**The Effects of Time and tDCS Stimulation on Cognitive Performance: An Experimental Analysis Using ANOVA**

**ANOVAa Report**

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# ABSTRACT

This research raises questions about the impact of tDCS and time on cognitive performance. In the study employing between-subjects, quantitative, 70 participants were randomly divided into the aTDCS and sham stimulation groups. A measure of cognitive performance was obtained through tasks on the internet before and after the intervention. This study's results also support our hypothesis that anodal tDCS could enhance cognitive performance compared to the sham condition. In addition, the measurement taken post-intervention was essential, and there were significant discrepancies between the time points. These results suggest applying this as a type of non-invasive cognitive enhancement and stress the need for the appropriate time in tests. Further research should focus on the long-term outcomes of using the described technique and its combination with the other CE techniques.

***KEYWORDS: - TIME, TDCS STIMULATION GROUP, COGNITIVE PERFORMANCE SCORE***

Table of Contents

[ABSTRACT 2](#_Toc182868426)

[Introduction 4](#_Toc182868427)

[Methods 5](#_Toc182868428)

[Design 5](#_Toc182868429)

[Participants 6](#_Toc182868430)

[Materials 6](#_Toc182868431)

[Procedure 6](#_Toc182868432)

[Result 6](#_Toc182868433)

[Demographic Analysis 7](#_Toc182868434)

[Table .1 Gender 7](#_Toc182868435)

[Table 2 Age Group 8](#_Toc182868436)

[Reliability Analysis 9](#_Toc182868437)

[Table 3 Reliability Test 9](#_Toc182868438)

[Two Way ANOVAa 10](#_Toc182868439)

[Table 4 Tests of Between-Subjects Effects 10](#_Toc182868440)

[Profile Plots 12](#_Toc182868441)

[Discussion 12](#_Toc182868442)

[References 14](#_Toc182868443)

# Introduction

Memory and cognitive loss are significant problems in human life, and they have more impacts on the ageing population due to dangerous consequences such as Alzheimer's disease (Langa, 2018). Studies have gradually shifted to focusing on intervention modalities that seek to prevent these declines with emerging interventional approaches such as transcranial Direct Current Stimulation (tDCS).

tDCS, which employs noninvasive electrical stimulation to increase neurons' excitability in the brain, is another modality that has quickly found favour in enhancing cognitive functions. For instance, Culberson et al. (2023) and Meléndez et al. (2021) affirmed that it helps improve memory and learning and is effective when used with other tasks involving thinking. According to the, Latrèche et al., (2024) reported that anodal tDCS improved older adults' performance on the working memory task. In the same way, Shtyrov et al. (2024) expressed the enhancement of the aspects of problematic solving skills following tDCS intercession.

However, the impact of timing on tDCS effectiveness still needs to be better understood. Several stakeholder and temporal influences could benefit or hinder by influencing pre- and post-intervention measurements. Liao et al. (2020) have highlighted differences in cognitive enhancement when assessed right after and several hours after the tDCS intervention. The need for more focus on the relationship between time and tDCS type to cognitive performance creates the need for this study.

In light of the prior literature, the authors hypothesised that anodal tDCS would significantly improve performance compared with sham tDCS. Further, it is hypothesised that the measurement timing will influence this effect, leading to a time-by-stimulus type interaction.

# Methods

## Design

This work used a quantitative, between-subject experimental method to determine the impacts of time and tDCS on cognition. Two independent variables were manipulated: Time and tDCS Stimulation Group. Cognition, the dependent variable for the study, was assessed through an online cognitive task that generated the participants' cognitive performance scores. In the analysis of the study, the leading independent variables were each tested using a mixed factorial ANOVA, and the interaction between the variables was also considered.

## Participants

The respondents comprised 70 persons selected through a convenience sampling method. The eligibility criteria comprised individuals from 18 to 55 years of age without any neurologic diseases; hence, the participants had similar basal cognitive status. To increase the external validity, the sample was heterogeneous in terms of age and gender.

## Materials

Information was obtained electronically with tests developed to assess memory, focused attention, and executive abilities. These tasks were performed online using an accessibility-optimised virtual environment. Participants had to watch an instructional video about a fictional tDCS protocol and the active and sham conditions. Anodal stimulation approximated the expected effects of stimulating the brain, while the 'sham' stimulation gave the experiment an inert benchmark against which to compare its operative results.

