The Effectiveness of Neurofeedback on the Working Memory in Children with ADHD

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ABSTRACT

Objective: Working memory is the ability of maintaining and manipulating the required information for operating generalization in future. The aim of the present research is to investigate the effectiveness of neurofeedback therapy on the working memory in children with ADHD.

Methods: 24 children with ADHD who had the required standards to participate in the study were selected by accessible sampling and put randomly in an experimental group or a control group. The experimental group attended 20 sessions of neurofeedback instruction for 2 months. The individuals from both groups (experimental or control) were assessed and compared by giving SWM test in two stages of pre-test and post-test. The obtained results were analyzed by the statistic method of covariance analysis.

Results: Neurofeedback instruction is able to recover the working memory of children with ADHD.

Conclusion: Neurofeedback instruction can be used as an intervening method for working memory recovery in children with ADHD.

Key Words:
Neurofeedback,
Working Memory,
ADHD

1. Introduction

Attention deficit/hyperactivity disorder is the most common developmental-neurological disorder in children and it is estimated that 3 up to 7 percent of the children suffering from this disorder (Association, 2000; Gupta & Kar, 2009; Woodard, 2006). On the other hand, from a group of 20 students, at least one student has this disorder (DuPaul & Weyandt, 2006). Apart from this fact, the estimates of the researchers show that the boys are suffering 2 up to 9 fold as many as the girls from the mentioned disorder (Eyberg, Nelson, & Boggs, 2008). Based on the fourth issue of the diagnostic and statistical manuel of mental disorders (DSM) (Association, 2000), there are three subtypes of ADHD: Predominantly inattentive type, predominantly hyperactive type and the combined type. Attention deficit/hyperactivity disorder is not revealed on its own but is comorbid with many of the common disorders. These common comorbid disorders are comprised of learning disability, oppositional defiant disorder, conduct disorder, Tourette syndrome, depression, anxiety disorder, and bipolar disorder (Barkley, 2005; Cantwell, 1996). Various studies have reported that the disorder remains between 4 to 7.5 percent in the periods after maturity and adulthood (Association, 2000; Barkley, 2005).

That is the reason why this disorder is not merely considered as an illness of childhood. The researches display the fact that attention deficit/hyperactivity disorder is continued

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in 50 up to 80 percent of the children until the teenage years, and continued to exist in 30 up to 50 percent of the children until adulthood (Barkley, Murphy, & Fischer, 2010; Faraone, Biederman, & Mick, 2006). Attention deficit/hyperactivity disorder is in parallel with many difficulties in various domains of education such as poor performance at school, repetition of the school course, school dropout, poor state of family or friendly relationships, anxiety, depression, aggression, violation, drug abuse in young ages as well as the abundant break of the laws.

In addition, this disorder has the probable danger of coming along with other disorders like teenage aggression, defiance and oppositional disorders (Davids & Gastpar, 2005; Faraone et al., 2006). Therefore, it is necessary to intervene and diagnose in advance in order to reduce the mentioned difficulties. Working memory (WM) is the limited capacity of memory function that due to its ability for memorizing, operating and involving additional items related to scheduled objectives is considered to be different from the passive short-term memory (Pennington & Ozonoff, 1996).

Working memory involves phonological/verbal WM, visual/spatial WM, and the central executive that unites these minor processes. Examples of the working memory are included as recalling the list of daily chores while cleaning the bedroom, doing the mathematical calculations in your mind, bearing a question in mind that you may ask the teacher while learning the lesson. Most of the studies relating to the working memory reveal that the children with ADHD have extended difficulties on working memory compared with non-clinical groups (Barnett, Maruff, & Vance, 2009; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Sergeant, Geurts, & Oosterlaan, 2002; Toplak, Bucciarelli, Jain, & Tannock, 2008; Wåhlstedt, Thorell, & Bohlin, 2009; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005).

In addition, the students showed that there are significant differences between ADHD and nonclinical control groups in semantic-verbal memory (Barnett et al., 2009; Goldberg et al., 2005; Martinussen et al., 2005; Pasini, Paloscia, Alessandrelli, Porfirio, & Curatolo, 2007; Rapport et al., 2008; Re, De Franchis, & Cornoldi, 2010; Willcutt et al., 2005), and the difference between the two groups is more significant in the spatial working memory (Martinussen et al., 2005; Willcutt et al., 2005).

