Comparison of Cognitive Training Method and Transcranial Direct Current Stimulation (tDCS) on the Visual Attention Processes in the Students with Special Learning Disorders

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Abstract

Introduction: Learning disabilities creates long-lasting damages to any individual in the activities dependent on academic skills. The present study was aimed to assess and compare the cognitive training method and transcranial Direct Current Stimulation (tDCS) on the visual attention processes in the students with special learning disorders.
Method: Forty-five students were selected based on a purposive sampling method and assigned to three groups: the control group and two experimental groups. (Each containing 15 individuals) based on a simple randomized method. The study has been conducted based on a semi-experimental design of pretest-posttest type with control group. One of the experimental groups received cognitive training for a period of 20 to 30 sessions, each lasting for 45 minutes (twice a week) and the other group was subjected to transcranial direct current stimulation for 20 minutes during ten consecutive days. The statistical method of choice was Multivariate Analysis of Covariance (MANCOVA).
Results: The results of data analysis using analysis of covariance indicated that both of the cognitive training method and the transcranial tDCS are effective in the visual attention processes ($P<0.01$).
Conclusion: Cognitive training and the transcranial tDCS methods can be applied for improving the visual attention processes in students with special learning disabilities.

Keywords: Visual Attraction Processes, Cognitive Training, Learning Disabilities, Transcranial Direct Current Stimulation (tDCS)

Introduction

Special learning disabilities includes the existence of disorder in one or several psychological processes [1]; it features an inhomogeneous nature and it is reflected in academic patterns, strength and weakness of information processing as well as in the main classification systems in various forms of academic inability within a certain academic area [2]. This disability creates long-lasting damages to any individual in the activities dependent on the academic skills like occupational performance, and is characterized by issues such as dyslexia, dysgraphia and dyscalculia [3]. Children with special learning disabilities are both wonderful and with conflicts. These types of students make a lot of efforts for learning and often need additional supports for success at school [4]. In regards to the etiological study of the special learning disabilities, the research evidence underlines the biological-neural etiology and two cerebral structures: parietal lobe and the mechanisms that are controlled by it and prefrontal lobe and the mechanisms controlled by it for the fact that one important mechanism of this latter part is executive functions [5]. Executive functions include basic cognitive processes such as attentional control, cognitive inhibition, inhibitory control, working memory, and cognitive flexibility [6]. Attentional control appears to emerge in

infancy and develop rapidly in early childhood. Cognitive flexibility, goal setting, and information processing usually develop rapidly during ages 7–9 and mature by age 12. Executive control typically emerges shortly after a transition period at the beginning of adolescence [7]. Visual attention processes are amongst the executive functions investigated in the present study as the dependent variable. Attention is amongst the issues intensively interwoven with the routine life. An individual needs attention when performing activities during a day [8]. Actually, attention is a distributed and self-organizing phenomenon without any specific structure.

Visual attention is the ability of focusing on the visual stimuli and includes consciousness as well as selective, stable and divided attention. To perceive correct information, there is a need for a good deal of visual attention; resultantly, this would cause the storage of correct information in the memory. Selective attention refers to the humans' processing capacity limitations in paying attention to several stimuli at the same time. Thus, some information elements should be given more priority than the others. Stable attention pertains to the capability of continuing a consistent behavioral reaction during a continuous and repetitive activity. Therefore, an individual should be able to maintain focus on the intended subject during a long time period. Divided attention is the ability of simultaneously reacting to several different tasks. When attention is apportioned between several subjects, a short time is spent on changing the attention to the subjects and their displacement [9, 10]. Visual attention processes are necessary for secondary organization of the cerebral cortex and getting ready for brain's excellent cognitive activities [11]. Since the visual attention processes depends on some cerebral structures, it seems that the neurological interventions like transcranial Direct Current Stimulation (tDCS) can be effective on them. Actually, tDCS is a neural treatment method that inputs a direct and weak current to the cortex regions of the brain and facilitates or inhibits the spontaneous brain activities [12]. The method has been extensively examined and studied during the past decade and it is a noninvasive, cheap and safe alternative for changing the sensitivity of the cerebral cortex via changing the rest potential of the nerve cells therein [13, 14, 15]. This weak and direct current is transmitted by an anode and usually a cathode, two electrodes with different poles, that are connected to various spots of the skull surface and lead to the stimulation of the underlying neurons. Cathode stimulation causes reduction in brain's sensitivity and the anode stimulation causes an increase in brain's sensitivity [16]. It has been shown in the prior studies that tDCS has caused an improvement in the visual processing speed in the patients with major depressive disorder [12, 17], increases the executive attention of the healthy people [18] and the elevation of the eyesight vigor [19]. On the other hand, considering the fact that the visual attention processes are amongst the brain's executive functions and are associated with cognitive abilities, it seems that cognitive training, can be effective therein. Cognitive training or cognitive rehabilitation points to certain behavioral interventions that bring about improvement in the performance of the cognitive and executive areas; thus, an individual's executive capacity is enhanced [20]. In fact, cognitive training refers to the instructions that are based on cognitive sciences' findings but it tries through playing games (mostly computer games) to improve or enhance the cognitive performance and all of these cases point to the principle of brain's flexibility [21]. Mihuta [22] and Rilo [23], showed the effectiveness of this method for improving the cognitive performances of the patients with cancer and patients with MS in the area of executive performance. Furthermore, the usefulness of the cognitive training method has been well specified in the improvement of the cognitive performance of the patients with cerebral damage [24].

