Document Type: Original Article
https://dorl.net/dor/20.1001.1.26455455.2021.4.13.6.6

Iranian Journal of Learning and Memory 2021, 4(13), 56-65

Comparing the Effectiveness of Transcranial Direct Current Stimulation and Cup Stacking Game on Cognitive Inhibition, Auditory Attention and Visual Attention of Students with Attention Deficit

Parvaneh Feiz, Ph.D. Candidate
Susan Emamipour*, Ph.D.
Department of Psychology, Central Tehran Branch, Islamic Azad University, Tehran, Iran
Peyman Hassani-Abharian, Ph.D.
Department of Cognitive Rehabilitation, Institute for Cognitive Science Studies, Brain and Cognition Clinic, Tehran, Iran
Shirin Kooshki, Ph.D.
Department of Psychology, Central Tehran Branch, Islamic Azad University, Tehran, Iran

Abstract

The aim of this study was to compare the effectiveness of two methods of cup stacking game and transcranial electrical stimulation of the brain (tDCS) on cognitive inhibition, auditory attention and visual attention in students with attention deficit syndrome in 2019-2020. The present study was a quasi-experimental study with a pretest-posttest design and a control group. The present study population consists of all fifth and sixth grade elementary students with symptoms of attention deficit in Tehran in 2019-2020. Among the fifth and sixth grade students, 45 students with attention deficit symptoms were selected by convenience sampling and randomly assigned to three groups of 15 people including the brain stimulation group, the cup stacking game group and the control group. The tDCS experimental group was treated for 10 sessions of 30 minutes, and the cup stacking experimental group were exposed to ten 30-minute sessions of cup stacking game. In order to evaluate the research variables, the continuous auditory visual function test (IVA) of Rosvold, Sarason, Bransome, and Beck (1956) was used. The results of mixed analysis of variance showed that cup stacking game and tDCS are both effective in improving cognitive inhibition and auditory attention of students with attention deficit syndrome, but there is no significant difference between the two methods in influencing cognitive inhibition and auditory attention ($P > 0.05$). Also, only the cup stacking game had a significant effect on improving visual attention, but tDCS did not have a significant effect on improving visual attention.

Keywords: Auditory attention, cognitive inhibition, Cup stacking, tDCS, visual attention

Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a pattern of persistent or hyperactive attention deficit and impulsive behaviors that are more severe and more common than those commonly seen in children and adolescents with similar developmental levels (Wang et al., 2020). Attention Deficit Hyperactivity Disorder (ADHD) is a complex psychiatric disorder that affects not only the individual but also the wider integrated family system (De Zeeuw, Hottenga & Ouwens et al., 2019). Inattentive behavior in people with this disorder is associated with a variety of specific cognitive processes, and people with ADHD may show problems with attention or memory tests and in general executive functions (Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, 2013). Various studies show that executive dysfunction is one of the causes of ADHD problems in children, and executive dysfunction is associated with neurological dysfunction (Schwörer, Reinelt, Petermann & Petermann, 2020; Wang, Wang, Yan, & Fu, 2019). Executive functions are a set of higher cognitive processes that depend on the structure and function of the frontal lobe and include the maintenance and variability of a set, interference control, response

* **Corresponding Author**
Email: emamipursd@yahoo.com

Received: 05/08/2021
Accepted: 08/24/2021

control, scheduling, organization, and working memory (Schwörer et al., 2020).

Children may have a variety of symptoms, although they may have a number of primary symptoms of the disorder, such as inattention, impulsivity, and hyperactivity that are developmentally inappropriate, it is their attention, cognition and behavior problems that cause their conflict with the social environment (Boland et al., 2020). Tamm, Epstien, Peugh, Nakonezny, Hughes (2013) divide attention into five main factors: “Focused attention”, which indicates the need to focus on the same subject for the correct answer; “Sustained attention”, which indicates the ability to maintain attention to a particular subject, that is, after the attention is created, that attention is maintained for a while. “Selective attention”, which refers to the cognitive ability to respond appropriately to a topic related to the goal and not responding to a topic that is not related to the goal; “Alternating attention” devoted to cognitive flexibility in transferring attention from one stimulus to another, for example from visual to auditory and vice versa, and finally” divided attention “, which is called the ability to respond to several topics or tasks at the same time. For example, a person studies, watches TV and talks at the same time**.**

Weakness in inhibition control is an executive attention-related process that allows us to regulate our behaviors and be aware of the possible consequences of subsequent weaknesses in tasks that require selective attention due to their inability to avoid disturbing stimuli (Diamond, 2012). Therefore, successful mastery of each of the attention networks is essential for subsequent cognitive development as well as for controlling behaviors and for academic achievement (Walker, 2009).

Poor cognitive inhibition is also an important component of executive functions that provides the context for the problems of children with ADHD (Wang et al., 2019). The cognitive inhibition component refers to the ability to consciously suppress and stop automated and dominant responses in order to provide more appropriate and targeted responses (Mak, Tyburski, Madany, Sokołowski & Samochowiec, 2016). The inhibitory feature is the inhibition of responses or control of disturbing stimuli or inhibitory responses and includes emotional control and motor control (Marco et al., 2012).