The findings show that the spatial working memory probably plays a more important role than visual working memory in ADHD, and this is probably true that both of them play key roles in the occurrence of ADHD during childhood (Castellanos, Sonuga-Barke, Milham, & Tannock, 2006). One study (Alloway et al., 2005) revealed that there is a significant relationship between working memory deficiencies and the social difficulties of the pre-school children. Phillips, Tunstall, & Channon (2007), discussed that the working memory deficiencies in children with ADHD may possibly harm their abilities in maintaining and recalling the information related to the social functions and the effective processing of the social guidance.

Working memory has relationship with many aspects of life. Memory has prominence for all aspects of information processing and that is the reason why it is invaluable to have a good memory during middle ages and late adulthood. Considering the importance of memory, many techniques have been applied to recover the memory of individuals. One of these methods is neurofeedback. It is an appropriate device in order to recover the cognitive processes.

Neurofeedback is the response of technology towards mental therapy, cognitive rehabilitation and poor cortex functioning and is a comprehensive education system that enhances the development and the modification at the cellular base of the brain (Demos, 2005). The method is applied successively in the spectral therapy of disorders such as depression, anxiety, post-traumatic stress disorder, personality disorder, attention deficit/hyperactivity disorder, addiction, and the emotional issues. Neurofeedback training works directly with the brain. Each client is instructed based on the therapy protocol related to his own disorder and in each session the improvement of the trainee is observable. Some of the trainees report higher mental clarity and lower mental ambiguity during the first session. On these circumstances, the basic counseling skills are used to help the trainee. Sympathy as well as positive unconditioned care provides an exciting and secure therapeutic atmosphere(Demos, 2005; Robbins, 2000).

Neurofeedback is a kind of rehabilitative approach in the therapy of ADHD/ADD (Barabasz & Barabasz, 1995)and its objective is the persistent nominalization of behavior without permanent dependence to drugs or behavior therapy. Neurofeedback assumes the neurological on the basis of the disorder. It is considered that the children, teenagers and the adults with attention deficit disorder have more activity of slow brain wave (theta) and less beta activity in comparison with the normal individuals. Neurofeedback attempts to instruct the patients to normalize their brain wave reactions to the stimuli (Mann, Lubar, Zimmerman, Miller, & Muenchen, 1992). J. F. Lubar, (1995) assert that the main hypothesis underlying the operation of neurofeedback in the therapy of ADHD is consisted of this assertion: “if one of the symptoms of the ADHD and ADD is biological/ neural dysfunction especially on the cortex and is mainly accompanied by the pre-frontal lobe function and if this infrastructural neurological deficiency can be corrected, the children with ADD and ADHD can show the paradigms and the strategies that the children without ADD/ADHD have previously possessed. The number of the neurofeedback sessions must be 20 up to 80 sessions (between 40 minutes and 1 hour) to settle EEG and the clinical modifications (Barabasz & Barabasz, 1995).

Various studies show that this therapeutic method is effective on the reduction of hyperactivity, the elevation of attention and concentration, the elevation of intelligent quotient grades, the satisfaction of parents from the behavior of their children and the recovery of the indices related to the continuous attention that are usually assessed through tests of continuous function assessment such as TOVA (Gevensleben et al., 2010; May & Kratochvil, 2010).

On the other hand, this method has so many critics that one of them is the outstanding researcher and theorist of ADHD, Russell Berkeley. One of the most recent critical review studies is the study published in the magazine of “applied neuropsychology” by Loo and Berkley (Loo & Barkley, 2005). They believe that this therapeutic method has stimulated an utter controversy between clinical and scientific societies. In the recent review study on the field of neurofeedback (Arnold, 2001; Nash, 2000; Ramirez, Desantis and Opler, 2001; narrated by Loo and Berkeley, 2005), it is generally concluded that the primary studies are hopeful but it is also necessary to carry out stricter controlled scientific studies.

