IJBS
10.30491/ijbs.2025.526359.2242
International Journal of Behavioral Sciences
Original Paper

# Examining the Effectiveness of Transcranial Direct Current Stimulation on Selective Attention in Patients with Mild Traumatic Brain Injury

Samane Farzamkia[1] (MSc), Seyed Ruhollah Hosseini[1] (PhD), Babak Ganjeifar[2] (MD), Mohammad Saeid AbdeKhodaei[1] (PhD)

1. Department of Psychology, Ferdowsi University of Mashhad, Mashhad, Iran
2. Department of Neurological Surgery, Mashhad University of Medical Sciences, Mashhad, Iran

**Submitted:** 21 September 2025
**Accepted:** 14 October 2025

Int J Behav Sci. 2025; 19(3): 147-153

**Corresponding Author:**
Seyed Ruhollah Hosseini,
Department of Psychology,
Ferdowsi University of Mashhad,
Mashhad,
Iran
E-mail: r_hosseini@um.ac.ir

## Abstract

**Introduction:** Patients with mild Traumatic Brain Injury (mTBI) constitute a significant proportion of brain injury cases. The mTBI often leads to cognitive deficits, including impaired selective attention, which can significantly impact daily functioning. The purpose of the present study was to examine the effectiveness of transcranial Direct Current Stimulation (tDCS) on selective attention in patients with mTBI.

**Method:** The current study employed a single-blind randomized controlled trial and quasi-experimental design to examine the effectiveness of tDCS on selective attention in mTBI patients. The participants were randomly assigned to active, sham, and control groups. Fifteen female patients diagnosed with mTBI were recruited via convenience sampling. To evaluate participants' selective attention, a computerized version of CWST was used for pre- and post-intervention assessments. The intervention protocol included 20 minutes of 1.5 mA tDCS stimulation applied to the left dlPFC for 10 sessions. The data were analyzed using one-way ANCOVA in SPSS-24.

**Results:** Findings indicated a notable improvement in selective attention within the active tDCS group; however, the differences between groups did not reach statistical significance ($P > 0.05$).

**Conclusion:** These preliminary findings suggest a potential role for tDCS in improving selective attention in patients with mTBI, warranting further investigation with larger sample sizes.

**Keywords:** Mild Traumatic Brain Injury, Transcranial Direct Current Stimulation, Attention, Stroop Test

## Introduction

Traumatic Brain Injury (TBI) is one of the main causes of death among children and young adults [1]. Among TBI patients, approximately 90% of these individuals sustain a mild Traumatic Brain Injury (mTBI) [1, 2]. According to Silverberg et al. [3], mTBI is a head injury that results in at least one of the following: 1) Loss of consciousness for less than 30 minutes and a score of 13-15 on the Glasgow Coma Scale (GCS); 2) Any memory loss related to the events immediately before and after the accident with post-traumatic amnesia for less than 24 hours; 3) Any change in the person's mental state during the accident (for example, feeling awe, bewilderment, confusion); and 4) Focal neurological deficit(s) which may or may not be transient [4, 5]. Approximately, 50 million people around the world [6, 7], especially in third-world countries [8], suffer from TBI.

Among the most frequent problems that mTBI patients deal with are cognitive problems [9, 10] and specifically problems in executive functions [9-13] working memory followed

by reduced processing speed [14] and attention [10, 15-18]. In most cases, symptoms resolve naturally after a period of three month [1, 19]. However, reports demonstrate that more than 40% of mTBI patients experience debilitating post-concussive symptoms that may last from months to years [1, 20, 21]. Various types of attention play a crucial role in executive functions. Consequently, attention deficit can potentially lead to impairments across all executive functions, hindering individuals' ability to perform daily life activities. Therefore, considering the noteworthy number of mTBI patients and its prominent role in people's daily lives, it is of great importance to investigate ways to reduce or control the cognitive problems caused by mTBI.

