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The Effectiveness of Transcranial Direct Current Stimulation (tDCS) on Craving, Impulsivity and Cognitive Abilities in Stimulant Drug Users

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Craving plays an important role in triggering relapse after treatment in stimulant drug users, maintaining their consumption of and dependence on substance. A new treatment technique to solve this problem is transcranial Direct Current Stimulation (tDCS). Therefore, this study has been conducted with the aim of evaluating the effectiveness of tDCS on craving, impulsivity and cognitive abilities in stimulant drug users. This experimental trial study was carried out on 30 subjects with substance use disorder referred to a medical center in Tehran, Iran, from January 8th, 2020 to November 14th of the same year. The patients were randomized into 2 groups: 1) an intervention group (n=15, 10 sessions, 20 minutes every other day) and 2) a control group (n=15, with no intervention). The Barratt Impulsiveness Scale Version 11, Desire for Drug Questionnaire and Cognitive Abilities Questionnaire were used. The MANCOVA (by SPSS software version 24) and P<0.05 considered for data analysis and as significant level respectively. The subjects of this study were 30 substance users (26 males (87%)), age mean ±SD 29±7.7). Both groups were the same according to the demographical and base line variables. After intervention, the changes in the variable of cravings (-14.96 vs -2.15, P<0.001), cognitive abilities (6.6 vs -2.57, P=0.014) and impulsiveness (-10.8 vs -0.34, P=0.034) between the two groups were significant. The results of the current study indicate that tDCS is an effective technique for reducing craving, impulsivity and for increasing cognitive abilities.

Keywords: Transcranial Direct Current Stimulation, Impulsive Behavior, Craving, Cognitive Dysfunctions

Drug use is one of the major problems of human societies and few countries can be found that are not dealing with this issue in any way (Stevens et al., 2014). Addiction has chronic and progressive conditions that are characterized by coercive behaviors, uncontrollable cravings, drug-seeking behaviors, and the continued use of drugs despite the harmful social, psychological, physical, familial, and economic consequences that come with it (Sehrig et al., 2019).

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The main feature of substance use disorders is a set of cognitive, behavioral and physiological symptoms which indicate that a person continues to use drugs despite the drug-induced problems (Vahia, 2013). In the treatment process of addicts, after reaching the state of abstinence, there is a strong desire in them to re-experience the effects of psychotropic substances. Therefore, craving plays an important role in triggering relapse after treatment, maintaining the users' consumption of and dependence on substances (Mohammad Alizadeh Namini et al., 2017; O'Brien, 2008). In fact, it should be said that craving is one of the most important causes of recurrence due to which little progress has been made in treatments (Phillips et al., 2014). On the other hand, numerous studies have confirmed the effect of addictive substances on the brain and consequently on cognitive and impulsive abilities (Crean et al., 2011).

Impulsive behaviors include a wide range of actions that occur instantly, without the ability to concentrate, in the absence of proper planning, and are, thus, of high risk (Bakhshani, 2014).

On the other hand, there is a relationship between addiction readiness and cognitive abilities. In fact, it must be said that those vulnerable to drugs are impulsive, impatient, and extroverted (Ahmadian & Rostami, 2016). Various studies have shown that the forehead cortex regulates cravings and decision-making processes (da Silva et al., 2013; Heeren et al., 2013). Moreover, clinical studies show that the Dorsolateral Prefrontal Cortex (DLPFC) is the site of attention control (Heeren et al., 2013), manipulation of which can, therefore, lead to a change in attention control.

In fact, DLPFC plays a significant role in top-down inhibition control mechanisms and reward mechanisms, so stimulation of this part can be effective in reducing cravings (Weafer et al., 2019).

Non-invasive methods such as direct stimulation of the skull, using transcranial Direct Current Stimulation (tDCS) electric current, are used to regulate the activity of the DLPFC.

A simple expression is used in this method that passes a continuous and light electric current through the head using large electrodes placed on the person's head (Dennison et al., 2019). Numerous studies (Indlekofer et al., 2009; L. Simon, 2000; Mackinger et al., 2004) have confirmed the effects of addictive substances on the brain and thus on cognitive abilities, but the mechanism of the act of electrical stimulation and how it reduces cravings and impulsivity as well as how it increases the cognitive ability of stimulant addicts have not been evaluated. Therefore, this study was conducted with the aim of evaluating the effectiveness of tDCS on craving, impulsivity, and cognitive abilities in stimulants drug users.

