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# The Impact of Transcranial Direct Current Stimulation on Impulsivity and Irrational Beliefs in Students

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## ABSTRACT

**Objective:** This study investigates the effectiveness of tDCS in improving impulsivity control and reducing irrational beliefs in adolescents with substance use disorders.

**Methods and Materials:** A quasi-experimental pre-test and post-test design was employed, involving 40 12th-grade students with substance use disorders from an addiction treatment center in Shahriar, Iran. Participants were selected through purposive sampling and divided into two groups: an experimental group and a control group. The experimental group received 12 weekly transcranial direct current stimulation (tDCS) sessions, each lasting 30 minutes. Data were collected using the Emotion Control Questionnaire (ECQ) and the Irrational Beliefs Test (IBT). Statistical analyses included Multivariate Analysis of Variance (MANOVA) using SPSS version 26.

**Findings:** The findings revealed significant improvements in impulsivity control ($p < 0.05$) and reductions in irrational beliefs ($p = 0.003$) in the experimental group compared to the control group. Improvements were observed across multiple dimensions, including emotional inhibition, mental rumination, and dependency.

**Conclusion:** tDCS demonstrates significant potential as a non-pharmacological intervention for adolescents with substance use disorders. It offers a promising approach to improving psychological factors that contribute to addiction. Further research is recommended to investigate the long-term effects and broader applications of this approach.

**Keywords:** Adolescent Addiction, tDCS, Impulsivity Control, Irrational Beliefs, Neuromodulation Therapy.



## Introduction

Substance use disorders (SUDs) represent a pressing public health concern globally, particularly among adolescents. Adolescence is a critical developmental period characterized by heightened susceptibility to risky behaviors, including substance use, due to neurobiological and psychosocial changes. While the prevalence of substance use among adolescents has shown minor declines in recent years, it remains

significantly high, with substantial consequences for individuals, families, and societies (Johnston et al., 2023). Effective treatment options are essential, yet conventional methods often fail to address the complex interplay of psychological and neurobiological factors contributing to substance use and relapse.

One of the primary challenges in managing substance use disorders is the impaired impulse control observed in affected individuals. Impulsivity, defined as the inability to resist urges or delay gratification, is strongly linked to substance use initiation and maintenance (Smith et al., 2022). Neuroimaging studies consistently demonstrate dysfunctions in the prefrontal cortex, a brain region critical for executive functions and inhibitory control, among individuals with SUDs. These dysfunctions manifest as overemphasis on substance-related cues, diminished sensitivity to non-drug rewards, and reduced capacity to inhibit maladaptive behaviors (Volkow et al., 2021). Adolescents, due to ongoing brain maturation, are particularly vulnerable to these impairments, underscoring the need for targeted interventions during this developmental stage.

In addition to impulsivity, irrational beliefs play a significant role in perpetuating substance use behaviors. Irrational beliefs, as conceptualized by Ellis's Rational Emotive Behavior Therapy (REBT), are unrealistic, absolutist, and unprovable thoughts that mediate emotional distress and maladaptive behaviors. Adolescents with substance use disorders often exhibit beliefs such as catastrophizing failures or perceiving an excessive need for approval, which exacerbate emotional dysregulation and increase the likelihood of substance use as a coping mechanism (Ellis & Dryden, 2020; Hamarta et al., 2021). Despite these associations, irrational beliefs have received relatively less attention in the context of addiction treatment, particularly among adolescent populations.

Transcranial Direct Current Stimulation (tDCS) is an emerging non-invasive neuromodulation technique that holds promise for addressing these challenges. tDCS delivers a low-intensity electric current to specific brain regions, modulating cortical excitability and facilitating neural plasticity. Recent studies highlight its potential to improve impulsivity control and reduce cravings by targeting the prefrontal cortex and associated neural circuits (Fregni & Brunoni, 2022; McKim, Boettiger, et al., 2021; McKim, Dove, et al., 2021). Although evidence supports the efficacy of tDCS in adults with substance use disorders, research focusing on adolescents remains scarce. This gap is significant, given the unique neurodevelopmental and psychological profiles of adolescents and their heightened vulnerability to addiction.