Studies in recent years report the potential therapeutic ability of non-invasive neuromodulation methods [1, 15, 22]. To our knowledge, seven studies have examined non-invasive brain stimulation methods, such as transcranial Direct Current Stimulation (tDCS), as an intervention for PCS in patients with mild to mTBI. In the findings of Quinn et al. [10], while active and sham groups showed notable improvement in attention, no significant inter-group difference emerged. The ambiguity regarding tDCS effectiveness in their study stems from the inability to discern whether improvements resulted from the computer-based training or tDCS itself. Furthermore, Motes et al. [23] demonstrated significant improvement in executive functions, including attention of active group, compared to the sham group. However, the unclear severity of brain damage likely contributed to group heterogeneity. Additionally, the lack of a control group limited the assessment of improvement intensity over time.

Given the unfortunately limited number of studies investigating the efficacy of tDCS on attention improvement in mTBI patients, this research extended its scope to include investigations on a broader spectrum of severity of TBI patients. Similar to studies on mTBI patients, the findings of four studies indicate a notable improvement in attention among TBI patients [10, 15, 16, 18]. In the study by Kang et al. [15], the stimulation group received only a single tDCS session. Although attention improved in the active group, it dissipated after 48 hours, with no statistically significant difference remaining between groups. Furthermore, Leśniak et al. [16] demonstrated that although the difference between the active and the sham groups was not statistically significant, tDCS combined with cognitive training led to substantial improvement in patients. Similar outcomes were reported in another study conducted by Ulam et al. [18]. Moreover, Sacco et al. [17] achieved statistically significant improvement in patients divided attention by combining tDCS sessions with cognitive training.

The extant research literature indicates the benefits of tDCS across various variables, particularly concerning executive functions in patients with TBI. Nevertheless, several methodological limitations in the existing research raise concerns regarding the effectiveness of tDCS in patients with mTBI. These deficiencies include, but are not limited to, inconsistent sampling regarding injury severity, lack of gender control, broad age ranges (from 18 to 59) among participants, unspecified timing of the participants' initial brain injury, and studies investigating multiple independent variables simultaneously. The inclusion of a control group is deemed essential as it facilitates the comparison of patients' natural recovery against both active and sham intervention groups [9].

Therefore, the purpose of the present study was to investigate the effectiveness of tDCS on selective attention as one of the crucial components of executive functions in mTBI patients. The present study attempted to overcome some of the previous studies' gaps. To this end, the study controlled for gender, restricted the age range of participants to 20–40, narrowed the timeframe from participants' initial brain injury experience, incorporated a control group, and, most importantly, limited brain injury severity exclusively to mild cases. Accordingly, the following hypothesis was formulated:

H1: Utilizing tDCS will significantly enhance selective attention in the active group compared to the sham and control groups in mTBI patients.

## Method

The current study employed a single-blind quasi-experimental intervention, with all participants undergoing pre- and post-assessments. The participants were recruited via convenience sampling and then randomly assigned to three groups: active, sham, and control (n = 5 per group). Since the study was a single-blind trial, the participants were blinded to randomization process and the group assignment. The participants were 15 women diagnosed with mTBI at Shahid Kamyab Hospital in Mashhad in 2023. Prior to random assignment to their respective groups, participants were screened according to established inclusion and exclusion criteria. Accordingly, efforts were made to control the participants' gender, age range, and timeframe of initial brain injury experience in this study.

Based on the research background, the inclusion criteria for participants were the following: 1) diagnosis of mTBI by a hospital physician (GCS: 13-15); 2) injury occurred 3–12 months prior; 3) reported attentional complaints; 4) female gender; and 5) age between 20 and 40 years. Participants were excluded from the study if they met any of the following criteria: 1) history of any other neurological disease, epilepsy, seizures, or psychosis; 2) history of alcohol or drug addiction (within the past two years); 3) any electrical discontinuity in the skull, such as a skin flap; 4) any electrical device implanted in the body (e.g., a pacemaker); 5) medical or hospital admissions within the past three weeks; 6) change in psychotropic medication within the past two months; 7) inability to complete the protocol; 8) inability to consent to participate in the research; 9) pregnancy; or 10) incarceration period during the research.