Methods

Participants

An experimental study was carried out on 30 patients with substance use disorders referred to an addiction treatment center located in Tehran, from January 8, 2020 to November 14, 2020. First 43 substance users were assessed for eligibility, and 36 of them were selected and randomly assigned to either intervention (n = 18) or control groups (n = 18). Of each group 3 cases dropped and lost follow up assessments. Therefore, the final sample size consisted of 30 substance users (15 in each group). The inclusion and exclusion criterias included (i) At least one year has passed since addiction, (ii) $20 \leq$ Age ≤ 50, (iii) $90 \leq$ score of Barratt Impulsiveness Scale (BIS), (iv) $42 \leq$ score of Desire for Drug Questionnaire (DDQ), (v) existence of at least one anxiety disorder based on clinical interview, (vi) do not receive medication or psychological treatment for at least one year before participating in the study (vii) not having psychotic disorders and/or physical illnesses, (viii) not being in pregnancy or lactation period.

Participant unwilling to participate, having more than two absences in intervention sessions and failure to complete the questionnaires by the participants were excluded. In general, 47 patients were firstly registered in this research and according to research criteria and limitations, and the research finished with 30 patients (See Figure 1).

Measurement Instruments

Demographic Questionnaire: This form included variables such as gender, age, education, year of drug use, as well as a consent form.

The Barratt Impulsiveness Scale Version 11 (BIS-11): The Barratt Impulsiveness Scale (BIS) is widely used to measure impulsiveness. This questionnaire consists of 30 items (with responses to each ranging from 1 (never) to 4 (always)) which are scored to yield six first-order factors (attention, motor, self-control, cognitive complexity, perseverance, and cognitive instability impulsiveness) and three second-order factors (attentional, motor, and non-planning impulsiveness) (Barratt, 1967). The psychometric properties of the BIS-11 have been shown in various studies (Barratt, 1967; McLeish & Oxoby, 2007; Patton et al., 1995). The Cronbach's alpha of this scale in Persian version was reported 0.83 and 0.84 in healthy participants and those with substance abuse disorder respectively (Ekhtiari et al., 2008).

Desire for Drug Questionnaire (DDQ): The Desire for Drug Questionnaire (DDQ) is a 14-item questionnaire (with responses ranging from 1 (strongly disagree) to 5 (strongly agree)) for measuring drug use craving. This questionnaire has three factors (Thoughts about drug use, Desire and control, and Resistance to thoughts and intention). The psychometric properties of the DDQ have been shown in Franken et al study(Franken et al., 2002). In the Persian version, the validity and reliability of DDQ is confirmed (Hassani-Abharian et al., 2016; Oraki et al., 2013).

Cognitive Abilities Questionnaire (CAQ): The Cognitive Abilities Questionnaire (CAQ) is a 30-item questionnaire (with the answers to each item ranging from 1 (Never disagree) to 5 (Always)) for measuring cognitive abilities. This questionnaire has seven factors (memory, inhibitory control, selective attention, decision making, planning, sustain attention, social cognition and cognitive flexibility). Nejati et al evinced validity and reliability of this questionnaire (Cronbach's alpha=0.83) (Nejati, 2013).

Procedures

In this study, patients were randomly assigned into two groups (intervention and control groups). The random assignments were prepared outside the study center and by statistician and by using some random allocation software. The patients were randomly allocated into 2 groups: intervention group or control group. The intervention group received 10 sessions of tDCS. In the intervention group, a two-channel Chattanooga device with sponge impregnated with saline impregnated device was used for electrical stimulation. The tDCS with an intensity of 1.5 MA for 20 minutes for 10 sessions (every other day) with an area of 35 cm was performed directly on the skull. No intervention was performed for the control group (See Figure 1 for more details).

Data Analysis

The statistical analysis was carried out using SPSS for Windows version 24 at a significant level of $p < 0.05$. Qualitative and quantitative variables were reported by frequency (percent) and mean (±SD) respectively. The distribution normality of quantitative variables was checked by the Kolmogorov Smirnov test. Mann–Whitney U test or T-test was applied for measuring the between variable significance value, and the Chi-square test was used for qualitative variables. In this study for within and between P-value, Multivariate Analysis of Covariance (MANCOVA) was conducted.

Results

This study was performed on 30 substance users (26 males (87%)), 24 of whom being undergraduates (80%)) with mean ±Standard Deviation (SD) age of 29±7.7 and mean history of addiction of 2.45 ± 1.38.

