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Research Article

THE EFFECTIVENESS OF NEUROFEEDBACK TRAINING ON THE EXECUTIVE FUNCTIONS OF STUDENTS WITH MATHEMATICAL DISABILITIES (DYSCALCULIA)

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ABSTRACT
The main purpose of this semi-experimental study was to analyze the effectiveness of neurofeedback treatment on the executive functions of dyscalculiac students. There were 10 female dyscalculiac students from learning disorders center of Tehran-Iran who participated in this study. The subjects were analyzed by continuous performance tests (Rosvold *et al.*, 1965) the computer version of Tower of London (Morris *et al.*, 1993) the Stroop test (Stroop, 1935) and the Cornoldi working memory test (Cornoldi and Vecchia, 1995) for executive functions. The group was randomly divided into the test and control groups. The test group was educated by neurofeedback method for 20 sessions in 45 days and the control group was in front of computer for 20 sessions without being educated under neurofeedback method. After the test the executive functions of both groups were measured. The data was analyzed by co-variance analysis. The results indicated that the neurofeedback training had a significant effect on the executive function of dyscalculiac students.

Keywords*: Neurofeedback, Dyscalculia, Executive Functions*

INTRODUCTION
Executive function are a set of activities that are responsible for the guidance, direction and management of cognitive and emotional, and detailed behavioral functioning during problem solving activities and consist of the functions of answering. Executive function is a general term related to all the complex cognitive goal-directed processes in doing homework (Welsh and Penington, 1988). Executive function has a complex arrangement involving self-regulation skills in behaviors and excitements, and the development of executive function is formed in early childhood and pre-school and continues until puberty and adulthood. Nonverbal working memory develops in the first few months of life from 12 to 24 months. The ability to control emotions is enhanced in the early years and the more demand for sophisticated social behavior, leads to more development of executive function (Steinberg and Scott, 2003). In addition, experience has shown that brain damage in the different stages of organization from development of a cell to the of the whole brain system development causes problems to executive functioning, these problems are: Failure in self-control behaviors, Tourette's syndrome and stroke (Segal and Rean, 1989).
We value executive functions and their role in educational progress. Given the importance of executive function, there are many employed methods to improve individual's executive function; neurofeedback is one of these methods. Neurofeedback is a useful tool for improving cognitive processes. It is a safe and painless way to improve brain function and self-control. The underlying mechanisms include enhancing self-regulatory mechanism required to efficient functioning (Siegfried, 2008).
Biofeedback Electroensfalography or (EEG): At the beginning this technique was wellknown. Neurofeedback is a technique in which people learn to change the pattern of brain waves by the biofeedback induced by preconditioning factor (Masterpasqua and Healey, 2003; Berner *et al.*, 2006).
Neurofeedback teaches people to normalize their brain waves in response to stimuli (Mann *et al.*, 1992). Neurofeedback may be used to stimulate or regulate the brain function. Neurofeedback is also used for

normal people (Berner *et al.*, 2006). Neurofeedback increases the working memory, accuracy and attention (Grazilier and Agner, 2004; Vernon *et al.*, 2003).

Brain waves are classified into four different categories according to their frequency. The four categories of the longest and shortest and fastest to slowest are as follows: Delta (1-3 Hz), Theta (4-7 Hz), Alpha (8-13 Hz) and Beta (14-30 Hz). The alpha activity is recognized when the person is relaxed but awake. But when a person involved in a cognitive or problem solving activity and the beta waves appear. Delta waves appear when a person is in a deep sleep and in light sleep theta waves appear (Demos, 2003).

In a study of 32 medical students were taught to increase the sensorimotor rhythm activity (SMR) (12-15 Hz) or theta activity (4 - 7 Hz). Only the SMR showed a change in EEG and significant improvements in attention and working memory while in the theta group no significant changes occurred in EEG or the attention and working memory. After 8 sessions of neurofeedback the SMR group was able to selectively enhance their SMR activity compared with the control group (This increase was determined by the change in the ration of SMR to theta and SMR to beta) (Vernon *et al.*, 2003).