Many researches have been conducted about the effectiveness of the cognitive training method and tDCS on the students with special learning disabilities. Combined treatment using tDCS and reading instruction in the adolescents with reading problems has been proved effective [25]. Heth & Lavidor [26], as well, demonstrated in similar studies that tDCS is effective and improves the speed and fluency of reading in adults with reading problems. Anodic stimulation improves the visual/spatial performance of the children with dyslexia. In addition, it was found out in a study that the transcranial direct electrical current stimulation influences the active memory of the children with math problems [1]. The neurological rehabilitation has been proved effective in the math performance and working memory of the students with math problems [27]. Cognitive rehabilitation program can be utilized as a novel and fascinating method for children along with the other common methods for spelling disorders considering individual differences [28].

According to the prevalence rate of the learning disabilities in the society and considering the necessity for performing effective and on-time interventions as well as the recognition of the most effective treatment method, the present study was aimed to assess and compare the cognitive training method and tDCS on the visual attention processes (congruent response, incongruent response, rate of correct response and response time) in the primary school students with learning disorder.

Method

The present study was conducted based on a semi-experimental method (pretest-posttest) with a control group. The groups that received treatment included the cognitive training group and tDCS group, both of which were called experimental groups. There was also a control group which did not receive any intervention. The study population included 520 primary school (second to fifth grade) students with special learning disability in the city of Ilam during 2017-2018 academic years. These students had been referred to the education organization's counselling centers in Ilam by the request of their teachers and had been found with special learning disorders as figured out by the psychologists therein. Among them, 130 students who had the required features were listed

through availability sampling method. Then, 45 students were selected based on a purposive sampling method and assigned to three groups: the control group and two experimental groups (Each containing 15 individuals) based on a simple randomized method. The inclusion criteria were: aged between 8 and 12 years; IQ score between 85 and 115, in the Wechsler's intelligence scale for children; and not having a disorder other than learning disabilities. The study implementation stages included pre-test using meta-memory test using CogLab Software for both the experimental and control groups and, then, cognitive training and tDCS treatment sessions only for the experimental groups. The cognitive training was offered in twenty 30- to 45-minute sessions (twice a week) and transcranial direct current stimulation was carried out for ten consecutive days, 20 minutes each time. The control group did not receive any intervention. Two weeks after the pre-test, all three groups were subjected to post-test using meta-memory test, and there was no drop in the number of participants.

The tools used in this study were as follows:

Visual attention processes test: This test is a cognitive psychology experiment in CogLab software that, besides the visual attention processes, includes eight other primary parts (imagination, memory processes, working memory, short-term memory, sensory memory, neurology, perception and meta-memory). Each part is tested by several experiments each of which can be selected in proportion to the study intentions. Visual attention processes include several experiments. The present study makes use of two experiments, named Simon's effect and discovery of change. The Simon effect test includes the congruent and incongruent response indicators. The change discovery experiment, as well, incorporates two indicators of the rate of correct response and response time. Therefore, the aspects of the visual attention processes that were investigated in the present study are "congruent response", "incongruent response", "rate of correct response" and "response time". The software works as explained in the following words: a window appears for each experiment that is spread all over the screen and a smaller window also comes up with it that bears a summary of the instructions [29].