The frequency distribution of demographical variables of both groups is presented in Table 1. According to the results of this table, both groups were the same in terms of demographic variables. The study variables (impulsiveness, craving, cognitive abilities) before and after the study of both groups are descriptively presented in Table 1. The results showed that the two variables of impulsiveness and cognitive abilities showed a significant change only in the intervention group. The results, moreover, revealed that despite the reduction of the craving variable in both the intervention and control groups, these changes in the intervention group were significant compared to those of the control group.

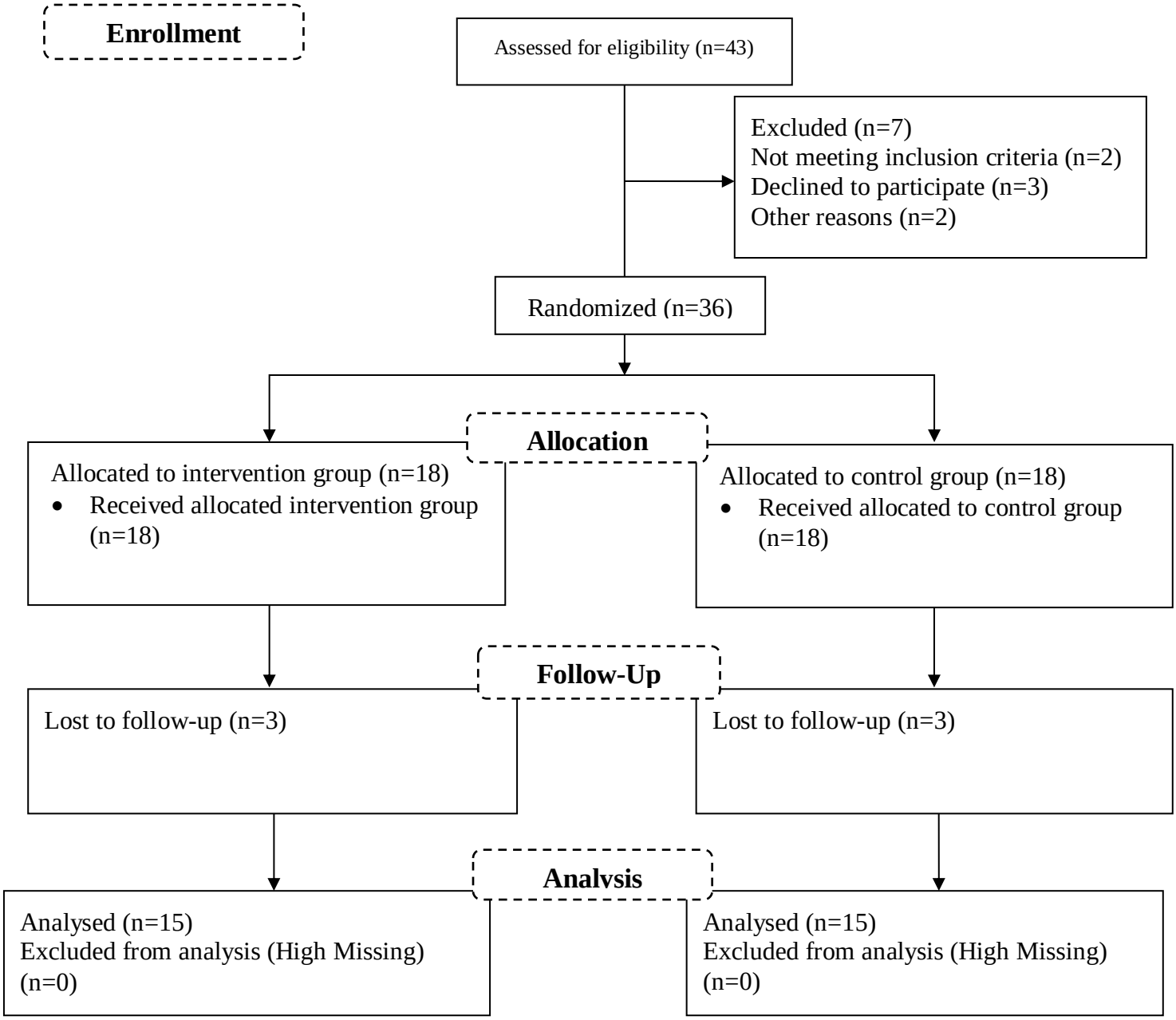

Figure 1: Participants Flow

Table1

The Distribution of the Demographic Variables

Variables	Levels	Intervention (n=15)		Control (n=15)		Total (n=30)		P-values
		N	%	N	%	N	%	
Gender	Male	12	80%	14	93%	26	87%	0.598
	Female	3	20%	1	7%	4	13%	
Age (year)	≤20	1	7%	2	13%	3	10%	0.473
	21 – 31	8	53%	9	60%	17	57%	
	31 – 40	3	20%	4	27%	7	23%	
	41 – 50	2	13%	0	0%	2	7%	
	50≤	1	7%	0	0%	1	3%	
Education	Under diploma	12	80%	10	67%	22	73%	0.554
	Diploma	1	7%	3	20%	4	13%	
	Upper diploma	2	13%	2	13%	4	13%	
History of Addiction (year)	≤1	3	20%	6	40%	9	30%	0.929
	1 – 2	5	33%	4	27%	9	30%	
	2 – 3	2	13%	3	20%	5	17%	
	3 – 5	2	13%	1	7%	3	10%	
	5≤	3	20%	1	7%	4	13%	

Table 2

The Mean±SD of study variables before and after study according to the two groups

Variables	Groups	Time				Diff	Within P-value	Between P-value
		Before		After				
		Mean	SD	Mean	SD			
Impulsiveness	Intervention	92.09	9.05	81.29	8.20	-10.8	<0.001	0.034
	Control	87.14	7.12	86.80	5.54	-0.34	0.839	
	P-value	0.1071		P-value	0.039			
Craving	Intervention	49.11	4.45	34.15	6.4	-14.96	<0.001	0.001
	Control	46.18	3.01	44.03	2.5	-2.15	0.003	
	P-value	0.05		P-value	0.0001			
Cognitive Abilities	Intervention	83.42	11.65	90.02	13.34	6.6	0.042	0.014
	Control	87.28	16.46	84.71	19.05	-2.57	0.578	
	P-value	0.464		P-value	0.4314			

Discussion

Today, addiction is considered as a brain disease. That is, by changing the nervous system and affecting the reward pathway in the brain, it leads to inappropriate activities and a great craving to return to drugs. Since tDCS is one of the therapies used to improve cravings (Taherpour et al., 2019), the present study was conducted with the aim of evaluating the effectiveness of tDCS on craving, impulsivity, and cognitive abilities in stimulant substance users.