Neurofeedback is a therapeutic model for changing the cognitive, emotional and physiological processes in patients. The results of the studies indicate that neurofeedback train the brain during sessions to fit the pattern of activity. There are many studies have been done on the effect of neurofeedback in the treatment of learning disorders. In Kouijzer *et al.*, (2009) that evaluates the effectiveness of neurofeedback on executive functions of autistic children the results showed that the executive functions had significant improvements after neurofeedback sessions. In Vosooghi *et al.*, (2013) the neurofeedback had positive effects on the executive functions of autistic children. Yaghobi *et al.*, (2009) showed that although Ritalin is more effective than neurofeedback but the patients should use the medications to control the symptoms but neurofeedback method has long term effect without side effect which makes it a better choice.

The executive functions need extensive structural and functional connections between different areas of the brain lobes. Recent studies show evidence of dissociation in the medial temporal lobe (Kaplan and Sadook, 2003).

The educational protocol was as follows: First the beta band (15-20 Hz) and long theta and beta bands were used as increasing and decreasing bands respectively and during the second part of the treatment the beta band of low beta band (12-15) was used as the increasing band.

MATERIALS AND METHODS

Method

The method of this study is semi-experimental. The introduced dyscalculiac students from learning disorders center of Tehran-Iran were randomly selected. The entrance criteria were the diagnosis of dyscalculia by DSM-IV and being 8-10years old with the IQ of 80 based on Wechsler's test mentioned in the student's profiles. After identifying the students with the criteria, their parents attended the center of learning disorders and after receiving the details of the method provided their agreements.

The entrance tests to measure the executive functions included continuous performance, Stroop, Tower of London and Cornoldi all of which were evaluated and standardized in the cognitive science research center (Tehrani *et al.*, 2003).

Then they were randomly divided into the test and control groups. The test group was educated by neurofeedback method for 20 sessions in 45 days and the control group was in front of computer for 20 sessions without being educated under neurofeedback method and just watching irrelevant pictures. In the end the groups took an executive function posttest. The results were followed a month later.

The tool used in this study was the demographic questionnaire (questions about age, degree and IQ).

The Cornoldi Working Memory Test

Cornoldi and Vecchia (1995). This test is known as working memory matrix. In this assignment only a 3*3 matrix which has a red spot on lower left side is used. This test includes three commands and the subject is asked to answer. The validity of this test based on the Cronbach's alpha coefficient is 0.61 and its reliability is reported 74% (Kakavand, 2003).

The Computer Version of Tower of London

According to Morris *et al.,* (1993) the tower of London was developed by Shallice (1982) to specify the planning ability of the patients with damage to the frontal lobe. In this test the last two rows of the figure are shown. In each sage the figure of the top row is kept intact and indicated the target figure and the lower row includes the rings that the subjects modify to get to the above figure. The movement of the rings is done through the first selection of the ring. Then the desired destination becomes possible. The target position is variable to the rings but the start point is the same. The less movements brings more score (Morris *et al.,* 1995). The variable are three types: 1) The number of Movements that the subject has resolved during the problem are considered as a measure of performance, 2) time to plan, time to touch the first circle 3) next thinking interval, which is the time between choosing the first ring and accomplishing the problem which is considered as a measure of performance (Morris *et al.,* 1993). The tower of London is used to measure the planning and organizing ability which is sensitive to the performance of the frontal lobe. The validity of this test is 0.79 and its reliability is reported 89% (Owen *et al.,* 1990; Morris *et al.,* 1993; Pantelis *et al.,* 1997).

Continuous Performance Test

Continuous performance test was designed by Rosvold *et al.,* (1965). This test used to be the most common way to measure inhibition and attention in 1990 in which the main stimulus is randomly placed on the screen among other stimuli and the subject was instructed to press a button when the target appeared. The variables include: 1) Number of errors made is the interval between the appearance of the target until the subject's response. The validity is confirmed by criterion validity and its reliability is reported 52%-93%.

The Stroop Test (Stroop, 1935)

This test that measures the attention, shifting ability and inhibition consists of three flashcards. The first flashcard is the point card. There are green, blue, red and yellow printed words on these flashcards. The subject is required to call the words irrespective of their colors. The third flashcard is the color card in which the green, blue, red and yellow words are printed with different colors. The subject is required to call the colors without paying attention to the meaning of the words. The error and time to read each flashcard are recorded. The Differentiation Index consists of the time to read the point and color flashcards. The validity of this test is 0.77-0.80 and the reliability is 86%-92%.