Transcranial Direct Current Stimulation (tDCS): It is a relatively old technology which has been resumed and it is applied for a vast spectrum of the cerebral diseases including learning disorder. The treatment is exerted by a device that is also known with the same name. The tDCS device is a small brain stimulator that transmits a constant electrical current through the skull into the brain via connecting electrodes with different polarities (anode, activator and cathode, deactivator) on the head skin. The electrodes are made of carbon and conductive and are placed inside artificial sponges soaked in saline for preventing any chemical reaction at the contact point between the electrode and the skin [30]. The electrodes' dimensions were 5×5 cm in the present study and they were placed on the dorsolateral prefrontal lobe of the left hemisphere for transmitting a 1.5-milliamper current for 20 minutes.

Cognitive training: The intervention used in the present study was an instruction offered by the use of Sound Smart Software to the experimental group. Sound Smart is a wonderful instructional program designed like computer games. The program has 11 games in various levels and, besides instructing and exercising alphabets, improves the attention skills and active memory, hearing skills, spelling and pronunciation of the letters, separation and distinguishing of the sounds, math lessons for students in the first to fifth grades, following the orders, processing speed of the brain and even impulse control (these are skills that are necessary for success in life and education). Sound Smart program has unexampled effects on the cognitive and learning abilities of the children, especial in the primary school and preschool ages [21]. Each of the participants in an experimental group were instructed about the work process and stages during the first session and all of them were presented with an exercise session to get familiar with the computer and computer space. After on, each of the participants was subjected to training sessions.

Data analysis was conducted using Multivariate Analysis of Covariance (MANCOVA) method.

Results

The test's presumptions were evaluated before multivariate covariance test. The investigation of the scatter diagrams was indicative of the existence of a linear relationship between the dependent variables and the data were found featuring normal distribution. Additionally, to observe the multivariate covariance test's assumptions, Box's M and Levene's tests were done. Based on Box's M test that gave no significant result for any of the variables, the variance and covariance matrices' homogeneity condition was observed. Based on Levene's test and considering its insignificant results for any of the variables, the parity condition of the inter-group variance was observed. The correlation results showed that there is a significant correlation between the dependent variables in an acceptable limit. The homogeneity assumption of the regression slopes was also observed.

Tables 1 and 2 give the results of the pre-test and post-test's means and standard deviations as well as the results of the modified means and standard deviations of the visual attention processes (congruent response, incongruent response, rate of correct response, response time) for the experimental and control groups. There was a significant difference between the control and experimental groups' mean in terms of the dependent variables of visual attention processes (congruent response, incongruent response, rate of correct response, response time) (Table 1). There was also a significant difference between the modified mean of the control group and experimental groups. The modified mean and standard deviation for dependent variables is presented in Table 2.

Cognitive training and tDCS were found exerting effects on the visual attention processes (congruent response, incongruent response, rate of correct response, response time) (Table 3). In addition, the results of Wilk's lambda

test were significant for the combined variable of visual attention processes. The results of the comparing cognitive training and tDCS methods between the experimental and control groups and the results of the analysis of covariance for the dependent variables of the visual attention processes have been summarized in Tables 4, 5 and 6. The significance of the new combined variable is suggestive of the idea that the participants from all three groups were different from one another and the mean values of the intervention groups were found significant subject to the effect of independent variable.

According to the data presented in Table 4, the mean scores of the visual attention processes for both of the experimental groups and the control group in the post-test stage were found significantly different at least in terms of one of the visual attention processes' variables.

Table 5 gives the analysis of covariance results between the experimental groups and control groups. Eta value is reflective of the idea that almost 62.7% of the congruent response variations, 74.5% of the incongruent response variations, 79.5% of the rate of correct response variations and 68.7% of the response time variations have been accounted for by the group variable. Considering the fact that the calculate F-value was significant for the amounts obtained for the visual attention processes, Lam-Trix follow-up test was employed to compare the difference between the mean values of attention processes in the cognitive training group and tDCS group.

Table 1. Statistical characteristics of the dependent variable components of the visual attention processes

Components		Groups					
		Cognitive		tDCS		Control	
		M	SD	M	SD	M	SD
Congruent response	Pre-test	632.66	72.50	626.19	70.61	671.18	55.91
	Post-test	672.74	72.50	646.64	70.61	671.25	55.92
Incongruent response	Pre-test	681.34	46.47	46.40	46.40	653.31	81.69
	Post-test	563.03	45.94	598.34	55.98	634.91	81.96
Rate of correct response	Pre-test	1.65	.23	1.60	.34	1.66	.13
	Post-test	2.68	.22	2.18	.25	1.72	1.26
Response time	Pre-test	729.49	744.67	7444.14	420.31	6980.07	759.61
	Post-test	6547.87	816.16	7081.69	393.51	6960.24	774.21

