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**Original Article**

# TRANSCRANIAL DIRECT CURRENT STIMULATION AND MANUAL ASYMMETRIES: THE EFFECT OF THE STIMULATION ON THE MANUAL DEXTERITY

## ESTIMULAÇÃO TRANSCRANIANA POR CORRENTE CONTÍNUA (ETCC) E ASSIMETRIAS MANUAIS: O EFEITO DA ESTIMULAÇÃO NA DESTREZA MANUAL

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**ABSTRACT**
The aim of this study was to evaluate the effect of transcranial direct-current stimulation (tDCS) on the primary motor cortex (M1) in the manual performance asymmetries in a manual dexterity tasks. The sample consisted of 28 volunteers, right-handed, men and without neurological impairment. The task (Grooved Pegboard) consisted of inserting 25 pins in 25 receptacles, as soon as possible. The task was executed in the pretest with both hands to define the level of manual asymmetry. tDCS or Sham were applied a week after the pretest, then the subjects were evaluated in the post-test. The results revealed that the effects of tDCS in M1 did not reduce asymmetries in a manual dexterity task. However, only the tDCS group improved the performance from pretest to the posttest ($p < 0.05$) in both hands. Stimulation of the right M1 may have generated benefits in the contralateral M1.
**Keywords**: Motor dexterity. Electrical stimulation. Functional laterality.

**RESUMO**
O objetivo foi avaliar os efeitos da estimulação transcraniana por corrente contínua (ETCC) sobre o córtex motor primário (M1) nas assimetrias de desempenho manual em uma tarefa de destreza manual. A amostra foi composta por 28 voluntários, destros, do sexo masculino e sem comprometimento neurológico. A tarefa (Grooved Pegboard) consistiu em encaixar 25 pinos em 25 receptáculos, o mais rápido possível. A tarefa foi executada no pré-teste com ambas as mãos para definição do nível de assimetria manual. Uma semana após o pré-teste foi aplicado a ETCC ou placebo, em seguida os sujeitos foram avaliados no pós-teste. Os resultados revelaram que os efeitos da ETCC no M1 não foram capazes de diminuir as assimetrias manuais em uma tarefa de destreza manual em sujeitos destros. Entretanto, somente o grupo ETCC melhorou o desempenho do pré-teste para o pós-teste ($p<0,05$) em ambas as mãos. A estimulação do M1 direito pode ter gerado benefícios no M1 contralateral.
**Palavras-chave**: Destreza motora. Estimulação elétrica. Lateralidade funcional.

## Introduction

Transcranial Direct-Current Stimulation (tDCS) is a non-invasive and painless cortical modulation technique that, through the application of low-intensity direct current on the scalp, can modulate cortical excitability[1-3]. Although mechanisms of neural plasticity related to tDCS have not yet been fully elucidated, changes in the excitability of stimulated cortical cells stand out as the main mechanism. Stimulation via anode (positive electrode) leads to a hyperpolarization of the dendrites and a depolarization of the cell body (summation); while stimulation via cathode (negative electrode), to a depolarization of the dendrites and a hyperpolarization of the cell body (summation)[3-5].

The literature has been finding tDCS benefits in reducing one's desire for alcohol consumption[6], cigarettes[7], in psychiatric diseases[8], in patients with stroke[9] and Parkinson[10], and in improving motor control[11,12]. Regarding motor control, stimulation of the primary motor cortex (M1) is associated with this improvement[2,12,13]. A change in the excitability of the M1 increases corticospinal excitability, strengthening synaptic connections and facilitating synaptic transmission[14,15].