Neurofeedback Device

This device is used for two purposes: 1) recording the brain waves 2 representing feedback. The Procamp device had 5 channels and was made in Canada and it had sampling sensitivity of 256 Hz.

RESULTS AND DISCUSSION

Findings

Table 1 shows that there are reductions of redundant movements in level 3 and 4 in number of movements which is normal. There is a difference between the posttest scores of the test and control groups but it is not significant. There is a reduction of thinking interval in level 5 which is normal since the purpose is to reduce the time and this difference in statistically significant. There is a reduction in thinking interval of level 4 which is not significant but it is significant when the post test of the control and test groups scores are compare at the 3^{rd} and 5^{th} level. There is also a significant difference in post test planning interval scores of 3^{rd}, 4^{th} and 5^{th} level between the two groups after the neurofeedback education.

The pre and post test score of the two groups indicate the effectiveness of neurofeedback. There is no significant difference between the post test and follow up of the dependent variables which means that the changes made in the post test stage survived until the follow up.

Based on table 2 measures of attention, shifting ability and inhibition indicate that the time to interpret the point flashcards is relatively more than word and color flashcards in the test group compared to the control group which is significant. There is significant different between the error components of the test and control groups.

Table 1: The t-test results and correlation between the research variables in the computer version of Tower of London

variable	test group n=5 M pre test	post test	follow up	SD	control group n=5 M pre test	post test	follow up	SD	t	P
Number of movements										
Level 3	3/82	2/39	3/10	3/01	1/13	3/24	3/14	2/19	0/58	0/34
Level 4	9/53	6/8	6/53	1/92	2/33	8/65	8/15	8/58	0/26	0/31
Level 5	25/12	27/6	2/17	2/35	2/19	9/51	9/11	10/32	*0/00	10
Thinking interval										
Level 3	18/11	41/19	40/29	0/38	0/39	/11 21	23/43	26/80	*0/01	2/11
Level 4	21/62	35/31	34/72	1/51	1/32	/27 37	32/26	33/56	0/27	0/26
Level 5	38/17	58/42	59/60	1/32	1/92	/14 45	38/50	39/50	* 0/00	12
Planning interval										
Level 3	3/39	15/0	1/92	2/42	12/5	7/09	1/66	1/13	* 0/00	6/8
Level 4	4/61	71/1	2/65	2/78	66/3	4/75	1/23	1/67	*0/000	44/7
Level 5	6/47	69/1	1/49	3/15	11/4	6/61	0/69	0/21	*0/000	/12 52

$p<0.05$

So the neurofeedback has reduced the amount of errors in the word flashcards. In other words this component has improved attention, shifting ability and inhibition. The comparison of the post test and follow up indicated no significant difference between the two stages which means that the changes made in the post test stage survived until the follow up.

The mean, standard deviation and t-test results on the continuous performance test in the pretest, posttest, and follow-up of two groups are shown in Table 3.

Based on the table 3 after the post test the number of errors, the number of removals and decision making interval of the two groups is significantly different. In other words neurofeedback has improved attention, and inhibition of the dyscalculiac students. The comparison of the post test and follow up indicated no significant difference between the two stages which means that the changes made in the post test stage survived until the follow up.

Table 4 indicated the mean of the working memory scores of the dyscalculiac student's before and after the neurofeedback. In the 2nd and 3rd commands, there is a significant different between the posttest scores of the two groups.

Table 2: The t-test results and correlation between the research variables in the Stroop test

	Test group n=5				Control group n=5					
	M				M					
Variable	**Pre test**	**Post test**	**Follow up**	**SD**	**Pre test**	**Post test**	**Follow up**	**SD**	**P**	**t**
Time	22	19	17	3/65	36	35	29	1/92	*0/000	10/91
errors	/320	0/24	0/21	0/64	0/50	0/43	0/39	1/19	0/71	0/59
interval	/452	2/16	2/21	2/56	1/79	1/68	54	2/02	0/53	0/43
errors	/792	2/10	2/00	1/67	2/12	0/54	1/19	2/01	*0/019	2/23
interval	/132	1/49	1/42	2/65	2/51	2/02	2/13	5/57	0/59	0/25
errors	/033	1/34	1/25	1/23	3/61	2/64	2/21	3/48	0/78	0/82

p<0.05

Table 3: The summary of the t-test and correlation between the research variables in the continuous performance test