Inhibitory control plays an important role in fostering self-regulation by delaying the response causing behavioral flexibility and enabling strategy selection from alternative behaviors (Tomb &Wender, 2017). Inhibitory control may play a vital role in academic learning by increasing the child's ability to think about multiple dimensions or perspectives on a problem rather than self-conceit in their initial perceptual set (Thiele & Bellgrove, 2018). Although inhibition is often described as a single process, numerous studies have shown that motor and cognitive inhibition controls are distinct but interrelated in processes. It is thought that response inhibition may be a prerequisite for higher levels of executive function skills such as self-regulation, self-control, and purposeful behavior (Harfmann, Rhyner & Ingram, 2019).

Impairment in executive functions can have significant consequences on social, educational, and emotional functioning in children with ADHD (Jiang Liu, Ji & Zhu, 2018). Therefore, considering the fact that the role of brain executive functions and therapeutic trainings attributed to it can be understood in improving students' attention performance, we can note to its related teaching methods such as the cup stacking game technique (Tretriluxana, Taptong & Chaiyawat, 2015) and brain stimulation (Bandeira et al., 2016).

Cup stacking game is done by arranging and collecting cups according to a special instruction, this game has the best performance to increase concentration, eye-hand coordination, movement speed and provides simultaneous use of both hemispheres due to the simultaneous use of both hands and the body (Meyer, van & Hunnius, 2016). Research shows that the cup stacking game improves executive performance and is effective in some other underlying abilities, including the development of continuous visual motor activity (Meyer et al., 2016; Udermann, Mayer, Murray & Sagendorf, 2004), improvement of reaction speed (Tretriluxana, Taptong, & Chaiyawat, 2015), the ability to inhibit response, self-control and decision making (Lessa & Chiviacowsky, 2015). Research by Meyer et al. (2016), Lessa and Chiviacowsky (2015), as well as Tretriluxana et al. (2015) showed that cup stacking game has an effect on improving continuous visual motor activities and inhibitory control of children**.**

Electrical stimulation of the brain from the skull (tDCS) is a non-invasive brain stimulation technique (Zaehle, Sandmann, Thorne, Jäncke & Herrmann, 2011) that can alter areas of the skull by using a weak electric current to stimulate changes in the skull (Schlaug, Marchina, & Wan, 2011). tDCS increases or decreases brain function by using direct current to alter cortex excitability in target areas (Woods, 2016). Research shows that tDCS improves executive functions (Salehinejad, Wischnewski, Nejati, Vicario & Nitsche, 2019), reduces impulsive behaviors and improves behavioral inhibition (Allenby et al., 2018), improves attention span (Jacoby & Lavidor, 2018)) in people with ADHD. Some studies show that stimulation of the left lateral frontal cortex stimulates cognitive inhibition and stimulation of the right frontal cathode improves auditory attention (Breitling et al., 2016; Nejati et al., 2017; Soltaninejad, Nejati & Ekhtiari, 2019).

It seems that each of the experimental interventions in the field of repairing defects in cognitive inhibition and attention is viewed from a different angle to a single subject, and it is possible to take a closer look at these apparently separated interventions and discover some subtle and complex connections between these interventions that requires a comparison between these experimental interventions and review of their results. Therefore, in the present study, special attention has been paid to this issue and two experimental interventions (brain stimulation and cup stacking game) have been examined to clarify which method is more effective and can be presented to future researchers. Considering the above, examining the differences between the two methods and comparing the effectiveness of the two methods of brain stimulation and cup stacking game in improving students' attention and cognitive inhibition requires such research. Hence, considering this goal, the present study sought to compare the effectiveness of brain stimulation on the skull and teaching the cup stacking game on cognitive inhibition and types of attention in students with attention deficit syndrome.

Method

The present study adopted a quasi-experimental method with pretest-posttest design and control group. This research is an applied research considering its purpose.

Participants

The statistical population of this study included all students studying in the fifth and sixth grades of public primary schools in Tehran in the academic year 2019-2020. In an experimental research, the appropriate number of samples for each group is 15 people (Delavar, 1398). The sample size consisted of 45 students with attention deficit disorder who were selected by convenience sampling and randomly divided into three groups of 15 (brain stimulation group), (cup stacking game group) and control group (waiting list). Considering the criteria for inclusion in the study, those children were selected who had attention deficit syndrome and did not have hyperactivity and compound syndrome, had no history of epilepsy and other psychiatric disorders, and their age was more than 10 years.