All experiments were performed in compliance with relevant laws and institutional guidelines, following ethics approval (IR.UM.REC.1402.054) from the Research Ethics Committee of Ferdowsi University of Mashhad. A list of mTBI patients was then gathered. These patients had

been admitted to Shahid Kamyab Hospital within the preceding three to twelve months. Inclusion and exclusion criteria were then verified through patient contact. To control gender and age, only women aged 20 to 40 were contacted. Given these control variables (gender, age, time since injury [3–12 months], and restricted residence), only 322 out of 5200 mTBI patients remained eligible. Of the 94 individuals contacted, 26 eligible participants expressed interest in the study, with 11 subsequently declining for personal reasons. Consequently, 15 participants were randomly and equally assigned in a single-blind manner to three groups: active, sham, and control. An informed consent was obtained from all participants, and pre-test and post-test were administered to all three groups one day before and after intervention sessions, respectively, in a single session at the Cognitive Science Laboratory of Ferdowsi University of Mashhad. The average completion time for the solely test utilized in the study, which was CWST, was 10 to 15 minutes per participant. The active and sham groups received 10 sessions of tDCS intervention on weekdays (excluding Thursday and Friday) (Figure 1). Furthermore, to ensure consistent environmental conditions, participants in both the active and sham groups were accommodated in an identical quiet room with appropriate air-conditioning. Throughout the intervention sessions, they were also screened for irritation, itch, and impedance.

Active Group: Ten sessions of anodal stimulation were administered at a current of 1.5 mA for 20 minutes to the left dlPFC, specifically targeting the F3 position based on the international 10-20 system. The cathodal electrode was placed on the right arm, inferior to the deltoid muscle. The electrode sponges were soaked in 0.9% saline solution prior to initiating stimulation. The tDCS mode of the Mindalive, Canada Cranial Electrical Stimulation (CES) device was used. The ramping up/down current was 0.15 mA and during 10 seconds for both initiation and termination.

Sham Group: The procedure was identical to that of the active group, with the sole distinction that they observed a demonstration of the intervention, and the device remained inactive, therefore the participants did not feel any stimulation. Moreover, to eliminate the diffusion effect, all participants received the pre- and post-tests and intervention sessions at different times and remained unaware of each other as well.

Control Group: In the control group, no intervention was administered, and only pre-test and post-test were collected from the participants with a 10-day interval.