Prior research on tDCS and addiction has primarily concentrated on adults, with limited exploration of its applicability to younger populations. Moreover, existing studies often overlook the combined impact of psychological constructs like impulsivity and irrational beliefs on treatment outcomes. Addressing these gaps is critical to developing comprehensive, evidence-based interventions for adolescents. The present study seeks to investigate the efficacy of tDCS in improving impulsivity control and reducing irrational beliefs among adolescents with substance use disorders. By focusing on this underrepresented population, the study aims to provide novel insights into the utility of neuromodulation techniques in addiction treatment. It hypothesizes that tDCS will significantly enhance psychological functioning by targeting the neural underpinnings of impulsivity and irrational beliefs, thereby reducing the likelihood of relapse and improving overall treatment outcomes.

This research contributes to the growing body of evidence supporting the integration of neuromodulation methods into addiction treatment frameworks, with implications for both clinical practice and public health policies. By addressing the specific needs of adolescents, this study seeks to bridge critical gaps in the literature and advance our understanding of effective, non-invasive interventions for substance use disorders.

The intervention consisted of tDCS treatment administered over 12 weekly sessions, each lasting 30 minutes. The sessions were conducted under the supervision of a specialist to ensure adherence to safety protocols and intervention procedures. The experimental group received active tDCS, while the control group received no intervention but underwent the same pre-test and post-test assessments. The tDCS protocol involved delivering a low-intensity direct current (approximately two mA) to specific areas of the brain via electrodes placed on the scalp. Although the exact placement of electrodes (e.g., dorsolateral prefrontal cortex) and the polarity of stimulation (anodal or cathodal) were not specified, the stimulation was


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designed to modulate cortical excitability and facilitate neural plasticity. Further details about electrode configuration and montage would be essential for replicability. Both the experimental and control groups were assessed using the ECQ and IBT before and after the intervention to evaluate changes in impulsivity, control, and irrational beliefs. Ethical considerations, including confidentiality, informed consent, and the right to withdraw, were observed throughout the study.

## Methods and Materials

### *Study Design and Participants*

This study employed a quasi-experimental pre-test and post-test design with a control group to investigate the effects of transcranial direct current stimulation (tDCS) on impulsivity control and irrational beliefs among adolescents with substance use disorders. The statistical population consisted of all 12th-grade students diagnosed with substance abuse issues enrolled at the Atieh Roshan Addiction Treatment Center in Shahriar during the year 2024. A total of approximately 100 students were available in the center, from which 40 participants were selected based on inclusion and exclusion criteria. Purposive sampling was employed to ensure that the participants met the specific requirements of the study.

The inclusion criteria for the study were: (1) students diagnosed with stimulant substance abuse (e.g., methamphetamines, cocaine, and cannabis derivatives); (2) a history of substance use for at least six months; (3) enrollment in the 12th grade of high school; (4) willingness to participate and provision of informed consent; (5) current enrollment in addiction treatment programs at the Shahriar Addiction Treatment Center; (6) age between 15 and 19 years; (7) no physical illnesses such as diabetes, epilepsy, or kidney issues as indicated by medical records; (8) no psychological diagnoses other than substance abuse according to medical records; and (9) no psychological interventions received in the past six months. The exclusion criteria included: (1) prior use of medications for addiction treatment; (2) participation in similar intervention programs; (3) absence from more than three intervention sessions; and (4) withdrawal of consent for participation.

### *Instruments*

**Emotion Control Questionnaire (ECQ):** The Emotion Control Questionnaire, developed by Roger and Neshover (1987), was used to assess impulsivity control. This standardized questionnaire contains 56 questions across four dimensions: emotional inhibition, aggression inhibition, mental rumination, and benign inhibition. Each dimension consists of 14 items scored on a binary scale (0 or 1), resulting in total scores ranging from 0 to 56. The internal consistency coefficients reported by Roger and Neshwarian (1989) for the dimensions were as follows: emotional inhibition (0.68), aggression inhibition (0.70), rumination (0.76), and benign inhibition (0.77).