Instruments

Continuous Auditory Performance Test (IVA)

This test is a continuous 13-minute audio-visual test that evaluates two main factors, namely reaction control and attention. This test was developed in 1956 by Rosvold, Sarason, Bransome, and Beck. The IVA test is based on the DSM-IV Diagnostic and Statistical Manual of Mental Disorders and distinguishes between different types of attention (focused attention, sustained attention, alternating attention, and divided attention). The purpose of this test is to evaluate the observation and constant attention in the individual. In addition, this test is used to examine other problems and disorders such as self-control problems related to head injuries, sleep disorders, depression, anxiety, learning disabilities, dementia and other medical problems. This test is applicable for people with 6 years of age and older and adults. The duration of this test (including the training section) is about 20 minutes. The test task includes answering or not answering (inhibiting the answer) to 500 test stimuli. Each stimulus is presented for only one and a half seconds; therefore, the test needs to maintain attention. This test measures four main categories including attention, response inhibition, learning quality and mental fatigue whose creators obtained the validity of 0.83, 0.81, 0.75, 0.78, respectively (Rosvold, Sarason, Bransome & Beck, 1956). Simani, Roozbeh, Rostami, Pakdaman, Ramezani and Asadollahi (2020) in their study in Iran showed that IVA test has sufficient sensitivity (92%) and correct predictive power (89%) to correctly diagnose attention in children. Also in their research, the validity of the subtests of attention, response inhibition, learning quality and mental fatigue was 0.91, 0.83, 0.84 and 0.78, respectively which indicates the appropriate validity of the Persian version. In the present study, all three variables of inhibition, visual attention and auditory attention were evaluated with this tool.

CSI-4 Pediatric Pathology Questionnaire

In this study, in order to diagnose children with attention deficit hyperactivity disorder, the CSI-4 Pediatric Pathology Questionnaire of parental form was used. This 18-item questionnaire shows the intensity and severity of symptoms of Attention Deficit Hyperactivity Disorder and Impulsivity based on teachers 'and parents' judgments and based on the third edition of the American Psychiatric Disorders Statistical and Diagnostic Guide, it is designed for screening behavioral and emotional disorders in children from 5 to 12 years and have a valid diagnostic value. Gadow and Spirfiken (1994) reported the reliability coefficient of this test as 0.83 and in the revised form as 0.87. Also, the validity of this test for diagnosing stubbornness-disobedience disorder, conduct disorder and hyperactivity disorder was 0.93, 0.93 and 0.77, respectively. This questionnaire has been standardized in Iran by Mohammad Ismail (2004). This questionnaire has a relatively good reliability as a tool for measuring behavioral and emotional disorders in Iranian children. The cut-off point for diagnosing attention deficit disorder for the parent form is a score of 6 or higher and its validity for diagnosing Attention Deficit Hyperactivity Disorder was 0.91 (Mohammad Ismail, 2004).

Procedure

Students with attention deficit disorder were selected through the assessment criterion of Attention Deficit / Hyperactivity Disorder based on DSM-5 and CSI-4 parent form questionnaire, so that the subject based on DSM-5 criterion A (inattention) showed 6 marks or more for at least six months and had a score of 6 or higher in the CSI-4 questionnaire. Exclusion criteria were unwillingness to cooperate and not to participate in more than one treatment session or game therapy, based on which none of the sample was excluded from the study. The tDCS experimental group was treated for 10 sessions and in each session the treatment was administered as 13-10-13 (13 minutes of protocol implementation, 10 minutes of rest, again 13 minutes of treatment plan). Also, the experimental group of cup stacking was exposed to 10 sessions of 30 minutes of cup stacking game. The control group did not receive any intervention. At the end of the sessions, questionnaires for measuring research variables were administered to all three sample groups. Also, in a one-month follow-up, in order to assess the duration of the impact of the interventions, questionnaires were administered again on all three groups. Data were analyzed using the mixed analysis of variance.

The cranial stimulation protocol was derived from Banderia et al.'s (2016) protocol. In this method, the subject sits on a comfortable chair and according to the treatment protocol, the desired points are measured and determined and direct anodal electrical stimulation is applied in the lateral dorsal region of the right hemisphere and the cathode or reference electrode is placed on the forehead area of the left eyeball, and through this, subjects receive a current intensity of 2 mA with electrodes measuring 35 cm2 for 13 minutes, 10 minutes of rest and 13 minutes of stimulation.

The cup stacking protocol was derived from the game therapy protocol of Tretriluxana, Taptong, and Chaiyawat (2015). The first session was to get acquainted with the cup and the necessary exercises to learn the cup stacking and use both hands. In the second session, the sirst stpe od training started in 3-3-3 pattern. In the third session, first the time of doing the sirst step was recorded and the new step of 3-6-3 was taught. From the third session to the end, the training of different arrangements was done with more cups and the time of stacking was recorded.

Findings

The mean age of students in tDCS group was 10/11 years, the mean age of cup stacking group was 10.02 years and the mean age of control group was 10.9 years. Descriptive indicators of research variables are presented in Table 1.