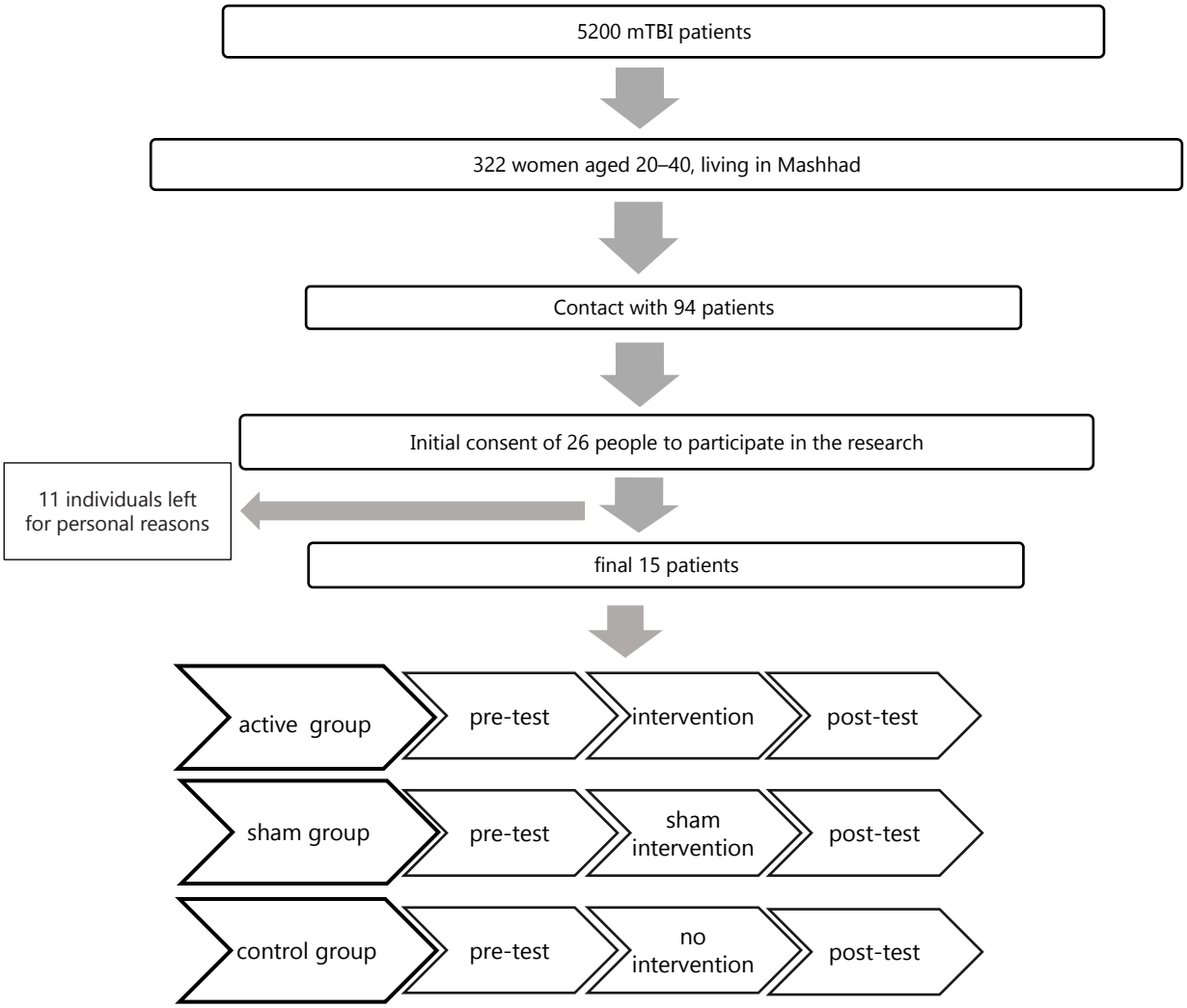


**Figure 1.** Flow chart of the research procedure.

The tools utilized in this study were as follows:

**Color-Word Stroop Test (CWST):** Originally developed in paper form by Ridley Stroop in 1935, this tool was administered in its computerized version in the current study to assess participants' selective attention in both pre- and post-assessments [24]. While the traditional paper form of the test needs orall responses, the computerized version needs non-verbal responses. Therefore, the participants are required to press colored buttons. Some minutes prior to commencing the main task, participants were instructed to familiarize themselves with the designated keyboard keys for each of the four colors (red, blue, yellow, and green). These target keys were marked with colored labels. The sufficient time for mastering keys were different for each participant; therefore participants were provided with ample time to master the color-key associations. To ensure procedural consistency in pre- and post-assessments, participants were tested in a quiet and comfortable setting. Participants were first required to master the color-coded labels on the computer keyboard. Subsequently, they could commence the main test. In the main test, participants were asked to press the colored keys based solely on their color, not on the word. Homack et al. [25] reported the reliability of this test for healthy adults as good (0.80). Considering the scoring was based on reaction time, only congruent and incongruent conditions were used for the final scoring.

**Transcranial Direct Current Stimulation (tDCS):** The intervention was conducted in 10 sessions utilizing the tDCS mode of Mindalive CES device. The anodal and cathodal rubber pads measured 4×4cm$^2$ and 3.5×7cm$^2$, respectively. Current ramp-up and ramp-down phases were set at 0.15 mA over 10 seconds for both initiation and termination. Anodal stimulation was administered at a current of 1.5 mA for 20 minutes to the left dlPFC, specifically targeting the F3 position according to the International 10-20 System. The cathodal electrode was placed on the right arm, inferior to the deltoid muscle. Prior to electrode application, both rubber pads were placed on sponges saturated with 0.9% saline solution. The intervention sessions for the active group were conducted at approximately the same time each day to control for circadian effects. Only the participants were blinded to group assignment, and the same operator conducted all sessions for both the active and sham groups.