Pointing out to certain studies that are done in the field of neurofeedback (Fuchs, Birbaumer, Lutzenberger, Gruzelier, & Kaiser, 2003; Lévesque, Beauregard, & Mensour, 2006; J. F. Lubar, 1995; J. F. Lubar, Swartwood, Swartwood, & O’Donnell, 1995; Monastra et al., 2006), Loo and Berkley concluded that the weak points of the methodology of previous studies make difficult to decisively deduce the usefulness and the precision of this method. Although the field of ADHD will have the profit of administering a non-medical therapeutic method, it is not advisable empirical data EEG-biofeedback in the clinical field. These researcher believe that though the current surveys of EEG-biofeedback revealed hopeful results in the therapy of ADHD, the belief in ADHD as an authorized therapy cannot be verified without precisely accurate scientific studies. But there are some researchers (J. F. Lubar, 1995; Monastra et al., 2006) who believe that if neurofeedback be presented in a body of multi-faceted therapeutic program, it can lead to behavior normalization and would raise the educational, social performance and general adjustment of the patient with ADHD in his everyday life. J. F. Lubar (1995) claims that neurofeedback would have the utmost effect when administered simultaneously with the medical treatment to treat the children with ADHD/ADD because the patient is treated from both sides. Mixed therapy of neurofeedback and stimulant drug is able to modify both the cortical and the arousal function.

Considering what is mentioned above, this research is carried out with the objective of designating the effectiveness of neurofeedback therapy on the working memory of children with attention deficit/ hyperactivity disorder.

2. Methods

The present study is a real experimental project with pretest and posttest owing to its having the control group. This research is done on 24 children with attention deficit/ hyperactivity disorder. The subjects were placed in two groups. 12 subjects received neurofeedback therapy and the other 12 did not. The subjects were matched based on the factors of age, sex, education, intelligence quotient (IQ), disorder intensity, and affliction by another comorbid mental disorder. The devices below were used to congregate data in the present research.

Spatial working memory in CANTAB

SWM is a test that assesses the ability of the subject in maintaining the spatial information and manipulation of the items presented in the working memory. This test is a sensitive scale for frontal lobe function and executive dysfunction. The test begins with a series of Colored Square on the screen. The objective of the test is that the subject should find a blue indicator in each page by means of elimination process and should use them to fill the empty column in the right side of the screen. The number of the square is rised from 3 to 8, and their color and place are modified from a trial to the other. Lowe and Rabbit (Falleti, Maruff, Collie, & Darby, 2006) have evaluated 162 advanced age subjects during 4 weeks. The reliability of the test-retest is

Table 1. Mean of and the standard deviation of working memory grades.

	Experimental		Control	
	M	SD	M	SD
WM	50	15.71	60.75	15.38

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Table 2. Levin test.

f	df1	df2	P
25.32	1	22	0.000

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reported (r= 0.7 total error) for the assignment of the spatial working memory.

Neurofeedback Training

In the research, neurofeedback instruction was carried out on the subjects of the experimental group that included a training course which was modeled as 2 months, 3 times a week and totally 20 sessions. The experimental group received a feedback during the session of the neurofeedback training that depended to their performances. The time allowed for each session was 1 hour. At the beginning of every session the primary assessment was taken (for 2 min) and then the training was given in the experimental group with the protocol of increase (SMR) (12-15)/theta repression (4-7).

3. Results

In order to study the hypothesis whether neurofeedback training affects the increase of working memory in children with ADHD, their working memory grades were compared in the stages of pre-test and post-test in both control and experimental groups. Table 1 shows the mean and standard deviation of working memory grades in the stages of pre-test and post-test in the studied groups.

Regarding the content of Table 1, it is observable that the mean of working memory grades in the experimental groups and control group were 50 and 60.75, respectively. Before analytic examination of the results in relation with the hypothesis, the research from the homogeneity variance is done as the necessary presumption to employ the covariance analysis in which the obtained results are inserted Table 2. Levin supposition is not reliable about the working memory variable, but while the groups are equal with each other, the lack of functioning in homogeneity variance supposition can be ignored.

As it is shown in Table 3, the differences between the grades of pre-test and post-test of two experimental and control groups were significant for the working memory variable ($P<0.01$) $F (21, 1)=33.16$, and the average of experimental group's grades is more than the control group in the working memory variable with the value of $F (21,1)=13.24$ and at the level of $P<0.01$. Therefore, the obtained results indicate the effect of neurofeedback training on the increase of working memory. In other words, neurofeedback training was successful in increasing the working memory of children with ADHD.

4. Discussion

The obtained results indicate that the neurofeedback training brings about the working memory recovery. These results are homolateral with the results obtained from the researches of Vernon et al (Vernon et al., 2003). Part of the protocol applied in this research was the increase of SMR. During the three past decades the researchers showed that the manifest practice of SMR activity has beneficial effects on the processing ability of the individuals with learning difficulties.