Table 1.
Descriptive Statistics of the Study Variables in the Three Groups

Variable		Pre-test		Post-test		Follow-up	
		Mean	SD	Mean	SD	Mean	SD
Cognitive Inhibition	TDCS group	71.07	19.93	103.07	9.38	106.53	13.41
	CUP group	68.07	18.41	99.21	9.98	98.64	10.01
	Control group	70.40	17.10	70.47	16.83	71.13	16.69
Auditory Attention	TDCS group	74.07	18.07	97.00	12.29	95.67	19.08
	CUP group	81.93	15.38	99.57	13.84	94.43	20.14
	Control group	79.07	14.06	78.47	13.03	77.33	13.14
Visual Attention	TDCS group	60.53	12.92	85.07	19.24	93.07	22.07
	CUP group	73.86	22.38	96.07	20.73	101.14	16.64
	Control group	72.47	18.43	72.27	18.75	72.40	18.53

Table 1 shows that in the TDCS experimental group and the CUP experimental group, the mean scores of cognitive inhibition, visual and auditory attention in the post-test and follow-up stages increased compared to the pre-test stage, while in the control group, the scores of these three tests did not show a significant difference.

To examine the significance of these differences, the mixed analysis of variance test is used. In order to investigate the normal distribution of scores of dependent variables in the pre-test stage, Kolmogorov-Smirnov test was used. Therefore, it is assumed that the distribution of scores of dependent variables is normal. The homogeneity of variances was also examined and this assumption was also valid. Sphericity test for cognitive inhibition ($P < 0.05$, X^2 (2) = 31.540) and auditory attention ($P < 0.05$, X^2 (2) = 27.069) and visual attention ($P < 0.05$), $X^{2\ (2)\ =}$ 15.049) showed that the sphere assumption is not valid. Therefore, the results of intragroup analysis of variance should be calculated according to the lack of sphericity assumption.

Table 2.

Summary of Results of Mixed Analysis of Variance with Intragroup and Intergroup Factors in the Cognitive Inhibition Variable

Group	Factor	Sources of Change	Sum of Squares	Df	Mean Squares	F	Significance	Effect Size
tDCS Control	Intragroup Factor	Intervention Stages	5889.49	1.39	4246.76	38.182	.000	.577
		Stages*Group	5584.96	1.39	4027.17	36.208	.000	.564
		Error	4318.89	38.83	111.22			
	Intergroup Factor	Group	11787.778	1	11787.778	19.473	.000	.410
		Error	16949.778	28	605.349			
CUP Control	Intragroup Factor	Intervention Stages	4716.63	1.14	4149.67	47.698	.000	.639
		Stages*Group	4483.80	1.14	3944.83	45.343	.000	.627
		Error	2669.92	30.69	87.00			
	Intergroup Factor	Group	7020.01	1.00	7020.01	11.634	.002	.301
		Error	16291.64	27.00	603.39			
tDCS CUP	Intragroup Factor	Intervention Stages	20170.700	1.290	15639.816	78.625	.000	.744
		Stages*Group	98.976	1.290	76.743	.386	.592	.014
		Error	6926.679	34.822	198.917			
	Intergroup Factor	Group	524.304	1	524.304	1.508	.230	.053
		Error	9389.421	27	347.756	38.182		

The results of Table 2 show that there is a significant difference between F calculated for the interaction of intervention stages and group in the tDCS experimental group with the control group and the CUP experimental group with the control group, but there is no significant difference between the two tDCS and CUP experimental groups. The effect size is calculated for the CUP training effect equals to (Eta2 = 0.301) and for the tDCS cranial stimulation program is (Eta2 = 0.410). Therefore, both methods of teaching cup stacking and cerebral stimulation from the skull have been effective on cognitive inhibition. The effect of cerebral stimulation from the skull is slightly greater than the control group compared to teaching cup stacking, but this difference is not statistically significant.

Table 3.

Summary of Results of Mixed Analysis of Variance with Intra-Group and Inter-Group Factors of Auditory Attention

Group	Factor	Sources of Change	Sum of Squares	Df	Mean Squares	F	Significance	Effect Size
tDCS Control	**Intragroup Factor**	Intervention Stages	2248.867	1.336	1682.996	10.503	.001	.273
		Stages*Group	2745.756	1.336	2054.855	12.823	.000	.314
		Error	5995.378	37.414	160.243			

Group	Factor	Sources of Change	Sum of Squares	Df	Mean Squares	F	Significance	Effect Size
	Intergroup Factor	Group	2538.711	1	2538.711	5.326	.029	.160
		Error	13346.889	28	476.675			
CUP Control	**Intragroup Factor**	Intervention Stages	1075.998	1.197	899.139	5.433	.021	.168
		Stages*Group	1331.125	1.197	1112.331	6.721	.011	.199
		Error	5347.565	32.311	165.504			
	Intergroup Factor	Group	4069.848	1	4069.848	8.418	.007	.238
		Error	13054.221	27	483.490			
tDCS CUP	**Intragroup Factor**	Intervention Stages	6882.154	1.333	5162.951	16.964	.000	.386
		Stages*Group	302.476	1.333	226.916	.746	.430	.027
		Error	10953.432	35.991	304.341			
	Intergroup Factor	Group	204.092	1	204.092	.472	.498	.017
		Error	11666.621	27	432.097			

The results of Table 3 show that there is a significant difference between the F calculated for the interaction of the intervention stages and the group in the CUP experimental group and the tDCS experimental group with the control group, but there is no significant difference between the two experimental groups of tDCS and CUP. The effect size calculated for the CUP training effect (Eta2 = 0.238) is slightly larger than that in the tDCS group (Eta2 = 0.160). Therefore, the method of teaching cup stacking and brain stimulation from the skull has been effective on auditory attention.