## Results

A description of the sample's demographic indicators showed that the mean age and standard deviation of participants in the active group were 32.80 and 6.91, respectively. These values were 28.60 and 5.77 in the sham group and 32.40 and 6.43 in the control group. Furthermore, a one-way ANOVA revealed no significant difference between the groups ($F = 0.53$, $P > 0.05$). None of the participants reported drug abuse. Other demographic indicators have been presented in Table 1. The results of the chi-square test showed no significant differences in education status ($\chi^2 = 1.90$, $P > 0.05$), tobacco consumption ($\chi^2 = 0.68$, $P > 0.05$), caffeine consumption ($\chi^2 = 0.08$, $P > 0.05$), time since trauma ($\chi^2 = 0.90$, $P > 0.05$), and the Glasgow Coma Scale ($\chi^2 = 1.90$, $P > 0.05$).

The hypothesis was tested using a one-way analysis of covariance (ANCOVA). The results of the Shapiro-Wilk test indicated that the distribution of selective attention across groups was normal ($P > 0.05$). The results of Levene's test indicated that the assumption of homogeneity of variances was met ($F_{(2,12)} = 0.15$, $P > 0.05$). The assessment of the homogeneity of regression slopes also confirmed the validity of this assumption ($F_{(2,9)} = 0.97$, $P > 0.05$). Additionally, the results demonstrate that there is a linear relationship between the covariate and the dependent variable ($P < 0.05$). The descriptive statistics and ANCOVA results have been presented in Table 2.

**Table 1.** Descriptive Statistics and Demographic Indicators

| Indices | Subgroups | Active | | Sham | | Control | |
|---|---|---|---|---|---|---|---|
| | | *f* | Percent | *f* | Percent | *f* | Percent |
| Education status | Diploma | 2 | 40 | 1 | 20 | 2 | 40 |
| | Bachelor's degree | 1 | 20 | 1 | 20 | 2 | 40 |
| | Master's degree | 2 | 40 | 3 | 60 | 1 | 20 |
| Tobacco consumption | No | 4 | 80 | 4 | 80 | 3 | 60 |
| | Yes | 1 | 20 | 1 | 20 | 2 | 40 |
| Caffeine consumption | No | 4 | 80 | 4 | 80 | 4 | 80 |
| | Yes | 1 | 20 | 1 | 20 | 1 | 20 |
| Time since trauma | Since 3 months ago | 1 | 20 | 1 | 20 | 2 | 40 |
| | Since 4 months ago | 1 | 20 | 1 | 20 | 1 | 20 |
| | Since 5 months ago | 1 | 20 | 1 | 20 | 1 | 20 |
| | Since 6 months ago | 2 | 40 | 2 | 40 | 1 | 20 |
| The Glasgow Coma Scale | 13 | 1 | 20 | 1 | 20 | 2 | 40 |
| | 14 | 2 | 40 | 1 | 20 | 1 | 20 |
| | 15 | 2 | 40 | 3 | 60 | 2 | 40 |

**Table 2.** ANCOVA Results of Pre-test and Post-test

| Group | Pretest | | Posttest | | F | P | Partial $\eta^2$ |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | | | |
| Active | 0.23 | 0.11 | 0.06 | 0.05 | | | |
| Sham | 0.21 | 0.11 | 0.19 | 0.15 | 3.77 | 0.06 | 0.41 |
| Control | 0.19 | 0.16 | 0.26 | 0.21 | | | |

Table 2 demonstrates that the post-test mean values of the active and sham groups were significantly lower compared to the control group. The findings revealed a significant effect of the pretest (covariate variable). The results of the analysis of covariance (ANCOVA) indicated that the between-group difference in selective attention was not significant ($F = 3.77$, $P > 0.05$, Partial $\eta^2=0.41$). The comparison of adjusted means also revealed that the participants in the active group had a lower mean compared to those in the active group. These means were 0.05, 0.19, and 0.28 for the active, sham, and control groups, respectively. Additionally, the comparison of adjusted means using the Bonferroni post-hoc test revealed no significant differences among the groups ($P > 0.05$).

## Discussion

This study sought to investigate the effectiveness of tDCS on selective attention in individuals diagnosed with mTBI. The research hypothesis was evaluated through a single-blind intervention, incorporating pre- and post-assessments across three distinct groups: active, sham, and control.