Note: There was a significant difference between the control and experimental groups' mean

Table 2. Modified mean and standard deviation for the dependent variables of visual attention processes in the post-test stage

Components	Groups					
	Cognitive		tDCS		Control	
	M	SD	M	SD	M	SD
Congruent response	683.936	3.283	663.544	3.354	643.145	3.649
Incongruent response	544.786	7.426	583.482	7.586	668.009	8.252
Rate of correct response	2.693	.054	2.213	.055	1.673	.060
Response time	6487.729	52.525	6871.431	53.65	7230.641	58.369

Note: There was a significant difference between the control and experimental groups' modified mean

Table 3. Multivariate analysis of covariance of F ratio for the mixed variable size of visual attention processes

Source	Value	F	p	η
Combined variable (group)	.059	27.239	.0001	.757

Table 4. Multivariate analysis of covariance results of visual attraction processes

Tests	Value	F	df	Error df	p	Effect size
Pillais Trace	.001	9.023	8	72	.0001	.501
Wilks Lambda	.059	27.239	8	72	.0001	.757
Hotelling's Trace	14.896	63.307	8	72	.0001	.882
Roy's Largest Root	14.827	133.441	4	36	.0001	.937

Table 5. Single-variable analysis of covariance for the variable of visual attention processes

Source of variable	SS	df	MS	F	p	Effect size	Power
Congruent response	9635.467	2	4817.734	31.921	.0001	.627	1.00
Error	5735.281	38	150.928				
Incongruent response	85540.876	2	42770.438	55.396	.0001	.745	1.00
Error	.174	38	.005				
Rate of correct response	5.957	2	2.979	73.796	.0001	.795	1.00
Error	1.534	38	.040				
Response time	32200085.132	2	610042.566	41.683	.0001	.687	1.00
Error	1467796.094	38	38626.213				

A significant difference was found between the adjusted means of both of the groups in terms of congruent response (Table 6). The difference in the mean value of "I recall" (F = 20.391) for the students with special learning disability is suggestive of the idea that those who had been subjected to cognitive training tend to exhibit more congruent response than those subjected to tDCS.

Based on the results of Table 6, there is a significant difference between the adjusted means of the two groups in terms of incongruent response. The difference in the mean value of "I only know" (F = - 38.696) for the students with special learning disability is reflective of the idea that those who had been subjected to cognitive training tend to exhibit less incongruent response than those subjected to tDCS.

As it is shown in the covariance results presented in Table 6, there is a significant difference between the adjusted means of the two groups in terms of the rate of correct response. The difference in the mean value of "rate of correct response" (F = 0.481) for the students with special learning disability is indicative of the idea that those who had been subjected to cognitive training tend to give more correct responses than those subjected to tDCS.

A significant difference was found between the adjusted means of the two groups in terms of the response time. The difference in the mean value of "response time" (F = -383.702) for the students with special learning disability demonstrated that those who had been subjected to cognitive training needed shorter response time than those subjected to tDCS.

Table 6. Single-variable analysis of covariance for the variable of visual attention processes in cognitive training and tDCS groups

Source of variable	SS	df	MS	F	p
Congruent response	3034.152	1	3034.152	20.103	.0001
Error	5735.28	38	150.928		
Incongruent response	10926.321	1	10926.321	14.152	.0001
Error	29339.003	38	772.079		
Rate of correct response	1.685	1	1.685	41.742	1.685
Error	1.534	38	23.113		
Response time	1074311.402	1	1074311.402	28.813	.0001
Error	1467796.094	38	38626.213		

Discussion

The present study was carried out with the objective of determining the effectiveness of cognitive training and tDCS in the visual attention processes of the students with special learning disabilities. The results indicated that cognitive training is effective in the visual attention processes. This finding is consistent with what has been attained in the study by Mihuta [22] who showed the effectiveness of this method in the improvement of the cognitive and executive functions. Rilo [23] also demonstrated the effectiveness of the foresaid methods in the cognitive processing speed. It can be stated in elaborating this finding that the learners' attention to the lesson's subject is amongst the primary factors in teaching and learning in such a way that Bandura emphasizes that the preliminary stage of each learning activity begins with visual attention and, in case that the attention is paid less than enough, the individual's learning would be flowed [31]. Attention is one of the most important tasks of the mind and it is alone one major aspect of the cognitive structure that plays a significant role in the structures of intelligence, memory and perception. The corroboration of the visual attention processes using cognitive training method can improve indicators of reading, written expression and math as well as the executive functions of the children with special learning disabilities [32]. The other logical reason is the strong relationship between the brain's performance and the cognitive training and instructions in such a manner that cognitive training causes an increase in the brain levels of norepinephrine and dopamine that are neurotransmitters playing an essential role in attention and thinking systems. Thus, cognitive training can improve the executive capacities of the individuals. On the other hand, computer games-assisted cognitive training is enjoyable to the majority of the children. Games cause pleasure and instigate the secretion of norepinephrine and dopamine in the brain and this enhances the visual attention processes and strengthens attention in the participants [33]. This finding is consistent with the research results conducted by Bogdanova et al. [24].