Table 4.

Summary of Results of Mixed Analysis of Variance with Intragroup and Intergroup Factors Visual Attention

Group	Factor	Sources of Change	Sum of Squares	Df	Mean Squares	F	Significance	Effect Size
tDCS Control	**Intragroup Factor**	Intervention Stages	4280.867	1.662	2575.642	18.647	.000	.400
		Stages*Group	4340.956	1.662	2611.796	18.908	.000	.403
		Error	6428.178	46.538	138.129			
	Intergroup Factor	Group	1159.211	1	1159.211	1.449	.239	.049
		Error	22401.689	28	800.060			
CUP Control	**Intragroup Factor**	Intervention Stages	2979.176	1.285	2318.102	14.629	.000	.351
		Stages*Group	3033.291	1.285	2360.209	14.895	.000	.356
		Error	5498.594	34.700	158.462			
	Intergroup Factor	Group	7172.075	1	7172.075	8.065	.008	.230
		Error	24010.316	27	889.271			
tDCS CUP	**Intragroup Factor**	Intervention Stages	14224.560	1.509	9426.776	32.469	.000	.546
		Stages*Group	111.825	1.509	74.108	.255	.713	.009
		Error	11828.727	40.742	290.334			
	Intergroup Factor	Group	2624.829	1	2624.829	4.043	.054	.130
		Error	17529.516	27	649.241			

The results of Table 4 show that there is a significant difference between the F calculated for the interaction of the intervention stages and the group in the CUP experimental group with the control group, but there is no significant difference between the tDCS and CUP experimental groups. The effect size is calculated for the CUP training effect equals to (Eta2 = 0.230). Therefore, the method of teaching cup stacking has been effective on visual attention, but brain stimulation from the skull has not had a significant effect on visual attention.

Discussion

The aim of this study was to compare the effectiveness of two methods of teaching cup stacking game and brain stimulation from the skull on cognitive inhibition of auditory attention and visual attention in students with attention deficit syndrome. The results of the present study showed that the effect of both interventions on students 'cognitive inhibition was significant but there was no significant difference between the effectiveness of tDCS and CUP on students' cognitive inhibition. The results of the present study are consistent with the research of Soltaninejad et al. (2019); Nejati et al. (2017); Breitling et al. (2016); Banderia et al. (2016) which showed that stimulation of the dorsal lateral cortex of the left forehead cortex improves inhibitory control. Also, the findings are similar to those found in the research of Meyer et al. (2016) and Lessa and Chiviacowsky (2015) who showed that the cup stacking game is very effective on continuous visual motor activities and inhibitory control of children in their development**.**

The results of the present study also showed that the effect of both interventions on students 'auditory attention was significant but there was no significant difference between the effectiveness of tDCS and CUP on students' auditory attention. Therefore, the present study similar to that of Nejati et al. (2017) suggests that dysfunction of the right frontal lobe is the basis of auditory attention deficit; thus, these individuals are unable to perform abilities such as attention retention, motor inhibition, strategic planning, cognitive flexibility, and impulse control (Leffa et al. , 2016). In other words, researchers in the field of neurophysiology have mainly found evidence of decreased activity of the frontal and middle central lobes in approximately 85 to 90% of people with attention deficit disorder (Halperin & Healey, 2011). Electrical stimulation of the skull increases blood flow to the stimulated cortical areas, which improves the function of these areas (Strobach & Antonenko, 2017); therefore, the location of the electrode can change the electric current, and this change in the current will improve the activity of the stimulated site**.**

Cup stacking game, especially when done in groups, requires attention to the instructions that people give to each other for group coordination. Failure to pay attention to the audio messages will cause the group to lose coordination and lead to failure or unsuccessful performance in picking the cup (Canino, 2017). Therefore, the child must constantly maintain his auditory attention to coordinate with other people in the group, and the continuous use of this ability during play can lead to improved auditory attention ability (Riggins, 2017).

The results of the present study also showed that the effect of cup stacking intervention on students 'visual attention was significant but tDCS was not significant on improving students' visual attention. Results of the present study are consistent with those of Meyer et al. (2016) and Tretriluxana et al. (2015). Among the skills needed to succeed in the game of cup stacking and holding the cup tower on top of each other is to use the ability of sight and visual attention. During the game, the person must constantly observe and decide on the shape of the cuptower, the number of cups, the position of the cups, the next moves to be made and the next cups to be arranged; therefore, during the cup stacking game, visual attention is one of the skills that is constantly involved in the game, and continuous use of this ability leads to mastery in using it and improving the ability of visual attention (Meyer et al., 2016).