The findings indicate that participants in the active group/within-group exhibited substantial improvement in the post-test compared to both the sham and control groups; however, the inter-group differences in selective attention were not statistically significant. This finding is crucial, as the randomized design ensures that the lack of a statistically significant difference between groups suggests that the intervention's effect on selective attention was not superior to the effects observed in the sham and control conditions. Based on these results, the current research hypothesis is rejected, meaning that utilizing tDCS did not significantly enhance selective attention in the active group compared to the sham and control groups in mTBI patients.

Despite a notable improvement within the active group, the intervention sessions failed to yield a statistically significant difference when compared to the other two research groups. This outcome aligns with the majority of previously reported studies [10, 15, 16, 18]. The findings of these studies similarly indicated that despite substantial progress in the attention variable within the active group, this improvement was not statistically significant [10, 15, 16, 18].

Conversely, the findings of the present study are inconsistent with those reported by Sacco et al. [17]. In contrast to the current research, Sacco et al. [17] found not only substantial improvement in participants' selective attention but also statistically significant differences between their groups. This discrepancy between the current study and Sacco et al. [17] might be attributed to the role of cognitive training and targeted area for stimulation. Sacco et al. [17] incorporated 40 minutes of cognitive training for participants after the completion of tDCS sessions. It also appears that cognitive training might play a more prominent role than tDCS sessions, given that participants in Sacco et al. [17] included patients with more severe brain injury, unlike the mild traumatic brain injury patients in the present study.

It is also possible that other factors, such as the type of cognitive training and the individualized targeting of stimulation areas based on patient needs, may contribute to explaining statistically significant improvements demonstrated in participants in the study of Sacco et al. [17]. For instance, while Quinn et al. [10] also employed cognitive training concurrently with tDCS sessions to enhance participant performance, Sacco et al. [17] utilized fMRI to determine the optimal stimulation area for each participant prior to intervention, thereby individualizing the tDCS sessions. Overall, despite the notable improvement found in participants in the present study, caution is warranted when drawing conclusions regarding the utility of this specific protocol—including the stimulation site, number of sessions, session duration, and current intensity—for improving selective attention in mTBI patients.

While this study aimed to address several methodological gaps and achieved success in certain areas, particularly in controlling gender, restricting participant age and injury severity (mild cases only), narrowing the timeframe of brain injury onset, and incorporating a control group, still certain limitations persist.

The primary limitations of the current study include a small sample size of only 15 women aged 20-40, which restricts the generalizability of the findings regarding other populations and poses a threat to external validity due to the exclusive focus on one gender, meaning our findings may not be applicable to other populations, particularly men. In addition, this small sample size significantly restricts the statistical power of our findings, increasing the risk of a Type II error where a true effect may have been present but was not detected. Furthermore, the absence of post-intervention follow-up prevents conclusions regarding the long-term maintenance of achieved changes. In addition, the present study was a single-blind trial; therefore, the operator was aware of the participants' group assignments, which increases the risk of the Rosenthal effect.

Future research is encouraged to overcome these limitations by recruiting larger, more diverse samples and incorporating follow-up assessments to determine the durability of treatment effects. Researchers are also

encouraged to explore different stimulation sites, such as the pre-Supplementary Motor Area (pre-SMA) or the dorsal Anterior Cingulate Cortex (dACC), a current intensity higher than 1.5 mA, or to conduct intervention sessions using High-Definition transcranial Direct Current Stimulation (HD-tDCS).Additionally, it is recommended that future studies integrate further intervention groups investigating cognitive training. This would facilitate a comprehensive comparative analysis of tDCS, cognitive training, or their combination, thereby enhancing the understanding of methods to improve selective attention in mTBI patients. In addition, the use of other brain assessment techniques, such as fMRI, may play a potential role in future tDCS studies to optimize stimulation parameters, including the stimulation site, current intensity, and number of sessions, and so forth. It is recommended that future researchers conduct a double-blind trial to minimize the Rosenthal effect and reduce possible biases.

## Conclusion

This study demonstrated that tDCS can be possibly an effective intervention for enhancing selective attention in mTBI patients. However, despite the present study's notable improvement in the active group's selective attention, caution is warranted when interpreting these findings. Conclusions regarding the precise utility of this specific protocol—including its stimulation site, number of sessions, duration of stimulation, and current intensity—for improving selective attention in mTBI patients remain limited. Further research is essential to validate and generalize these preliminary findings.

