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The Effectiveness of Cognitive Training Method and Transcranial Direct Current Stimulation (tDCS) on the Metamemory in the Students with Special Learning Disorders

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Abstract

Background: *The present study was aimed to determine the effectiveness of cognitive training method and transcranial direct current stimulation (tDCS) on the metamemory in the students with special learning disorders.*
Methods: *The study has been conducted based on a semi-experimental design of the pretest-posttest type with a control group. Forty-five students were selected based on a purposive sampling method and assigned to two groups, a control group and an experimental group (each containing 15 individuals) based on a simple randomized method. One of the experimental groups received cognitive training for a period of 20 to 30 sessions, every 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 covariance analysis (ANCOVA). Significant level was set at 0.05.*
Results: *The results of data analysis using covariance analysis indicated that both the cognitive training method and the transcranial direct current stimulation (tDCS) were effective in the metamemory (Pvalue < 0.01).*
Conclusions: *Cognitive training and the transcranial direct current stimulation (tDCS) methods can be applied for improving the metamemory in students with special learning disabilities.*

Keywords: Metamemory, Cognitive training, Learning disabilities, Transcranial direct current stimulation (tDCS).
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Introduction

The term "Learning disability" was first introduced by Samuel Kirk in 1962. Since then, the disorder has been always taken into consideration by researchers.[1] The specific learning disability is a disorder in one or more psychological processes,[2] has heterogeneous nature, and can be seen in education models, and information processing strength and weakness, as well as major classification systems as specific domain learning disorder.[3] In the fifth edition of the American Diagnostic and statistical manual of mental disorders (DSM-5), the learning disorder is renamed to a specific learning disorder; and reading, writing, and mathematical disorders, each of which was previously considered as a separate disorder, are now included in the specific learning disorder as a marker.[4] The prevalence of learning disabilities is reported to be from 5% to 15%.[5]

Memory is an important feature in children with specific learning disability[6] and refers to the ability to acquire, maintain and retrieve information that is classified in various ways.[7] The metacognitive knowledge of memory is called the metamemory[8] that refers to self-checking and controlling memory in acquiring new information and reviewing the previously-acquired information and includes the individual memory capabilities and strategies that can help one's memory in fields that are involved in the self-control.[9] The optimal memory function includes an accurate estimation of individual memory capabilities and the use of memory principles to enhance performance.[10] Memory has two main components in terms of content, each of which is equivalent to a particular type of knowledge. The variable is the first component which represents the enduring knowledge about variables that affect memory. The second component includes memory monitoring and controlling, and is also called the process knowledge.[11] Memory, along with other factors such as beliefs, thoughts, attention, and metacognition are parts of cognitive processes that are involved in information processing.[12,13]