**Irrational Beliefs Test (IBT):** The Irrational Beliefs Test, developed by Albert Ellis and Albert Jones (1968), was utilized to measure irrational beliefs. This test contains 100 items covering 10 dimensions, including the need for approval, high expectations, blame tendency, reaction to failure, emotional irresponsibility, excessive worry, problem avoidance, dependency, hopelessness, and perfectionism. Responses are scored on a five-point Likert scale. Higher scores indicate more irrational beliefs. Jones (1968) reported a test-retest reliability of 0.92, with individual subscale reliabilities ranging from 0.66 to 0.80.

### *Intervention*

**Transcranial Direct Current Stimulation (tDCS):** tDCS is a non-invasive neuromodulation technique that has been rediscovered for its therapeutic potential in treating various disorders. It uses a low-intensity continuous electric current (approximately two mA) applied to specific brain areas via electrodes placed on the scalp. This method enhances the brain's ability to process information and may amplify the efficacy of other treatments. In this study, 12 weekly sessions of tDCS were conducted, each lasting 30 minutes, under the supervision of a specialist.

### *Data Analysis*

Descriptive statistics (percentages, frequencies, means, standard deviations, etc.) were calculated initially. For hypothesis testing, inferential statistics were employed. The Shapiro-Wilk test was used to

assess the normality of data distribution. If normality was confirmed, Levene's test was used to examine homogeneity of variances, followed by Multivariate Analysis of Variance (MANOVA) for group comparisons. All analyses were conducted using SPSS version 26.

## Findings and Results

Participants were aged 15 to 19 years, focusing on adolescents in their late teenage years, a critical developmental stage where substance use disorders (SUDs) often emerge and intensify. All participants were enrolled in the 12th grade of high school, ensuring a relatively homogeneous educational background. This suggests that the population represents adolescents at a comparable academic level.

**Table 1**

*Means (SD) of research variables*

| Variable | Group | Pre-test | | Post-test | |
|---|---|---|---|---|---|
| | | M | SD | M | SD |
| Impulsivity Control | Experimental | 48.33 | 7.21 | 40.15 | 5.69 |
| | Control | 47.51 | 7.10 | 46.69 | 7.03 |
| Irrational Beliefs | Experimental | 265.18 | 79.44 | 220.15 | 67.81 |
| | Control | 260.89 | 76.53 | 257.49 | 75.13 |

To evaluate the normality of the data, the Z statistic was calculated at a 95% confidence level with an error margin of 0.05. The results confirmed the normal distribution of the data, as the Z-statistic values fell within the acceptable range of ±1.96. Multivariate analysis of variance (MANOVA) assumptions, including homogeneity of variance-covariance matrices, were examined using Box's test. As the Box's test result was non-significant ($p > 0.01$), the homogeneity assumption was satisfied. Additionally, Levene's test was used to assess the equality of error variances between the experimental and control groups. The significance level of the F-statistic for all variables exceeded 0.05, indicating that the error variances were statistically homogeneous.

**Table 2**

*Results of Multivariate Analysis of Variance (MANOVA)*

| Test | Value | F | df Hypothesis | df Error | P-value | Eta Squared |
|---|---|---|---|---|---|---|
| Pillai's Trace | 0.193 | 16.995 | 2 | 35 | 0.001 | 0.493 |
| Wilks' Lambda | 0.807 | 16.995 | 2 | 35 | 0.001 | 0.493 |
| Hotelling's Trace | 0.971 | 16.995 | 2 | 35 | 0.001 | 0.493 |
| Largest Root | 0.971 | 16.995 | 2 | 35 | 0.001 | 0.493 |

Table 2 presents the results of MANOVA, comparing the means of the dependent variables (impulsivity control and irrational beliefs) between the experimental and control groups.

**Table 3**

*Results of ANOVA for Research Variables*

| Dependent Variable | SS | df | MS | F | P-value | Eta Squared |
|---|---|---|---|---|---|---|
| Impulsivity Control | 1.381 | 1 | 1.381 | 34.089 | 0.001 | 0.486 |
| Error | 1.458 | 36 | 0.041 | | | |
| Irrational Beliefs | 1.031 | 1 | 1.031 | 17.323 | 0.003 | 0.209 |
| Error | 1.425 | 36 | 0.095 | | | |

According to Table 3, the mean scores for impulsivity control differ significantly between the experimental and control groups ($F=34.089$, $p<0.001$). Similarly, there is a significant difference in the mean scores for irrational beliefs between the experimental and control groups ($F=17.323$, $p=0.003$). These results suggest that the

intervention (tDCS treatment) was effective in reducing impulsivity control issues and irrational beliefs in the experimental group compared to the control group.