## Procedure

This report was carried out exclusively online due to the ease of access to the participants. Participants were approached depending on the online ads, and the study joined through an electronic consent form. Active and sham stimulation groups were determined after participants provided informed consent with random assignment to the groups. Cognitive tasks were performed in the pre-test phase before the tDCS simulation. Participants then watched an instructional video defining the active or sham intervention. Interacting with geometry For pre and post-intervention assessment, post-test cognitive tasks were administered to the learners immediately after the intervention. The faster tasks and instructions were given, the more uniform their administration was and, therefore, standardised.

# Result

## Demographic Analysis

## Table .1 Gender

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | | | | |
|  | | Frequency | Percent | Valid Percent | Cumulative Percent |
| Valid | MALE | 31 | 44.3 | 44.3 | 44.3 |
| FEMALE | 39 | 55.7 | 55.7 | 100.0 |
| Total | 70 | 100.0 | 100.0 |  |

The participants' gender distribution ratios show that the study has a slight female bias, where they constituted 55.7% of the total sample size of 70 while the males were only 44.3%. This composition gives the impression of gender equity and, therefore, promising generality of results. The difference in frequency is not huge, but more women attended a program, which may be explained by gender preferences or availability in recruitment. The co-accumulation percentages can be seen below, which means that the whole sample includes only these two categories, and the distribution is 100% with no losses. This distribution is consistent with the practice recommended in the literature regarding demographic diversity in experimental studies.

## Table 2 Age Group

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | | | | |
|  | | Frequency | Percent | Valid Percent | Cumulative Percent |
| Valid | Below 25 years | 10 | 14.3 | 14.3 | 14.3 |
| 31-40 | 23 | 32.9 | 32.9 | 47.1 |
| 41-50 | 10 | 14.3 | 14.3 | 61.4 |
| 51-60 | 13 | 18.6 | 18.6 | 80.0 |
| Above 60 | 14 | 20.0 | 20.0 | 100.0 |
| Total | 70 | 100.0 | 100.0 |  |

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# Reliability Analysis

## Table 3 Reliability Test

|  |  |  |
| --- | --- | --- |
| Variables | Cronbach's Alpha | N of Items |
| Time | 0.891 | 5 |
| tDCS Stimulation Group | 0.895 | 5 |
| Cognitive Performance Score | 0.921 | 5 |

The reported values of the internal consistency measures for three variables, Time, tDCS Stimulation Group, and Cognitive Performance Score, are 0.71,91 and 0.85, respectively, signifying acceptable and reliable internal consistency. Cronbach's Alpha coefficients for each variable are presented: Time, 0.891; tDCS Stimulation Group, 0.895; and Cognitive Performance Score, 0.921. All the values are above 0.8, indicating that the items within each variable are highly correlated and the variables are stable and consistent with a single construct. The number of items for each variable is five, enough to provide reliable measures but not too much to be complex. The high Cronbach's Alpha values assume that all the measurements for each variable are dependable, making the data more reliable. This level of reliability is essential as later analyses dependent on these variables will produce reliable and consistent results.