The results of the present study is inconsistent with those of Banderia et al. (2016) which showed that stimulation with an intensity of 1.5 mA for 15 minutes with an interval of 72 hours between sessions for 20 sessions can improve the visual attention of children and adolescents with ADHD. One of the reasons for this discrepancy is the results of differences in tDCS executive protocols. In the present study, direct anodal electrical stimulation was applied to the lateral dorsal region of the right prefrontal cortex and the cathode or reference electrode was placed on the frontal region of the left eyeball. The subjects were stimulated with a current of 2 mA with electrodes measuring 35 cm2 for 10 sessions (10 consecutive days); therefore, this comparison shows that the executive protocol of Banderia et al. (2016) is more effective in improving tDCS on visual attention and 10 sessions are not enough to affect visual attention. The effect of parietal stimulation with tDCS on visual-spatial perception attention was tested by Vance et al. (2007) for two groups of healthy individuals and individuals with unilateral visual-spatial neglect disorder. Other studies also show that the frontoprotal network is involved in the regulation of attention-related functions, especially visual attention (Kehrer, Kraft, Koch, Kathmann, Irlbacher, & Brandt, 2015**).** Therefore, in explaining that the results of tDCS stimulation had no significant effect on visual attention, according to the results of the research, it can be stated that the best place to place the electrode in order to affect the visual attention is the parietal region of the cerebral cortex. In the present study, the electrodes were placed on the lateral dorsal region of the right and left forehead, which, despite their effect on improving visual attention, the effect was not significant.

Conclusions

Research shows that electrical stimulation of the prefrontal cortex of the brain does not cause two tasks to be processed simultaneously, but increases the speed of the first processing when a person has to process two tasks simultaneously and reduces the psychological response period (Rostami, Besharat , Karimi, & Farahani, 2016). This improves people's reaction time; thus, transcranial electrical stimulation of the brain speeds up the movement of impulses or facilitates their inhibition, which leads to improved cognitive inhibition ability (Soutschek, Taylor & Schubert, 2016).

Following the cup stacking game, one has to decide when to place the cups and when to stop placing them. Careless arrangement of the cups on top of each other leads to premature collapse of the cup tower, so one should try to drop the cup and place the next cup when one is sure of the balance and correct position of one cup (Li, Coleman, Ransdell, & Irwin, 2011). This process requires coordination and the use of several cognitive skills such as decision making, attention and accuracy, timely action and control of unwanted movements as well as control of inaccurate movements. Therefore, in addition to speed of action in performing precise motor activities, one should prevent inaccurate motor activities at the same time whose continuous performance leads to improved ability to control inhibition and cognitive inhibition (Zareian & Delavarian, 2014).

Among the limitations of the present study was the average number of sessions which seemed to be 8 sessions for cup stacking game and 10 sessions for tDCS. Another limitation is that this study was performed only on students with attention deficit disorder, so generalizing the results to other groups of children and adolescents should be done with caution. Finally, we failed to control some variables that may have affected the results of the study, such as age, socio-economic status of the family, the amount of motor and visual activities, the amount of motor-visual skills, the amount of using computer games, etc.

Due to the importance of the subject and considering the results obtained in this study, cup staking game can be used both as a fun and as a therapeutic activity in improving the executive functions of students with ADHD. Also, since cup stacking game is effective in improving executive functions such as cognitive inhibition, visual and auditory attention, it is suggested that it be included in the educational and sports program of students in order to improve the level of perceptual-motor skills. Due to the effectiveness of cup stacking game and tDCS in improving cognitive inhibition and auditory attention in students with ADHD, these interventions can be used to improve cognitive functions in students with ADHD. Moreover, considering that in the present study, there was no significant difference between these two interventions in improving students' cognitive inhibition and auditory attention, it is suggested that the cup stacking game be used as a more accessible intervention by teachers in schools while tDCS intervention should be used by experts in the field of pediatric disorders**.**

Acknowledgments

We thank all the students, teachers and parents who helped us in the process of this research.

No conflict of interest.

References

Allenby, C., Falcone, M., Bernardo, L., Wileyto, E. P., Rostain, A., Ramsay, J. R., & Loughead, J. (2018). Transcranial direct current brain stimulation decreases impulsivity in ADHD. *Brain Stimulation, 11*(5), 974–981.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5®).* American Psychiatric Pub.

Bandeira, I. D., Guimarães, R. S. Q., Jagersbacher, J. G., Barretto, T. L., de Jesus-Silva, J. R., Santos, S. N., ... & Lucena, R. (2016). Transcranial direct current stimulation in children and adolescents with attention-deficit/hyperactivity disorder (ADHD): A pilot study. *Journal of Child Neurology*, *31*(7), 918-924.

Boland, H., DiSalvo, M., Fried, R., Woodworth, K. Y., Wilens, T., Faraone, S. V., & Biederman, J. (2020). *A literature review and meta-analysis on the effects of ADHD*.

Breitling, C., Zaehle, T., Dannhauer, M., Bonath, B., Tegelbeckers, J., Flechtner, H. H., & Krauel, K. (2016). Improving interference control in ADHD patients with transcranial direct current stimulation (tDCS). *Frontiers in Cellular Neuroscience*, *10,* 72.