The results showed that tDCS reduced cravings in the intervention group (-14.96 vs -2.15, P<0.001) in comparison with those in the control group. In this regard, the results of the present study are consistent with the studies done by Mousavi et al (Mosavi et al., 2020), Khosravian et al (Khosravian & Soleimani, 2018), Forogh et al (Forogh et al., 2018) and Taherpour et al (Taherpour et al., 2019), and Khodabande et al (Khodabande & Latifi, 2020). In fact, tDCS can

reduce the desire and intention to use drugs and create a negative reinforcement towards the desire to do so. On the other hand, it reduces the pleasure and intensity of craving. In this way, the use of drugs will not be satisfactory for people and they will take the opportunity to think about using drugs.

Stimulants increase dopamine in the mesocorticolinbic system, of which the prefrontal cortex is a part. It is likely that stimulation of this part of the brain by affecting hormone levels also reduces cravings in addicted people.

Moreover, the results indicated that tDCS increased cognitive abilities of the intervention group (6.6 vs -2.57, P=0.014) in comparison with those of the control group. In this respect, the results of the present study are in line with the studies done by Bayat Mokhtari et al (Bayat Mokhtari et al., 2017), Elsner et al (Elsner et al., 2020), Woods et al (Woods et al., 2018) and Narmashiri et al (Narmashiri et al., 2021). The results also showed that tDCS reduced impulsiveness of the experimental group subjects (-10.8 vs -0.34, P=0.034) in comparison with that of the control group. In this regard, the results of the present study are consistent with the studies done by Mayer et al (Mayer et al., 2020; Mayer et al., 2019), Brevet-Aeby et al (Brevet-Aeby et al., 2016) and Teti et al (Teti et al., 2019). Substance abuse is associated with cognitive impulsivity (decision-making and response inhibition) (Pourmohseni Koluri & Hazrati, 2018); therefore, reducing the desire to consume substances leads to a decrease in impulsivity and an increase in cognitive ability.

The limitations of the present study included the limitedness of the present sample to a small number of patients in Tehran. It is recommended that, in future studies, larger samples be considered for a better generalization and effectiveness of the tDCS on craving, impulsivity, and cognitive abilities in stimulant substance users.

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Statements:

There is no conflict of interest to report. Ethical aspects of this study was approved by the scientific and ethical committee for research of Islamic Azad University, Saveh Branch. All the participants studied and signed the informed consent forms.

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