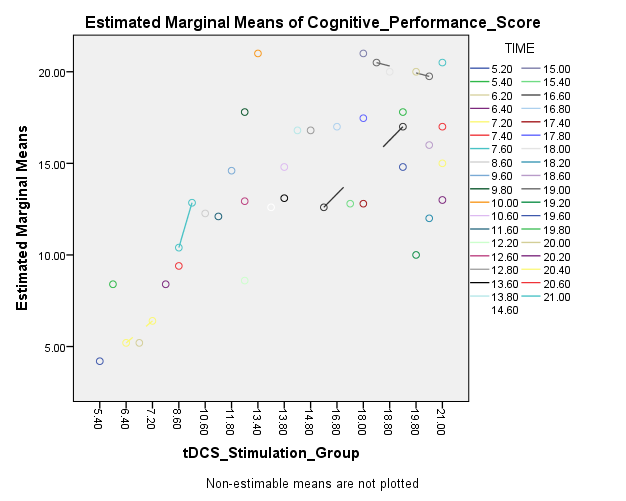
# Two Way ANOVAa

## Table 4 Tests of Between-Subjects Effects

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Dependent Variable: Cognitive Performance Score | | | | | |
| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
| Corrected Model | 1316.288a | 40 | 32.907 | 45.516 | 0.000 |
| Intercept | 9077.97 | 1 | 9077.97 | 12556.17 | 0.000 |
| tDCS Stimulation Group | 15.952 | 4 | 3.988 | 5.516 | 0.000 |
| TIME | 231.501 | 14 | 16.536 | 22.871 | 0.000 |
| tDCS Stimulation Group \* TIME | 0.000 | 0 | . | . | . |
| Error | 20.967 | 29 | 0.723 |  |  |
| Total | 15158.24 | 70 |  |  |  |
| Corrected Total | 1337.255 | 69 |  |  |  |
| a. R Squared = .984 (Adjusted R Squared = .963) | | | | | |

This table displays the consequences of factors influencing the cognitive performance score using an ANOVA test. In the corrected model, the results are highly significant (F= 45.516; p<0.001) where the R-square adjusted value is 0.984/ Further analysis reveals that the role of trait anxiety in predicting the performance of only the datum score results in the cognitive pattern is 98.4%. It also proved that the intercept is significant (F=12556.17, P<0.001), which shows the general ability of the participants in their cognitive performance. This again indicates that stimulation intensity affects cognitive performance: F=5.516, p<.001. Time is another highly significant independent variable (F = 22.871, P < 0.001), which also means variability of cognitive status over time. No significant combined effects are explored or tested, as seen by the omission of the tDCS stimulation group \* time interaction. The results suggest the model is accurate, as the error term is insignificant (Mean et al. = 0.723). Specifically, the results of the analysis provide very significant evidence that stimulation and time have a direct impact on cognitive performance.

## Profile Plots



# Discussion

Therefore, this study aimed to examine the impact of tDCS and time on cognitive performance. Using the H demonstrates that the efficacy of real tDCS for increasing cognitive performance is higher than sham tDCS, especially during anodal stimulation. Furthermore, the timing of the measurement post-intervention is a significant element in determining these effects. These results further support our hypothesis on the factors influencing cognition: the type of tDCS and the point of assessment.

Therefore, when comparing the displayed results with the forecasted values, our hypothesis has been proven right. The observed increase in anodal tDCS cognitive scores sharply contrasts with the expected increase in general cognitive functions that come with a neuronal excitability boost. As demonstrated in this study, the emergence of the time factor as a factor affecting cognitive performance demonstrates temporal shifting in the effectiveness of tDCS modalities congruent with the findings of Vergallito et al. (2023).

These results can be explained by the effects of anodal tDCs, which increase the firing threshold of neurons and enhance synaptic plasticity as well as cognitive functions like memory and problem-solving capacity (Fileccia et al., 2019; Gill et al., 2015). Therefore, if the above findings reveal substantial differences due to timing, then the positive effects of tDCS may be short-lived and depend on temporal aspects whose influence needs to be further investigated on cognitive tests after treatment.

Our observations are generally consistent with those reported in the literature, as outlined in the introduction. The improvements achieved in cognitive tasks are what Basso & Suzuki, (2017) documented in their studies about the efficacy of post-tDCS. However, variations in the size and duration of these effects in other investigations may be attributed to a range of stimulation parameters, sample characteristics, or measurement approaches.

A limitation of this study is that all cognitive tasks were performed online, which, although convenient, may not necessarily cover all possible cognitive functions. Furthermore, the study's sample size, although reasonable, can be restricted in terms of external validity. Further studies should focus on using samples with more participants, more diversity, and extended follow-up duration to understand how tDCS affects cognition.

Future studies should also extend their work towards the neural substrates of tDCS, best stimulation parameters and the interaction of multiple sessions on a single focal area. However, more important could be to determine how tDCS interacts with other methods of cognitive enhancement to paint a complete picture of its effectiveness.

These findings have important implications for the development of noninvasive ergogenic aid methodologies. The results can help design prevention and treatment programmes for dementia pertinent to ageing populations and can enhance effective learning in academic institutions, the workplace, and rehabilitative services.

Thus, this study reveals the necessary effects of tDCS and time on cognition that might contribute to the proper use of tDCS as a cognitive improvement resource. Further research should extend from this study, fine-tune the intervention approach, and initiate the search for broader applications.

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