Canino, J. M. (2017). The Development and experimental characterization of a haptic feedback array to enhance user-perception of locomotor function and motor control of an EMG-controlled prosthetic limb. Clarkson University.

Delaware, A. (2019). Theoretical and practical foundations of research in humanities and social sciences. Tehran: Roshd Publications.

De Zeeuw, E. L., Hottenga, J. J., Ouwens, K. G., Dolan, C. V., Ehli, E. A., Davies, G. E., ... & van Bergen, E. (2019). Intergenerational transmission of education and ADHD: Effects of parental genotypes. *bioRxiv*, 664128.

Diamond, A. (2012). Activities and programs that improve children's executive functions. *Current Directions in Psychological Science, 21*(5), 335-341.

Gadow, K. D., & Spirfiken, J. (1994). *Child symptom inventories manual*. Stoony Boroks: NY, Chechmak Plus.

Halperin, J. M., & Healey, D. M. (2011). The influences of environmental enrichment, cognitive enhancement, and physical exercise on brain development: Can we alter the developmental trajectory of ADHD? *Neuroscience & Biobehavioral Reviews*, *35*(3), 621-634.

Harfmann, E. J., Rhyner, K. T., & Ingram, R. E. (2019). Cognitive inhibition and attentional biases in the affective go/no-go performance of depressed, suicidal populations. *Journal of Affective Disorders, 256*, 228-233.

Jacoby, N., & Lavidor, M. (2018). Null tDCS effects in a sustained attention task: The modulating role of learning. *Frontiers in Psychology*, *9*, 476.

Jiang, X., Liu, L., Ji, H., & Zhu, Y. (2018). Association of affected neurocircuitry with deficit of response inhibition and delayed gratification in attention deficit hyperactivity disorder: A narrative review. *Frontiers in Human Neuroscience*, *12*, 506.

Kehrer, S., Kraft, A., Koch, S. P., Kathmann, N., Irlbacher, K., & Brandt, S. A. (2015). Timing of spatial priming within the fronto-parietal attention network: A TMS study. *Neuropsychologia*, *74*, 30-36.

Leffa, D. T., de Souza, A., Scarabelot, V. L., Medeiros, L. F., de Oliveira, C., Grevet, E. H., ... & Torres, I. L. (2016). Transcranial direct current stimulation improves short-term memory in an animal model of attention-deficit/hyperactivity disorder. *European Neuropsychopharmacology*, *26*(2), 368-377.

Lessa, H. T., & Chiviacowsky, S. (2015). Self-controlled practice benefits motor learning in older adults. *Human Movement Science*, *40*, 372-380.

Li, Y., Coleman, D., Ransdell, M., Coleman, L., & Irwin, C. (2011). Sport stacking activities in school children's motor skill development. *Perceptual and motor skills*, *113*(2), 431-438.

Mak, M., Tyburski, E., Madany, Ł., Sokołowski, A., & Samochowiec, A. (2016). Executive function deficits in patients after cerebellar neurosurgery. *Journal of the International Neuropsychological Society, 22*(1), 47-57.

Marco, E. J., Harrell, K. M., Brown, W. S., Hill, S. S., Jeremy, R. J., Kramer, J. H., ... & Paul, L. K. (2012). Processing speed delays contribute to executive function deficits in individuals with agenesis of the corpus callosum. *Journal of the International Neuropsychological Society, 18*(3), 521-529.

Martin, D.M., Liu, R., Alonzo, A., Green, M., Player, M.J.,Sachdev, P., & Loo, C.K. (2013). Can transcranial direct current stimulation enhance outcomes from cognitive training? A randomized controlled trial in healthy participants. *International Journal of Neuropsychopharmacology, 16*(9), 1927-1936.

Meyer, M., van der Wel, R. P., & Hunnius, S. (2016). Planning my actions to accommodate yours: joint action development during early childhood. *Philosophical Transactions of the Royal Society B: Biological Sciences, 371*(1693), 20150371.

Muhammad Ismail, E. (2004). Evaluation of validity, reliability and determining the cut points of problems in CSI-4 pediatric symptoms questionnaire. Tehran: Exceptional Children Research Institute.

Nejati, V., Salehinejad, M. A., Nitsche, M. A., Najian, A., & Javadi, A. H. (2017). Transcranial direct current stimulation improves executive dysfunctions in ADHD: implications for inhibitory control, interference control, working memory, and cognitive flexibility. *Journal of Attention Disorders*, 1087054717730611.

Riggins, S. M. (2017). The Woman in the principal's office: A reflective approach to using self-study to understand the successes and challenges of two urban school principalships (Doctoral dissertation, University of Pennsylvania).

Rostami, R., Besharat, M.A., Karimi, M., & Farahani, H. (2016). The effectiveness of transcranial Direct Current Stimulation on the brain function of obese individuals. *Applied Psychological Research Quarterly, 7*(3), 127-145.