Cognitive training or rehabilitation methods and transcranial direct current stimulation are two effective methods to treat and improve the performance of students with specific learning disabilities. Cognitive education is an approach that has been utilized to reduce symptoms of learning disability in recent years.[14] The method includes a wide range of therapeutic methods, such as performance-based therapies, which aim to reinforce or re-establish previous behavioral patterns and stabilize new behavioral patterns.[15] In fact, cognitive training refers to training that is based on findings of cognitive sciences, but in game forms (generally computer games) and seeks to improve or promote cognitive functions (accuracy, attention, visual-spatial perception, auditory discrimination, memory types, and other executive functions) that all point out the brain flexibility principle.[16] The researchers' findings indicate the effectiveness of cognitive training techniques.[17-19] Mihuta et al.[20] studied the effectiveness of this method in improving cancer patients' cognitive functions in the field of executive function and attention. Rilo et al.[21] also found that cognitive training programs significantly improved working memory, verbal memory and executive functions in patients with MS. In a study to determine the effectiveness of computer assisted cognitive rehabilitation (CACR) on working memory in children with attention deficit/hyperactivity disorder, Arshad[22] concluded that the CACR was successful in improving active memory deficits and symptoms of attention-deficit/ hyperactivity disorder. Nazari et al.[23] examined the effectiveness of cognitive rehabilitation in reducing spelling errors in students with dyslexia and concluded that the cognitive rehabilitation program could be used as a new and attractive method for children, along with other common methods for spelling disorder by taking into account individual differences. Kesler et al.[18] conducted a study titled "a preliminary review of an online cognitive training program for executive functioning skills in children with brain injury-related cancer. Their results indicated that the computerized cognitive training program significantly increased processing speed, cognitive flexibility, verbal and visual declarative memory scores, and also played a significant role in increasing the prefrontal cortex (PFC) activity. On the other hand, the transcranial direct current stimulation (tDCS) is a neuro-therapeutic approach that enters direct and weak current into the cortex and facilitates or inhibits self-stimulated neural activity.[24] The method has been extensively tested and studied over the past decade and acts as a noninvasive, inexpensive, and safe alternative[25-27] to change the cortical stimulation by altering the resting potential of cortical neurons. This weak and direct current via an anode and the connection of two electrodes to different poles (of usually a cathode) leads to the stimulation of inferior neurons at different points on the skull surface. The cathode stimulation reduces brain stimulation, but the anode stimulation increases the brain stimulation.[28] In a study with an aim to investigate the impact of transcranial direct current stimulation and phonological awareness training on visual/spatial dimension of working memory in dyslexic children, Bayat-Mokhtari et al.[29] found that the anodic stimulation improved the individual performance in visual/spatial memory and subsequently, improved the problem of dyslexia in children. With an aim to investigate the therapeutic effect of transcranial direct current stimulation (tDCS) on the active memory of children with the mathematical disorder, Arjmandnia et al.[2] found that the intervention was effective in improving the active memory in children with the mathematical disorder. In a study with an aim to improve executive functions of the brain using direct electrical current, Samiei Sanjani[30] found that the anodic stimulation promoted selective attention and memory. In a study to investigate the effects of the tDCS on working memory in the posterior lateral prefrontal cortex, Arkan and Yaryari[31] found that the anode stimulation reduced response time and increased number of correct responses, and it seemed to improve working memory. Bennabi, and Haffen[32] found the effectiveness of tDCS in the treatment of major depression. Garcia et al.[33] found that there was a distinction in the effectiveness of tDCS on the metacognition, sense of understanding, and recall between stimulation of primary anterior lobe and dorsal prefrontal cortex; and the effectiveness was moderated by task difficulty. Lally et al.[34] studied the effectiveness of transcranial direct current stimulation on increased working memory. Andrews et al[35] used transcranial direct current stimulation to improve working memory and examined its effects on cognitive activity in the left prefrontal cortex. As mentioned, studies have been conducted on the effectiveness of each of interventions on memory function, and there is no research on the comparison of these two therapies.

On the other hand, there has been no study on the effectiveness of any cognitive training and transcranial direct current stimulation methods on the metamemory.[36] Given the prevalence of learning disorders in society and the need for effective and timely interventions as well as identifying the most effective therapeutic methods, the present study investigated whether there was a difference between the effectiveness of cognitive training methods and transcranial direct current stimulation (tDCS) on the metamemory (I only know; I remember; percentage of reminder clues; percentage of memory judgment; and false memory) in students with learning disorder at elementary schools of Ilam.

Materials and Methods

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 the experimental groups; there was also a control group that did not receive any intervention. The study population included the entire primary school students with a special learning disabilities in the city of Ilam during the 2017-2018 academic years. These students had been referred to the education organization’s counseling centers in Ilam by the request of their teachers and had been found with special learning disorders as figured out by the psychologists therein. Forty-five students were selected based on a purposive sampling method and assigned to two groups, a control group and an experimental group (each containing 15 individuals) based on a simple randomized method. The study implementation stages included pretest using a metamemory 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. In the end, all three groups were subjected to a posttest using a metamemory test. The instruments used in this study included the following:

Metamemory test: the test is a cognitive psychology experiment in CogLab software that, besides the metamemory, includes eight other primary parts (imagination, memory processes, working memory, short-term memory, sensory memory, neurology, perception, and metamemory); each part is tested by several experiments each of which can be selected in proportion to the study intentions. The metamemory includes three tests, namely remember/know, false memory, and I have totally forgotten effect. The remember/know test consisted of components, namely I only know and remember; and the test of I have totally forgotten included two components, namely percentage of recall clues and percentage of memory judgment. A false memory test also lacks any component. Therefore, the examined metamemory dimensions in the present study were as follows: "In only know", "I remember", "percentage of recall clues", "percentage of memory judgment" and "false memory". According to software instructions, a window will appear for each experiment that covers the entire screen with a smaller window with a summary of instructions[37].