The present study's findings also indicated that tDCS influences the visual attention processes. This finding is in compliance with what has been found in the studies by Gögler [17] who showed that tDCS causes an improvement in the visual processing speed. Also, it is in accordance with the findings of the study by Miler et al. [18] who figured out that tDCS increases executive attention. This finding can be clarified in this way that the electrical stimulation of the skill causes changes in the neurons' performance and heightens the surficial sensitivity in the cortex to increase dopamine release. As it was mentioned above, dopamine causes an increase in cognitive ability and the visual attention processes are enumerated amongst the executive and cognitive functions. As a result, this process also causes an increase in learning. On the other hand, tDCS changes the neurons' sensitivity and the displacement potential of the surficial neurons' cortex parallel to depolarization or hyperpolarization of them in order to enable the higher or the lower charging of the brain cells. Visual attention processes, including the executive functions, are associated with such parts of brain as the prefrontal cortex and this part is stimulated via a weak current as a result of which the brain's neurons' function is decreased or increased. Since the epicenter of transcranial direct

current stimulation on the skull is somewhat limited, its functional effects directly appear in the limited region beneath the electrodes and this causes an increase or decrease in the neurons' functioning [30]. Actually, tDCS can modulate cortical excitability through the application of a current between two electrodes [34]. Typically, anodal tDCS is thought to induce subthreshold membrane depolarization [35], and it has been suggested that tDCS modulates mechanisms of cortical meta plasticity which in turn modifies the synaptic bonds between neurons [36]. As tDCS modulates cortical plasticity (cortical plasticity is generally involved in learning), the application of tDCS has the potential to modulate learning and memory [37]. Moreover, several studies have found modulating effects of parietal cortex tDCS in episodic memory [38, 39, 40].

According to the fact that the study sample volume was consisted of the students with special learning disabilities in the present study, reference can be made to other research that have investigated the effectiveness of the cognitive training in this special population [27, 28]. One of the reasons that can be offered in this regard is that the changes in all of the participants were brought about during the intervention stage and the recorded evaluations demonstrated changeability of the individuals' scores along the baseline. Additionally, considering the fact that the cognitive processes are engaged in special learning disabilities, cognitive training programs that are mostly concentrated on the enhancement of the cognitive abilities are enumerated as a special and unique treatment. The other matter that can be introduced in elucidating the foresaid finding is that the instruments utilized in the cognitive training are different in all experiments which as a result end up not being repetitive for the students. Moreover, these exercises strengthen attention, memory and problem solving within the format of game and match. The fascinating appearance of these games makes the children get involved in them with more excitement and without getting tired and the temporal limitations entice more efforts and increase in the children's speed of performing the activities. Therefore, these attractions help to improve the homework performance in students with special learning disabilities [1, 25, 26, 30].

Although the examined study groups in the present study were similar in every respect, the findings cannot be generalized due to the aforementioned cases. Also, it can be suggested that future research should consider running the cognitive training method and tDCS on groups featuring more diversity and various degrees of learning disorders as well as larger study sample sizes.

Conclusion

Since cognitive processes such as visual attention have a great role in the occurrence of specific learning disabilities, electrical stimulation of the skull changes the function of the neurons and enhances cognitive ability, and increases the attention and stimulating-response learning process. As a result, increasing visual attention processes can improve learning disabilities. So, it is suggested that timely diagnosis of learning disabilities and the use of electrical stimulation and cognitive training methods can prevent secondary problems caused by this disorder in students. The moderating role of gender and family-related variables should be also taken into account in regards of the aforementioned methods' effectiveness in the future researches. Since the cognitive rehabilitation method was associated with the game, the participants' motivation to participate and respond to it was more than the tDCS method.

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