	Test group n=5				Control group n=5					
	M				M					
	Pre test	**Post test**	**Follow up**	**SD**	**Pre test**	**Post test**	**Follow up**	**SD**	**P**	**t**
Variable										
Number of errors	2/19	1/06	1/01	0/54	2/81	2/62	2/58	0/63	* 0/000	3/5
Number of removals	1/12	0/31	0/343	0/73	1/43	1/26	1/25	0/53	*0/000	3/9
interval	9/45	5/65	5/02	0/32	10/28	10/91	9/61	0/71	*0/000	6/2

p<0.05

Table 4: The summary of the t-test and correlation between the research variables in the working memory test

	Test group n=5				Control group n=5					
	M				M					
Variable	**Pre test**	**Post test**	**Follow up**	**SD**	**Pre test**	**Post test**	**Follow up**	**SD**	**P**	**t**
1st command	0/54	0/75	0/76	0/54	0/63	0/61	0/62	0/68	0/16	0/92
2nd command	0/33	0/79	0/63	0/61	0/49	0/24	0/21	0/16	*0/000	2/9
3rd command	0/25	0/65	0/65	0/19	0/61	0/59	0/48	0/29	*0/044	1/49

p<0.05

Then based on the above results the neurofeedback treatment has increased the working memory of the dyscalculiac students. The comparison of the post test and follow up indicated no significant difference between the two stages which means that the changes made in the post test stage survived until the follow up.

Conclusion

The results indicate the neurofeedback treatment improves executive function. This result is in line with Vernon *et al.,* (2003). A part of the protocol of this study was the simultaneous increase of Cz. This can be justified by the fact that the neurofeedback educational method affects three sensory, motor cortexes.

The therapists increased the sensorimotor rhythm activity in focus of attention through reducing the theta activity (7-12). And the group showed a significant improvement in executive functions.

After 8 neurofeedback session the test group could change the selective SMR beta activity into theta and the increase of SMR was done through the improvement of significance in SMR performance curve. The result indicated that the group showed Recall, task working memory and concentration (Vernon *et al.,* 2003).

Grazilier and Agner (2001) supposed that the neurofeedback treatment facilitates information processing because SMR reduces voluntary control of motor systems interact on cognitive information processing. Thus the results indicate the neurofeedback treatment improves executive function. In other words neurofeedback training could improve executive function in test group of students.

Increased sense of rhythm - move through neurofeedback improves perceptual sensitivity and reduces commission errors on the tasks and its impact on the SMR activity. However, the direct relationship with cognitive activity is not completely proven (Vernon *et al.*, 2003).

Sensorimotor cortex helps the cerebral cortex in physical and cognitive tasks of encoding and this is a performance of executive function. It is understandable why the early pioneers in the field of neurological treatment begun learning process along the sensorimotor cortex. In addition, Ratey (2001) adds "Brain circuits used for the regulation, sequencing and timing of a mental practice are the same as the ones used in regulation, sequencing and timing of a physical operation. This means that the sensorimotor cortex shares the leadership of both physical and mental processes. This cortex's responsibility is more than conducting sensorimotor functions."

Therefore, the clients who have difficulty in understanding sequential cognitive tasks can benefit from neurofeedback training in the treatment process.

neurofeedback training, systems that deal with sense of excitement, attention and working memory so closely that constitute the power supply, external actions (moves) and internal actions (reasoning, thinking) (Damasio, 1994).

In the SMR region in another explanation for the findings in this study it can be said that the increase leads to the activation of Neuronal circuits involved in executive function. The previous studies have shown that the working memory is based on Neuronal circuit which is the result of the interaction between the attention control system in the prefrontal cortex and the storage of emotional information in the communication dorsal cortex (Sarnthein *et al.,* 1998; Von *et al.*, 1999; Von and Sarnthein, 2000).

Theta suppression was part of the protocol; studies show that theta is associated with poor performance. The results indicated that theta suppression group had a better performance in discovery and the increased theta group had poor performance. In other words the neurofeedback training has positive impact on the mental performance and cognitive processes of individuals which is in line with Haness Mayer *et al.,* (2005); Watson (1978); quoted in Norris and Currieri (1999); Sterman *et al.,* (1994); Rasey *et al.,* (1995).

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