Transcranial direct current stimulation (tDCS): it is a relatively old technology the use of which has been resumed and it is applied for a vast spectrum of cerebral diseases including learning disorder. The treatment is exerted by a device that is also known with the same name. 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[29]. The electrodes' dimensions were 5 × 5 in the present study and they were placed on the dorsolateral prefrontal lobe of the left hemisphere for transmitting a 1.5-milliampere current for 20 minutes.

Cognitive training: the intervention used in the present study is 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 primary school and preschool age[20]. Each of the experimental group's individuals was 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; next, each of the participants was subjected to training sessions. Data analysis was conducted using multivariate analysis of covariance method.

Results

Tables 1 and 2 present the examination of mean and standard deviation of pre-test and post-test and adjusted metamemory level (I remember, I only know, false memory, percentage of recall clues, percentage of memory judgment) in experimental and control groups. Table 1 presents the statistical characteristics of experimental and control group variables.

According to figures of table 1, there is a difference between the mean of control and experimental groups independent metamemory variables (I remember, I only know, false memory, percentage of recall clues, percentage of memory judgment). Table 2 presents the results of the adjusted mean for dependent variables.

The Eta-squared (η2) values in table 3 are a fraction of variance that is associated with a new hybrid variable. The general rule is that if this value is 0.14, there is a high degree of cognitive training and transcranial direct current stimulation (tDCS). Table 3 presents the value for a new hybrid variable called the 0.786 group. It indicates the effect of cognitive training and transcranial direct current stimulation (tDCS) on metamemory (I remember, I only know, false memory, percentage of recall clues, and percentage of memory judgment). Furthermore, the results of the Lambda Wilks test were significant about the hybrid metamemory variable (I remember, I only know, false memory, percentage of recall clues, and percentage of memory judgment). Tables 4, 5 and 6 presents a comparison of cognitive training and transcranial direct current stimulation (tDCS) and the control group in results of the analysis of covariance for dependent metamemory variables (I remember, I only know, false memory, percentage of recall clues, and percentage of memory judgment). The significance in the new combination variable indicates that participants are different in the three groups and the mean of groups is significantly affected by the independent variable (F = 24.249 and Pvalue < 0.01).

According to the data of Table 4, the mean metamemory scores (I remember, I only know, false memory, percentage of recall clues, and memory judgment percentage) in both experimental and control groups were significantly different at least in one of metamemory disorder variables (I remember, I only know, false memory, percentage of recall clues, and memory judgment percentage). For an accurate investigation, table 5 presents the results of analysis of covariance in the difference between experimental and control groups in each of the metamemory variables (I remember, I only know, false memory, percentage of recall clues, and percentage of memory judgment).

Results of univariate analysis of covariance (ANCOVA) are presented in table 5. Since there are 5 dependent variables, the Bonferroni correction is implemented by dividing 0.01 by American psychiatric association.[5] Therefore, the significance level is less than 0.002 and it is true for all five variables. Eta value indicates that almost 85.1% of "I remember" variable variance, 78.9% of "I only know" variance, 72.8% of "false memory" variance, 68.8% of "recall clues" variance, and 65.9% of "memory judgment percentage" variance is taken into consideration for the group variable (table 5).

Since the calculated f-value of metamemory level (I remember, I only know, false memory, percentage of recall clues, and memory judgment percentage) was statistically significant, the Lometrics post hoc test was used to compare difference in the mean metamemory (I remember, I only know, false memory, percentage of recall clues, and percentage of memory judgment) in the cognitive and transcranial direct current stimulation (tCDC) groups to determine which group was more effective in amount of metamemory (table 6).

Based on the results of the analysis of covariance in table 6, there was a significant difference between the adjusted mean of two groups in the "I remember" variable (F = 80.533, Pvalue < 0.01) (table 6). The mean difference of "I remember" (0.478) indicated that students with specific learning disabilities under the influence of cognitive training had higher scores in the "I remember" variable than the group of transcranial direct current stimulation (tDCS.

There was a significant difference between the adjusted mean of two groups in the "I only know" variable (F = 56.484, Pvalue < 0.01) (table 6). The mean difference of "I only know" (0.209) indicated that students with specific learning disabilities under the influence of cognitive training had higher scores in the "I only know" variable than the group of transcranial direct current stimulation (tDCS).

Based on the results of the present study There was a significant difference between the adjusted mean of two groups in the "false memory" variable (F = 12.833, Pvalue < 0.01) (table 6). The mean difference of "false memory" (-6.988) indicated that students with specific learning disabilities under the influence of cognitive training had higher scores in the "false memory" variable than the group of transcranial direct current stimulation (tDCS).