## Conflict of Interest

The authors declare that they have no conflicts of interest regarding this article.

## Ethical Approval

In this study, an informed consent was obtained from all participants, and the confidentiality of their information was strictly maintained. The study was approved by the research ethics committee of Ferdowsi University of Mashhad under approval number IR.UM.REC.1402.054. Also, this study was carried out according to the main ethical standards of human experimentation in accordance to the Helsinki Declaration.

## Declaration of Generative AI and AI-Assisted Technologies

The authors declare that no AI tolls were used in this study.

## Acknowledgement

The authors extend their appreciation and gratitude to all the participants in the study.

## References

1. de Amorim RLO, Brunoni AR, de Oliveira MAF, Zaninotto ALC, Nagumo MM, Guirado VMdP, et al. Transcranial direct current stimulation for post-concussion syndrome: study protocol for a randomized crossover trial. Frontiers in neurology. 2017;8:164. https://doi.org/10.3389/fneur.2017.00164
2. Cassidy JD, Carroll L, Peloso P, Borg J, Von Holst H, Holm L, et al. Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. Journal of rehabilitation medicine. 2004;36(0):28-60. https://doi.org/10.1080/16501960410023732
3. Silverberg ND, Iverson GL, Group ABISI, Cogan A, Dams-O-Connor K, Delmonico R, et al. The American congress of rehabilitation medicine diagnostic criteria for mild traumatic brain injury. Archives of physical medicine and rehabilitation. 2023;104(8):1343-55. https://doi.org/10.1016/j.apmr.2023.03.036
4. Esselman PC, Uomoto J. Classification of the spectrum of mild traumatic brain injury. Brain Injury. 1995;9(4):417-24. https://doi.org/10.3109/02699059509005782
5. Ruff RM, Iverson GL, Barth JT, Bush SS, Broshek DK, Policy N, et al. Recommendations for diagnosing a mild traumatic brain injury: a National Academy of Neuropsychology education paper. Archives of clinical neuropsychology. 2009;24(1):3-10. https://doi.org/10.1093/arclin/acp006
6. Maas AI, Menon DK, Adelson PD, Andelic N, Bell MJ, Belli A, et al. Traumatic brain injury: integrated approaches to improve prevention, clinical care, and research. The Lancet Neurology. 2017;16(12):987-1048. https://doi.org/10.1016/S1474-4422(17)30371-X
7. Wu L, Li Y, Sun M, Ye P, Zhang Z, Liu W. Global, regional, and national burdens of mild traumatic brain injuries from 1990 to 2019: findings from the Global Burden of Disease Study 2019–a cross-sectional study. International Journal of Surgery. 2025;111(1):160-70. https://doi.org/10.1097/JS9.0000000000001837
8. Savulich G, Menon DK, Stamatakis EA, Pickard JD, Sahakian BJ. Personalised treatments for traumatic brain injury: cognitive, emotional and motivational targets. Psychological medicine. 2018;48(9):1397-9. https://doi.org/10.1017/S0033291718000892
9. Mollica A, Greben R, Oriuwa C, Siddiqi SH, Burke MJ. Neuromodulation treatments for mild traumatic brain injury and post-concussive symptoms. Current Neurology and Neuroscience Reports. 2022;22(3):171-81. https://doi.org/10.1007/s11910-022-01183-w
10. Quinn DK, Upston J, Jones T, Brandt E, Story-Remer J, Fratzke V, et al. Cerebral perfusion effects of cognitive training and transcranial direct current stimulation in mild-moderate TBI. Frontiers in Neurology. 2020;11:545174. https://doi.org/10.3389/fneur.2020.545174
11. Kaup AR, Toomey R, Bangen KJ, Delano-Wood L, Yaffe K, Panizzon MS, et al. Interactive effect of traumatic brain injury and psychiatric symptoms on cognition among late middle-aged men: findings from the Vietnam era twin study of aging. Journal of neurotrauma. 2019;36(2):338-47. https://doi.org/10.1089/neu.2018.5695
12. Maegele M. Traumatic brain injury in 2017: exploring the secrets of concussion. The Lancet Neurology. 2018;17(1):13-5. https://doi.org/10.1016/S1474-4422(17)30419-2
13. Tate DF, Wade BS, Velez CS, Drennon AM, Bolzenius JD, Cooper DB, et al. Subcortical shape and neuropsychological function among US service members with mild traumatic brain injury. Brain imaging and behavior. 2019;13:377-88. https://doi.org/10.1007/s11682-018-9854-8
14. Cunningham J, Broglio SP, O'Grady M, Wilson F. History of sport-related concussion and long-term clinical cognitive health outcomes in retired athletes: a systematic review. Journal of athletic training. 2020;55(2):132-58. https://doi.org/10.4085/1062-6050-297-18
15. Kang E-K, Kim D-Y, Paik N-J. Transcranial direct current stimulation of the left prefrontal cortex improves attention in patients with traumatic brain injury: a pilot study. Journal of rehabilitation medicine. 2012;44(4):346-50. https://doi.org/10.2340/16501977-0947
16. Lesniak M, Polanowska K, Seniów J, Czlonkowska A. Effects of repeated anodal tDCS coupled with cognitive training for patients with severe traumatic brain injury: a pilot randomized controlled trial. The Journal of head trauma rehabilitation. 2014;29(3):E20-E9. https://doi.org/10.1097/HTR.0b013e318292a4c2
17. Sacco K, Galetto V, Dimitri D, Geda E, Perotti F, Zettin M, et al. Concomitant use of transcranial direct current stimulation and computer-assisted training for the rehabilitation of attention in