Rosvold, H.E. M.A., Sarason, I., Bransome, Jr. E.D., & Beck, L.H.A. (1956). Continuous performance test of brain damage. *Journal of Consulting Psychology, 20*(5), 343.

Salehinejad, M.A., Wischnewski, M., Nejati, V., Vicario, C. M., & Nitsche, M. A. (2019). Transcranial direct current stimulation in attention-deficit hyperactivity disorder: A meta-analysis of neuropsychological deficits. *PloS one*, *14*(4).

Schlaug, G., Marchina, S., & Wan, C.Y.(2011). The use of non-invasive brain stimulation techniques to facilitate recovery from post-stroke aphasia. *Neuropsychol Rev., 21*(3), 288-301.

Schwörer, M. C., Reinelt, T., Petermann, F., & Petermann, U. (2020). Influence of executive functions on the self-reported health-related quality of life of children with ADHD. *Quality of Life Research*, 1-10.

Simani, L., Roozbeh, M., Rostami, M., Pakdaman, H., Ramezani, M., & Asadollahi, M. (2020). Attention and inhibitory control deficits in patients with genetic generalized epilepsy and psychogenic nonepileptic seizure. *Epilepsy & Behavior, 102*, 106672.

Soltaninejad, Z., Nejati, V., & Ekhtiari, H. (2019). Effect of anodal and cathodal transcranial direct current stimulation on DLPFC on modulation of inhibitory control in ADHD. *Journal of Attention Disorders*, *23*(4), 325-332.

Soutschek, A., Taylor, P. C., & Schubert, T. (2016). The role of the dorsal medial frontal cortex in central processing limitation: a transcranial magnetic stimulation study. *Experimental Brain Research*, *234*(9), 2447-2455.

Strobach, T., & Antonenko, D. (2017). tDCS-induced effects on executive functioning and their cognitive mechanisms: a review. *Journal of Cognitive Enhancement*, *1*(1), 49-64.

Tamm, L., Epstien, J.N., Peugh, J.L., Nakonezny, P.A., Hughes, C.W. (2013). Preliminary data suggesting the efficacy of attention training for school-aged children with ADHD. *Developmental Cognitive Neuroscience*, *4*, 16-28.

Thiele, A., & Bellgrove, M. A. (2018). Neuromodulation of attention. *Neuron*, *97*(4), 769-785.

Tomb, D.A., & Wender, P. H. (2017). ADHD: Attention-deficit hyperactivity disorder in children and adults. Oxford University Press.

Tretriluxana, J., Taptong, J., & Chaiyawat, P. (2015). Dyad training protocol on learning of bimanual cup stacking in individuals with stroke: Effects of observation duration. *Journal of the Medical Association of Thailand(Chotmaihet thangphaet)*, *98*, S106-12.

Udermann, B. E., Mayer, J. M., Murray, S. R., & Sagendorf, K. (2004). Influence of cup stacking on hand-eye coordination and reaction time of second-grade students. *Perceptual and Motor Skills*, *98*(2), 409-414.

Vance, A., Silk, T., Casey, M., Rinehart, N., Bradshaw, J., Prakash, C., Bellgrove, M., & Cunnington, R. (2007). Right parietal dysfunction in children with Attention Deficit Hyperactivity Disorder, combined type: an fMRI study. *Molecular Psychiatry*, *12*(9), 826-32.

Walker, J. M. (2009). Perceptions of recess and the effects of a morning recess break on the oral reading fluency of second grade students.

Wang, N., Wang, Z., Yan, F., & Fu, W. (2019). Correlation between single nucleotide polymorphisms of neurotrophic factors and executive function characteristics in children with attention deficit hyperactivity disorder. *Wei sheng yan jiu= Journal of Hygiene Research*, *48*(4), 577-582.

Wang, P., Yang, L., Liu, L., Sun, L., An, L., ... & Wang, Y. F. (2020). Altered brain white matter microstructural asymmetry in children with ADHD. *Psychiatry Research*, 112817.

Woods, A. (2016). A technical guide to TDCS, and related non-invasive brain stimulation tools. *Clinical Neurophysiology, 127* (2016), 1031–1048.

Zaehle, T., Sandmann, P., Thorne, J. D., Jäncke, L., & Herrmann, C. S. (2011). Transcranial direct current stimulation of the prefrontal cortex modulates working memory performance: combined behavioural and electrophysiological evidence. *BMC Neuroscience*, *12*(1), 2.

Zareian, E., & Delavarian, F. (2014). Effect of sport stacking on fine motor proficiency of children with Down syndrome. *International Journal of Sport Studies*, *4*(8), 1010-1016.

How to Site: Feiz, P., Emamipour, S., Abhariyan, P., & Kooshki, S. (2021). Comparing the effectiveness of transcranial direct current stimulation and cup stacking game on cognitive inhibition, auditory attention and visual attention of students with attention deficit. *Iranian Journal of Learning and Memory*, *4*(13), 61-70. Dor: 20.1001.1.26455455.2021.4.13.6.6