There was a significant difference between the adjusted mean of two groups in the "percentage of recall clues" variable (F = 23.862, Pvalue < 0.01) (table 6). The mean difference of "percentage of recall clues" (3.555) indicated that students with specific learning disabilities under the influence of cognitive training had higher scores in the "percentage of recall clues" variable than the group of transcranial direct current stimulation (tDCS).

There was a significant difference between the adjusted mean of two groups in the "percentage of memory judgment" variable (F = 27.054, Pvalue < 0.01) (table 6). The mean difference of "percentage of memory judgment" (3.174) indicated that students with specific learning disabilities under the influence of cognitive training had higher scores in the "percentage of memory judgment "variable than the group of transcranial direct current stimulation (tDCS).

Table 1. Statistical characteristics of metamemory variables in the experimental and control groups

Groups / Variable		Cognitive		tDCS		Control	
		Mean	SD	Mean	SD	Mean	SD
I remember	Pre - test	1.80	0.35	1.33	0.36	1.07	0.039
	Post - test	1.82	0.14	1.39	0.21	1.09	0.22
I only know	Pre - test	1.66	0.018	1.35	0.020	1.45	0.020
	Post - test	1.71	0.26	1.38	0.22	1.36	0.13
False memory	Pre - test	133.10	1.28	140.90	1.42	152.19	1.40
	Post - test	132.86	17.61	140.75	20.88	151.77	16.24
Percentage of recall clues	Pre - test	81.08	0.48	77.50	0.53	74.73	0.52
	Post - test	81.19	3.05	75.80	4.97	76.35	2.60
Percentage of memory judgment	Pre - test	67.21	0.40	64.03	0.44	62.33	0.44
	Post - test	68.11	4.72	63.79	4.80	61.67	0.07

Table 2. Results of adjusted mean for metamemory variables

Groups / Variable	Cognitive		tDCS		Control	
	Mean	SD	Mean	SD	Mean	SD
I remember	0.98	0.26	0.93	0.22	1.09	0.22
I only know	1.41	0.31	1.22	0.29	1.35	1.23
False memory	152.90	21.27	152.69	21.27	152.04	16.44
Percentage of recall clues	74.39	4.24	76.03	2.48	71.64	4.86
Percentage of memory judgment	62.38	5.18	62.38	4.84	60.81	3.23

Table 3. Multivariate analysis of covariance of the F ratio for the metamemory variables

Source	Value	F	Pvalue	η2
Hybrid variable (group)	0.046	24.249	0.000	0.786

Table 4. Multivariate analysis of covariance for comparing the mean of metamemory

Tests	Value	df	Error df	F	Pvalue	Effect size
Pillais trace	1.26	10	68	8.757	0.000	0.563
Wilks lambda	0.046	10	66	24.249	0.000	0.786
Hotelling's trace	17.099	10	64	57.716	0.000	0.895
Roy's Largest root	16.877	5	34	114.761	0.000	0.944

Table 5. Analysis of univariate covariance for the metamemory variables

Source of diffraction	SS	df	MS	F	Pvalue	Effect size	Statistical power
I remember	3.644	2	1.822	105.792	0.000	0.851	1.00
Error	0.637	37	0.017				
I only know	0.639	2	0.325	68.996	0.000	0.789	1.00
Error	0.174	37	0.005				
False memory	2284.950	2	1142.475	49.431	0.000	0.728	1.00
Error	855.166	37	23.113				
Percentage of recall clues	262.825	2	131.413	40.845	0.000	0.688	1.00
Error	46.987	37	1.342				
Percentage of memory judgment	162.018	2	81.009	35.811	0.000	0.659	1.00
Error	83.698	37	2.262				

Table 6. Analysis of univariate covariance for the metamemory variable in tCDS and cognitive groups.