traumatic brain injured patients: behavioral and neuroimaging results. Frontiers in behavioral neuroscience. 2016;10:57. https://doi.org/10.3389/fnbeh.2016.00057
18. Ulam F, Shelton C, Richards L, Davis L, Hunter B, Fregni F, et al. Cumulative effects of transcranial direct current stimulation on EEG oscillations and attention/working memory during subacute neurorehabilitation of traumatic brain injury. Clinical Neurophysiology. 2015;126(3):486-96. https://doi.org/10.1016/j.clinph.2014.05.015
19. Åhman S, Saveman B-I, Styrke J, Björnstig U, Stålnacke B-M. Long-term follow-up of patients with mild traumatic brain injury: a mixed-methods study. Journal of rehabilitation medicine. 2013;45(8):758-64. https://doi.org/10.2340/16501977-1182
20. de Freitas Cardoso MG, Faleiro RM, De Paula JJ, Kummer A, Caramelli P, Teixeira AL, et al. Cognitive impairment following acute mild traumatic brain injury. Frontiers in neurology. 2019;10:198. https://doi.org/10.3389/fneur.2019.00198
21. Mayer AR, Quinn DK, Master CL. The spectrum of mild traumatic brain injury: a review. Neurology. 2017;89(6):623-32. https://doi.org/10.1212/WNL.0000000000004214
22. Cerruti C, Schlaug G. Anodal transcranial direct current stimulation of the prefrontal cortex enhances complex verbal associative thought. Journal of cognitive neuroscience. 2009;21(10):1980-7. https://doi.org/10.1162/jocn.2008.21143
23. Motes MA, Spence JS, Yeatman K, Jones PM, Lutrell M, O'Hair R, et al. High-definition transcranial direct current stimulation to improve verbal retrieval deficits in chronic traumatic brain injury. Journal of neurotrauma. 2020;37(1):170-7. https://doi.org/10.1089/neu.2018.6331
24. Nekar DM, Lee D-Y, Hong J-H, Kim J-S, Kim S-G, Seo Y-G, et al., editors. Effects of augmented reality game-based cognitive–motor training on restricted and repetitive behaviors and executive function in patients with autism spectrum disorder. Healthcare; 2022: MDPI. https://doi.org/10.3390/healthcare10101981
25. Homack S, Riccio CA. A meta-analysis of the sensitivity and specificity of the Stroop Color and Word Test with children. Archives of clinical Neuropsychology. 2004;19(6):725-43. https://doi.org/10.1016/j.acn.2003.09.003