Various studies showed that SMR practice significantly significantly the grades of sustained attention scale in the individuals with ADHD (Gevensleben et al., 2010; J. O. Lubar & Lubar, 1984; Tansey, 1991; Tinius & Tinius, 2000). Egnar and Grozilar (Egner & Gruzelier, 2001) discussed that the increase of SMR activity is correlated with the decrease of performance error and the improvement of perception sensitivity in TOVA test and also correlated with the attention elevation related with P3b. Therefore, it can be concluded that SMR practice can elevate the attention processing.

The primary studies indicated that the frontal cortex has been modified in the children with ADHD (Woods & Ploof, 1997) that brings about the symptoms of inattention, disinhibition and impulsiveness and these

Table 3. Covariance analysis.

	SS	df	MS	f	P	2η
Group	1300.58	1	1300.58	13.24	0.002	0.38
Pretest	3257.54	1	3257.54	33.16	0.000	0.61
Error	2062.70	21	98.22			

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symptoms reflect the deficiency of cognitive functions. These functions are widely correlated with the cerebral systems presented in the prefrontal lobe. In accordance with what is mentioned before, the examinations of magnetic resonance imaging has reported significant volume decrease of prefrontal context of the children with ADHD (Castellanos et al., 1996; Mostofsky, Cooper, Kates, Denckla, & Kaufmann, 2002; Valera, Faraone, Murray, & Seidman, 2007).

The studies shaped by using Position Emission Tomography (PET) has reported lower cerebral blood circulation and low intensity of metabolism in frontal area in the children with ADHD compared with the control group (Sadock, Kaplan, & Sadock, 2007). The recent studies shaped by the application of PET have revealed that three areas of brain are involved in children with ADHD: frontal lobe, its relation with the basic nucleus and with central parts of cerebrum in children with ADHD (Venter, 2006). The neuropsychological studies in the animals indicated that during the passive but concentrated and alert behaviour, the attenuation of somatosensory input increases the successive discharge in ventricle thalamus cores which are the initiators of SMR (Howe & Sterman, 1972).

In addition, wider activities are reported in human studies in the range of 11-15 Hz in the sensory areas of cortex when visually the stimulus is attended in comparison with performing a motor task (Perry, Troje, & Bentin, 2010). Therefore, it can be asserted that motor activities that are correlated with the repression of SMR activity have a role in perceptive components and uniting the information processing (Sterman, 1996). Finally, the volunteer learning of SMR activity could facilitate the information processing by decreasing such a motor intervention and simultaneously by maintaining perceptive and memory functions in the state of alert. Sterman has performed theoretical studies on the probable infrastructural neural mechanisms of neurofeedback effects on SMR (Sterman, 1996; Sterman & Egner, 2006).

SMR is in maximum magnitude in sensorimotor cortex and has a positive correlation with the overstimulation in cerebral fibers of thalami-cortical somatosensory and somatomotor (Sterman, 1996; Sterman & Egner, 2006). Presynaptic cells become more sensitive with the repeated increase of SMR magnitude, and therefore, the probability of the subsequent activities of these cells would be increased. With the increase of arousal threshold, neurofeedback may possibly have beneficial effects on sensitivity and the multitude of seizures in epileptic patients. It seems that a similar increased arousal threshold in ADHD is responsible for the reduction of cortical and thalami-cortical overstimulation and also for the reduction of impulsive inclinations.

To describe the finding of the research in another way, it can be mentioned that the increase of SMR lead to the activation of neural circuit involved in working memory. The prior studies indicated that working memory is based on the neural circuit which is the result of the interaction between attention control system located at prefrontal cortex and the sensory information storage at posterior connecting cortex (Sarnthein, Petsche, Rappelsberger, Shaw, & Von Stein, 1998; Senkowski, Schneider, Foxe, & Engel, 2008; Von Stein & Sarnthein, 2000). As a result, it can be concluded that the increase of the wave of SMR leads to working memory improvement.

The other part of the protocol used in this research was theta repression (4-8 Hz). (Cartozzo, Jacobs, & Gevirtz, (1995) perceived that 30 sessions of neurofeedback cause a significant decrease in theta amplitude, the increase of attention domain in TOVA and the grade improvement in the agent of freedom from distractibility in Wechsler intelligence scale for children-revisited. Whereas in the artificial therapy of the control group, any increase in theta amplitude and the improvement in TOVA or freedom from distractibility (FD) was not observed.

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