Assessing the effects of tDCS on the motor control of manual asymmetries, the literature has been finding a decrease in asymmetries when tDCS is applied to the M1[13,16]. A cause of decreased asymmetries is a change in the manual dexterity of one or both limbs[17]. For instance, Vines et al.[18] investigated the effects of tDCS on the performance of a sequential four-finger tapping task (only the thumb was not required) under different stimulation conditions. The participants should perform as many times as possible the tapping sequence in 30 seconds. Three 30-second attempts were made with each hand before tDCS (pretest) and after tDCS (posttest) to assess task learning. The performance measure analyzed was the percentage of changes in tapping sequence errors from pretest to posttest. Inhibition of the dominant hemisphere in right-handed subjects (left hemisphere) had an impact on both hands, decreasing the dexterity of the dominant hand and improving the dexterity of the non-dominant hand. Inhibition of the non-dominant hemisphere (right hemisphere), in turn, only affected contralateral performance, worsening the dexterity of the non-dominant hand. Boggio et al.[19] investigated, in right-handed individuals, the effects of tDCS on the dominant and non-dominant M1 in the performance of the Jebsen-Taylor Hand Function Test. The Jebsen-Taylor test is composed of seven subtests performed with the dominant and non-dominant hands to assess performance in writing, card manipulation, handling of small objects, use of cutlery, manipulation of small disks, and reaching and grabbing of light and heavy cans. The total time to perform all subtests, as well as the total time of each subtest, is assessed. Initially, each participant had 10 attempts to practice the test with both hands in order to stabilize performance. After the practice period, they were randomly assigned to the stimulated group and the placebo group. Results showed that the application of tDCS to only one hemisphere can improve the dexterity of both hands. However, the contralateral hand in relation to the stimulated hemisphere benefits more from tDCS compared to the ipsilateral one (same side).

Recently, Christova et al.[20] investigated whether different forms of stimulation associated with the motor practice of a manual dexterity task, the Grooved Pegboard Test, changes corticospinal excitability, and whether this change is associated with the motor learning of the non-dominant hand. Three groups made 16 attempts with the left hand and were tested 14 days later to assess the long-lasting effects of the practice associated with stimulation. Each practice group received a form of stimulation on the non-dominant M1: (1) placebo tDCS before and during practice, (2) placebo tDCS before practice and anodic tDCS during practice, and (3) cathodic tDCS before practice and anodic tDCS during practice. Results showed that the training *per se* does not change corticospinal excitability and that, while anodic tDCS during practice increases corticospinal excitability, cathodic tDCS before practice reduces excitability.

Performance showed that tDCS during practice leads to a better performance in manual dexterity compared to placebo tDCS. This difference was observed at the end of the practice period and 14 days into the learning test. These assessed studies[18-20] gave the participant an opportunity to practice. The motor practice of the tasks assessed in the experiments can be a confounding factor, thus not allowing the inference of tDCS effects isolated from motor practice effects.

Thus, the present study sought to investigate whether cortical stimulation alone can reduce manual performance asymmetry in a manual dexterity task. It is possible that increased corticospinal excitability via right M1 stimulation, without the benefits of practice, has an effect on the performance of the non-dominant hand in a manual dexterity task, thus reducing manual asymmetry, which is our study hypothesis.

## Methods

*Participants*

The sample was made up of 28 male university students (average age=23±2.16). The sample included right-handed participants that presented preference index above 80 points for the right hand in the analysis of the Edinburgh Handedness Inventory[21]. Exclusion criteria were self-reported history of neurological impairment and ingestion of medications that are likely to affect cortical excitability. All volunteers signed the Free and Informed Consent Form. The research was approved by the Ethics Committee of the University where it was developed, under protocol No 24116513.2.000.5149.

*Instruments and motor task*

For the determination of the handedness index, the Edinburgh Handedness Inventory[21] was employed. The equipment used to perform tDCS was the HDC Kit (Magstim Company Limited, Whitland, Wales, UK). A mobile application was used as hand timer to control the time of execution of the manual dexterity task. The instrument used to perform the manual dexterity test was the Grooved Pegboard Test (Lafayette Instrument Company, model No 32025). The Grooved Pegboard consists of a surface with 25 holes, each having a randomly positioned groove, and a concave surface where pegs are inserted. The pegs also have a groove, which must match spatially with that of the hole so they fit[22]. The goal of the task is to fit 25 pegs into a receptacle in their proper holes, one at a time, as quickly as possible, in a prescribed order. When the task is performed with the right hand, the prescribed order is from top to bottom, right to left (Figure 1a). When it is executed with the left hand, the order is from top to bottom, left to right (Figure 1b).