Source of diffraction	SS	df	MS	F	Pvalue
I remember	1.387	1	1.387	80.533	0.000
Error	0.637	37	0.17		
I only know	0.266	1	0.266	56.484	0.000
Error	0.174	37	0.005		
False memory	296.592	1	296.592	12.833	0.000
Error	855.166	37	23.113		
Percentage of recall clues	76.771	1	76.717	23.862	0.000
Error	119.042	37	3.217		
Percentage of memory judgment	61.198	1	61.198	27.054	0.000
Error	83.698	37	2.262		

Discussion

The results indicated that cognitive training affected metamemory. The finding was consistent with studies by Arkan and Yaryari,[31] who found that the effect of tDCS improved working memory and Kessler et al.[18] who found that the computerized cognitive training program significantly increased processing speed, cognitive flexibility, verbal and visual declarative memory scores and also raised prefrontal cortical activity. The explanation of this finding indicates that the memory is the ability to store, manipulate, information processing, experiences (temporary and permanent), and their use in subsequent interactions with the environment, and includes processes for acquiring, recording, encrypting, storing and retrieving information.[6] Memory is thus a central ability to examine remembered processes in the human cognitive system and can help people to succeed and meet challenges by finding its numerous determinants. Cognitive training is among these variables that affect and improves cognitive functions, and thus the memory and extra-memory functions in students with specific learning disabilities are also empowered and improved under the influence of this method. In this regard, Nazari et al.[23] conducted a research on the effectiveness of cognitive rehabilitation on spelling errors in dyslexic students and conclude that the cognitive rehabilitation program could be used as a new attractive method for children along with other common methods for spelling disorder by considering individual differences. Since students with specific learning disabilities usually suffer from cognitive impairments, the cognitive training method will improve memory, attention, metamemory, and metacognition in these students and also improve their academic achievement.by empowering this psychological variable. Cognitive training also reduces the likelihood of learning errors by reinforcing metacognition and can be considered as an effective mechanism at the cognitive level.

Results of the present study also indicated that the tDCS was effective on the metamemory. The finding is consistent with a research by Bayat Mokhtari et al.[29] who found that the anodic stimulation improved the individual performance in visual/spatial memory and subsequently improved dyslexia in children. Lali et al.[34] and Andrews et al.[35] also found that the tDCS affected the working memory. In particular, Arjmandnia et al.[2] found that the effect of tDCS on working memory of children with mathematical disorder improved their working memory. In fact, tDCS causes more brain cell firing by changes in the stimulation of neurons and displacement of superficial neuronal membrane potential for depolarization or hyperpolarization that increases or decreases functions of brain neurons.[29] Furthermore, the increased surface stimulation in the cortex results in an increase in dopamine release which in turn improves memory performance, especially metamemory. Since cognitive processes such as attention and memory play major roles in the incidence of specific learning disorders, the transcranial direct current stimulation changes neuronal functions, increases cognitive ability, and enhances memory and stimulus-response recognition and learning. Therefore, learning disorders also decreases as the result of increased memory. The result is consistent with a research by Samiei Sanjani[30] who found that the anodic stimulation promoted the selective attention and memory. Arshad[22] also found that the Computer Assisted Cognitive Rehabilitation (CACR) was effective in improving the working memory in children with attention deficit/ hyperactivity disorder.

Results of the present study also indicated that students with specific learning disabilities had higher scores in metamemory under the influence of cognitive training in comparison with the tDCS group; and cognitive training was more effective than the tDCS method. Despite a great number of studies on the effectiveness of cognitive training and tDCS on cognitive functions, there is no research on the comparison of the effectiveness of both methods. An acceptable explanation may be achieved by considering the cognitive training as a method based on findings of cognitive science, which is presented as games, and the tDCS as a biological therapy. Jamshid Bik[12] compared the effectiveness of both cognitive and drug therapies in treating depression and found that cognitive therapy was more effective than drug therapy. Moreover, Aghaei et al.[13] found that the impact of cognitive therapy was more than drug therapy. The findings indicated that different regions of cortex were involved in the incidence of specific learning disorders, and it was expected that the tDCS intervention, as a biological treatment approach, would improve cognitive functions and metamemory by relying on biological algebra and stimulation of neurons of in involved regions, and it was true. In explaining why, the cognitive training method was more effective, we can conclude that as the center of transcranial direct current stimulation is somewhat limited, its functional effects directly appear in few sites under the electrodes and may not include the involved regions in cognitive or memory processes. Furthermore, the effects of tDCS on the target region depends on the electrode polarity (anodic and cathodic) during stimulation and the stimulated regions in the brain.[29] Another possible explanation is that the impact of games on student learning cannot be ignored. Since in cognitive training, the cognitive rehabilitation is performed by computer games, in which students are much interested, the cognitive training method and its role in the metamemory are more effective than the tDCS method. The present study has useful implications for the effectiveness of cognitive training in treating specific learning disorders. The method can be also utilized by researchers and therapists in order to improve memory processes that are damaged by other psychological or psychosomatic disorders.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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