, has unsatisfactory side effects, or pharmaceutical compliance is low.

The results of the current study were consistent with the findings of the study by Gil et al. (48), Jacobs et al. (49), and inconsistent with those of Ghosh et al. (50), and Kollei et al (51). Studies show a significant relationship between the limbic area and the cortical areas, and therefore, cause significant effects on the occipital areas including the hippocampus, amygdala, orbitofrontal cortex, lipstick serotonin, cortex insulator, uncus, and the prefrontal cortex. On the other hand, these areas have a complex role in cognitive behaviors and features (52). Therefore, specific variations in the frequency of alpha waves in these areas are related to cognitive functions. The alpha/theta treatment drown mind into a state of tranquility and the individual achieves a mental relaxation. Subjectively, this pro-

cess is similar to the transition from wakefulness to sleep. According to the reports, many alpha/theta alumni experienced significant changes over the alpha/theta training (53). In fact, the alpha/theta protocol is widely used in various fields such as improving cognitive functions (53). However, by neurofeedback treatment, the risky behaviors can be reduced, which is the result of the current study using the alpha/theta protocol training.

In general, the current study results demonstrated that neurofeedback treatment of adolescents with ADHD is related to the decrease of high-risk behaviors such as substance abuse, etc. Hence, it seems that neurofeedback treatment has the potential to be the arrangement, instead of the cause, for high-risk behaviors such as alcohol/drug abuse, etc. among adolescents with ADHD. The current study results may be of major significance for professionals managing such patients and for the parents that need to make choices for their adolescents and for the community on the whole.

The current study had some limitations; the main limitation was the relatively small sample size; therefore, generalizing the outcomes should be made cautiously. Due to the nature of the subject and the short period of the study, to completely illustrate the presented results in the current investigation, longer studies seem to be necessary. Future planned studies in this field can be of assistance. In order to increase the credibility of the current study findings and more generalization, it is recommended to conduct similar studies with larger sample sizes. It is recommended that other therapeutic interventions such as cognitive-behavioral or third-wave therapies (i.e. acceptance and commitment therapy in ADHD symptoms) be used to evaluate the effectiveness of interventions.

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Footnotes

Authors' Contribution: Study design, data collection and analysis and manuscript preparation: Roghieh Nooripour, Simin Hosseinian, Gholam Ali Afrouz, Nour-Mohammad Bakhshani.

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