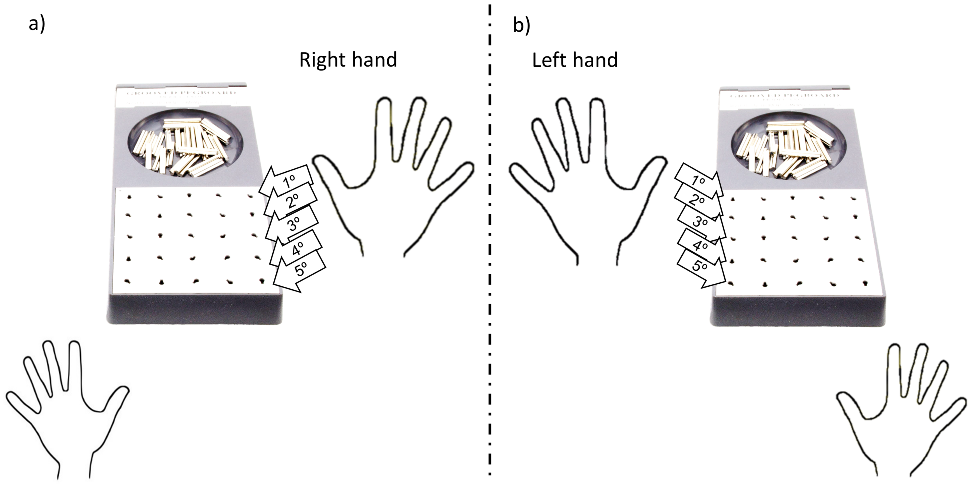


**Figure 1.** Grooved Pegboard manual dexterity assessment task and the prescribed order of execution with the right hand and the left hand.
Source: The authors.

*Procedures*

Data collection was done individually. All participants received standardized verbal demonstrations and instructions on the experiment and then performed part of the task, filling the first two rows of grooves with both hands to become familiar with the task. Subsequently, the pretest was applied, which consisted of motor assessment of both hands. The 28 volunteers were divided into two groups of 14 participants; one group started the pretest with the right hand and the other group with the left hand. One week after the pretest, the tDCS or placebo (tDCS simulated form) was applied. Immediately after the application of the tDCS or placebo, the subjects were assessed in the posttest. All volunteers started the posttest with the same hand with which they started the pretest (Figure 2).

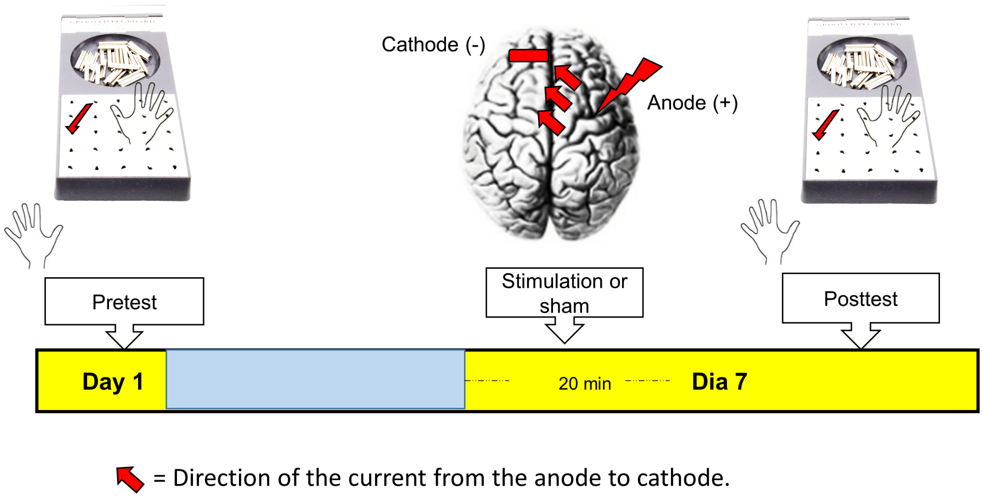


**Figure 2.** Timeline and procedures adopted throughout the study. The red arrows from the anode to the cathode position indicate the current direction.
Source: The authors.