## Discussion and Conclusion

This study investigates the effectiveness of tDCS in improving impulsivity control and reducing irrational beliefs in adolescents with substance use disorders. The findings of this study demonstrate that transcranial direct current stimulation (tDCS) is efficacious in improving impulsivity control and reducing irrational beliefs among adolescents with substance use disorders. These results align with prior research highlighting the role of the dorsolateral prefrontal cortex (DLPFC) in executive functioning and emotional regulation (McKim, Boettiger, et al., 2021; McKim, Dove, et al., 2021). The observed improvements in impulsivity control suggest that tDCS enhances neural plasticity in regions associated with inhibitory control, a critical factor in mitigating substance use behaviors. The reduction in irrational beliefs further supports the therapeutic potential of neuromodulation techniques in addressing cognitive distortions that perpetuate addiction (Ellis & Dryden, 2020).

Despite these promising findings, specific dimensions of irrational beliefs, such as high expectations, a tendency to blame, and perfectionism, did not show significant improvement. These results suggest that the current tDCS protocol may be less effective in addressing these specific cognitive distortions or that longer intervention durations are required to achieve measurable changes. Additionally, the reliance on self-reported measures for irrational beliefs introduces the possibility of underreporting or social desirability bias, which may have influenced the results. Future research should consider integrating objective measures, such as behavioral tasks or neuroimaging, to provide a more comprehensive evaluation of these constructs.

While this study focused on immediate post-intervention effects, it is crucial to acknowledge the absence of follow-up assessments to evaluate the sustainability of these benefits. Prior studies suggest that the effects of tDCS may diminish over time without reinforcement (Fregni & Brunoni, 2022). Therefore, future research should incorporate longitudinal designs to investigate the long-term effects of tDCS on impulsivity control, irrational beliefs, and relapse prevention. These findings could inform the development of maintenance protocols or adjunctive therapies to prolong the benefits of tDCS.

In interpreting these results, it is also essential to consider the broader clinical and cultural context. Adolescents in this study were drawn from a single addiction treatment center in Shahriar, Iran, which limits the generalizability of the findings to other populations. Cultural differences may influence the expression of impulsivity and irrational beliefs, as well as the efficacy of tDCS. Future studies should aim to replicate these findings in diverse populations and settings, including adolescents from different socio-economic and cultural backgrounds.

The absence of a sham-tDCS condition for the control group is another limitation of the study. While significant improvements were observed in the experimental group, the lack of placebo control means that the role of expectancy effects cannot be ruled out. Introducing a sham-tDCS condition in future studies would help isolate the specific effects of active stimulation and strengthen the validity of the findings. Finally, the study's reliance on a small sample size (n = 40) reduces statistical power. It limits the ability to conduct subgroup analyses, such as gender-based differences or the impact of baseline impulsivity levels on intervention outcomes. Expanding the sample size in future studies would enable more nuanced analyses and increase confidence in the generalizability of the findings.

This study provides preliminary evidence supporting the efficacy of tDCS in improving impulsivity control and reducing irrational beliefs among adolescents with substance use disorders. These findings highlight the potential of tDCS as a non-invasive, adjunctive treatment for addressing psychological factors that contribute to addiction and relapse in adolescent populations. By targeting the DLPFC and related neural circuits, tDCS presents a promising approach for enhancing executive functioning and reducing maladaptive cognitive patterns in this vulnerable population.

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## Declaration of Interest

The authors of this article declared no conflict of interest.

## Ethical Considerations

The study protocol adhered to the principles outlined in the Declaration of Helsinki, which provides guidelines for ethical research involving human participants. Ethical considerations in this study were that participation was entirely optional.

## Transparency of Data

By the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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## Authors' Contributions

All authors equally contribute to this study.

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