The tDCS was applied via electrodes protected by sponges embedded in a saline solution containing concentrations between 40 and 150nM of NaCl diluted in deionized water to eliminate direct contact of the electrode with the skin and thus minimize possible unpleasant reactions. At the beginning of the stimulation, it was expected that most of the subjects perceived a slight itching sensation, which then disappeared in most cases[23]. To stimulate the contralateral M1 in relation to the non-dominant hand, the anode electrode (positive) was placed on the C4 region (10/20 international standard for analysis of electroencephalographic signals). The other electrode – cathode – was placed over the contralateral supraorbital area. A constant current of 1mA was applied for 20 minutes; this stimulation parameter is safe according to previous studies[23]. For placebo stimulation, the electrodes were placed in the same configuration. However, in this condition the stimulus was gradually removed by the HDC Kit after 30 seconds, enough time for the volunteer to no longer perceive the presence of the current. The subjects from the stimulated group underwent the same conditions of the stimulation procedure.

*Treatment and statistical analysis*

The motor performance measure used for the manual dexterity task was time of movement. This measure corresponds to the time interval between the start command given to the volunteer and the insertion of the last peg. Descriptive analyses were performed in terms of mean, standard deviation and median.

For inferential analyses, a series of procedures were adopted. First, the Shapiro-Wilks test was conducted to analyze data normality ($p > 0.05$). The Shapiro-Wilks test indicated that the data did not meet normality assumptions ($p < 0.05$). A logarithmic transformation was performed (Log10) but the data were not normalized. Thus, the following non-parametric statistical procedures were used for intragroup analyses (tDCS and placebo): a) application of the Wilcoxon signed-rank test and b) Bonferroni correction, with adjustment of level of significance calculated by the following formula:

0.05 / 4 comparisons.

The four intragroup comparisons were: (1) right hand x left hand pretest; (2) right hand posttest x left hand posttest; (3) right hand pretest x right hand posttest; (4) left hand pretest x left hand posttest. The level of significance adopted for the multiple comparisons was $p<0.01$.

**Results**

The descriptive analysis of the two groups (tDCS and placebo) in the two moments of analysis (pretest and posttest) with both hands (right and left) is displayed in Table 1.

**Table 1.** Mean, standard deviation and median of the experimental groups in the two moments of analysis with both hands.

| Time of manual dexterity task (minutes) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Analysis | tDCS Group | | | | Placebo Group | | | |
| | Pretest | | Posttest | | Pretest | | Posttest | |
| | RH | LH | RH | LH | RH | LH | RH | LH |
| Mean | 0.76 | 0.99 | 0.66 | 0.86 | 0.82 | 1.01 | 0.72 | 0.95 |
| Standard Deviation | 0.28 | 0.26 | 0.25 | 0.28 | 0.26 | 0.20 | 0.24 | 0.26 |
| Median | 0.56 | 1.04 | 0.54 | 1 | 1.02 | 1.07 | 0.57 | 1.06 |

Source: The authors.

*Inferential analyses in the tDCS group*

Multiple comparisons with the Wilcoxon test showed significant asymmetry in the right hand x left hand pretest ($p < 0.01$) and in the right hand posttest x left hand posttest comparison ($p<0.01$) (Table 2). In both comparisons, the right hand performed better than the left hand did (Table 1). Significant difference was also found concerning the moment of the test; right and left hand pretests showed worse performance compared to the right and left hand posttests, respectively ($p<0.01$).

**Table 2.** Results of multiple comparisons in the tDCS group.

| Right hand pretest X left hand pretest | | Right hand posttest X left hand posttest | | Right hand pretest X right hand posttest | | Left hand pretest X left hand posttest | |
|---|---|---|---|---|---|---|---|
| Z | *p* | Z | *p* | Z | *p* | Z | *p* |
| 3.05 | 0.002 | 3.07 | 0.002 | 2.55 | 0.01 | 2.49 | 0.01 |

Source: The authors.

*Inferential analyses in the Placebo group*

Multiple comparisons with the Wilcoxon test showed significant asymmetry in the right hand x left hand pretest comparison ($p<0.01$) and in the right hand posttest x left hand posttest comparison ($p<0.01$) (Table 3). In both comparisons, the right hand performed better than the left hand did (Table 1). However, no significant difference was found in relation to the moment (Table 3). The pretests with the right and left hands presented the same performance as the posttests with the right and left hands, respectively ($p>0.05$).

**Table 3**. Results of multiple comparisons in the placebo group.

| Right hand pretest X left hand pretest | | Right hand posttest X left hand posttest | | Right hand pretest X right hand posttest | | Left hand pretest X left hand posttest | |
|---|---|---|---|---|---|---|---|
| Z | *p* | Z | *p* | Z | *p* | Z | *p* |
| 2.69 | 0.006 | 3.176 | 0.001 | 0.75 | 0.45 | 0.38 | 0.70 |

Source: The authors.

## Discussion

The present study aimed to assess the effects of tDCS on manual performance asymmetries during a manual dexterity task. The hypothesis that the tDCS applied to the right M1, without additional practice, would be sufficient to decrease performance asymmetry was not confirmed. The manual asymmetry found in the pretest in the tDCS group was found in the posttest as well. Thus, it is possible to affirm that tDCS in the M1 was not able to reduce manual asymmetries during a manual dexterity task in right-handed subjects.

There is frequent observation of performance asymmetry in the Grooved Pegboard task in different populations and experimental conditions[24,25]. Our results indicated that, regardless of the experimental condition, asymmetry was maintained with shorter time of movement for the right hand. This finding was expected for the placebo group, taking into consideration that all participants were right-handed. The non-reduction of asymmetry in the tDCS group does not contradict previous findings in the literature, since studies that have observed a decrease in asymmetry in manual tasks have associated tDCS with motor practice, promoting motor learning in the non-dominant hand[17,19]. On the other hand, studies that have observed improvements in motor performance using tDCS without practice did not assess the performance of the contralateral limb before and after application of tDCS[16,26].

Application of tDCS combined with practice promotes a prolonged change in cortical excitability, strengthening synaptic connections through the long-term potentiation mechanism[14,15]. tDCS applied for 10 minutes not only influences cerebral excitability during its application but may induce persistent changes in excitability that may last about 1 hour on the M1[27]. These changes in brain excitability associated with motor practice may favor the acquisition of a skill through memory-forming mechanisms[12]. It is possible that, for complex manual tasks such as those required in the Jebsen-Taylor hand function test, as well as for the task applied in the present study, a change in corticospinal excitability only is not enough to decrease the difference in performance between the dominant and the non-dominant hands. A change in the quality of motor control would also depend on practice with the non-dominant hand. This is a hypothesis that needs to be further investigated.

Another explanatory way to the non-reduction of manual asymmetry goes through the analysis of a rather interesting and unexpected result. The results of the present study indicate that tDCS in the right M1 led to changes in the performance of both hands. The comparisons between pretest and posttest moments, in both hands, showed an improvement in the posttest performance, only for the tDCS group. It could be argued that there was a learning effect; however, the placebo group did not show improvement between moments for either hand. Somehow, the stimulation of the right M1 resulted not only in improved left hand performance but also in improved right hand performance. It is possible that the maintained level of asymmetry derives from the inter-hemispheric cooperation benefit. In right-handed individuals, inter-hemispheric facilitation is observed when the right hemisphere is active; when the left hemisphere is active, there is the effect of interhemispheric inhibition[28]. It is possible that the stimulation of the right M1 has generated benefits in the contralateral M1, a factor which would lead to improved performance in both hands, thus maintaining the levels of asymmetry. A possible practical application of these results is associated with rehabilitation processes that require plastic changes in hemispheric functions. After a stroke, the spontaneous return of motor function is associated with the return of activity in the M1[29]. The hand function of a patient who has suffered a stroke in a subcortical region depends predominantly on the activity of the M1 of the injured hemisphere[30]. Because the results of our study indicate that the stimulation of the right M1 may have generated benefits in the contralateral M1, tDCS could have an adjuvant role in the spontaneous return of activities of the right M1. However, this hypothesis needs further investigations regarding long-term effects that tDCS on the non-dominant M1 has on the dominant M1.

As limitations, the present study did not assess corticospinal excitability level to measure the effects of tDCS on the non-dominant and dominant M1. This analysis would allow a more direct analysis of the effects of stimulation of one hemisphere on the other. Although the Grooved Pegboard Test is widely used for manual dexterity analysis, a battery with a greater number of manual tasks could have represented the concept of manual dexterity more comprehensively. Further studies that seek to advance on such limitations are suggested.

## Conclusions

The results of the present study allow to conclude that for a serial task of manual dexterity, with visuospatial demand, the effect of tDCS does not reduce asymmetries between limbs. However, the stimulation of the right M1 seems to favor the function of the contralateral M1 in some way.

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