Inhibitory Control in Young Healthy Adults – a tDCS Study

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Summary

Inhibitory control plays a role in the behavior selection and detection of conflicts. Defects in inhibitory control are an integral part of many neuropsychiatric disorders and the possibilities of influencing it are the subject of active study. Studies have shown and confirmed the activation of the dorsolateral prefrontal cortex (DLPFC) during the Stroop task and other tests involving response inhibition. Non-invasive brain stimulation is an emerging and actively developing group of methods used in cognitive research. In the present study, we used non-invasive, painless, and delicate transcranial direct stimulation (tDCS) for the study of inhibitory control, and to explore the effect of impulsivity on response inhibition ability in young healthy participants. We conducted a cross-over study with cross-hemispheric application of 2 mA tDCS with electrodes placed on the right – cathode, and left – anode – DLPFC. Participants performed a classic Stroop test before and after stimulation. Impulsivity was measured *via* the personal impulsiveness questionnaire. There was no significant difference in interference score alteration between active and sham stimulations, anodal and sham tDCS both induced slight improvement in Stroop test results. Individual impulsivity in healthy participants showed no influence on their results. Our study adds to the picture and helps to deepen knowledge about the impact of different stimulation parameters on cognitive functions.

Key words

Transcranial direct current stimulation • tDCS • Inhibitory control • DLPFC • Impulsivity

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Introduction

According to the APA Dictionary of Psychology [1], impulsive (as in an impulsive person) is something "describing or displaying behavior characterized by little or no forethought, reflection, or consideration of the consequences of an action, particularly one that involves taking risks". In an attempt to connect impulsivity to a cognitive function, researchers linked it to cognitive control [2]. Impaired cognitive control, and therefore impulsivity, may lead to negative personal and social outcomes, or even to psychiatric disturbances, such as drug and alcohol abuse, gambling, eating disorders, or attention deficit hyperactivity disorder (ADHD).

Inhibitory control, as one of the elements of a big group known as "executive functions and cognitive control", represents the ability to choose and regulate how we react and how we behave rather than being hostages of habit. Healthy participants with high trait impulsivity and individuals with "impulsivity" disorders (drug abuse etc.) often show decreased inhibitory control and error processing [3,4].

The dorsolateral prefrontal cortex (DLPFC) is associated with cognitive control in general, and with solving interference in particular [5-7]. FMRI studies have also shown activation of the DLPFC during response inhibition, which has promoted the view that the DLPFC is an important component of cognitive control [8,9]. The DLPFC manages conflict monitoring and inhibitory control along with the anterior cingulate cortex (ACC), inferior frontal gyrus, posterior parietal cortex, anterior insula, and parts of the visual cortex.

Several psychological measures can be used to

access inhibitory control, such as the Stroop task [10], Simon task [11], Flanker task [12,13], antisaccade tasks [14,15], delay-of-gratification tasks [16,17], go/no-go tasks [18], and stop-signal tasks (SST) [19]. Most studies use the Stroop task for the "quantification" of inhibitory control, which is one of the most well-known paradigms in the cognitive psychology [20]. During the test, color words are presented in various ink colors, with the participants' goal being to report the ink color (ignoring the word color). In comparison to incongruent trials, congruent trials elicit faster reaction times and fewer errors. The majority of popular theories on the Stroop effect (the difference between congruent and incongruent trials) assume that the meaning of the words is automatically processed, which interacts with responding to the incongruent ink color, resulting in slower reaction times and more errors. The neural basis of Stroop effect processes is thought to be primarily located in the left DLPFC [21,22], the region which is also believed to be responsible for cognitive control. MacDonald *et al.* found a link between Stroop interference and left DLPFC activity, validating the function of the left DLPFC in control implementation [5]. However, other inhibitory control tasks have been linked to the activation of the right DLPFC, such as SST. For example, Depue *et al.* showed that connections between the right DLPFC and right inferior frontal gyrus as well as ACC are predictive of the SST performance [23].

Several approaches that enable researchers to manipulate brain activity have recently attracted increased attention. Transcranial direct current stimulation (tDCS) is a non-invasive brain stimulation technology that changes the resting membrane potentials in specific brain areas. During stimulation, a low continuous current is supplied in a polarity-dependent way using electrodes attached to the skull. While cathodal current is thought to inhibit neural activation by decreasing cortical excitability, anodal tDCS is thought to enhance neural activation by increasing the cortical excitability [24]. Effects from a single session may be detected for 90 min after the stimulation application [25], while effects of repeated sessions (e.g. 10 sessions) have been observed at 1-month [26] and 3-month follow-ups [27].

In addition, tDCS appears to be a good candidate for generating unique therapeutic alternatives for neurological and psychiatric disorders due to its low occurrence of severe side effects, and painless, non-invasive, and cost-effective application. However, despite some promising findings, there is strong evidence that a variety of factors, including stimulation parameters [28-30], nicotine intake [31], or psychopathological traits [32] may influence the results of tDCS application. To-date, the precise processes by which tDCS influences brain activity including cognitive domain and behavior remain not fully understood. Nonetheless, focused regeneration of aberrant brain activity may open up new perspectives for the treatment of neuropsychiatric disorders. Despite its drawbacks, non-invasive brain stimulation may become a useful tool for studying and affecting cognitive processes, particularly cognitive control.

The question of whether tDCS may affect cognitive functions has led to many studies on this subject in recent years [33,34]. Anodal stimulation of the DLPFC has been linked to enhanced working memory [35] and enhanced cognitive control [36]. Anodal tDCS over the left DLPFC has been demonstrated to restore deficient cognitive control in depressed patients [37], while cathodal stimulation of the left DLPFC in healthy participants has induced impairments in cognitive control [38].

It is still uncertain whether single-session tDCS may improve inhibitory control in healthy subjects. Among the tDCS and inhibitory control studies, we decided to focus on research in which anodal tDCS was applied to the left DLPFC, and a cross-hemispheric design was chosen.

The study by Fecteau *et al.* showed that participants who received either of the bilateral DLPFC tDCS techniques exhibited a risk-averse response style, but no difference between laterality was shown, which suggested that risk-taking may be influenced by modulating both DLPFCs [39]. A second study by the same author demonstrated that tDCS over the left DLPFC (left anodal/right cathodal) may lower response latency for untruthful replies compared to truthful answers [40]. Research by Jeon and Han showed that Stroop interference was improved by left prefrontal tDCS [41]. Another study tested the possibility of an influence on the inhibitory control measured by the Stroop task and showed that anodal tDCS over the left DLPFC minimized impairment of inhibitory control, which led to a faster reaction time change score [42]. Frings *et al.* observed that cathodal stimulation of the left DLPFC, as opposed to anodal stimulation, interrupted interference processing, resulting in a significant single session tDCS effect on the Stroop effect in the error data. They subsequently concluded that the state of the left DLPFC, as modulated by tDCS, affects Stroop performance, and therefore

inhibitory control [43]. The latest and the most systematic study to date [44] that tested various tDCS parameters, such as anodal/cathodal polarity, different stimulation intensity, and laterality, confirmed an improvement in cognitive control performance only after anodal tDCS of the left DLPFC.

Building on previous research, there is potential for improvement in terms of the consistency of results and the elaboration of techniques. Understanding the efficacy of parameter adjustments is required for future progress [45].

The present study looks into the potential of tDCS to enhance inhibitory control measured by the Stroop test in healthy individuals. We expected that tDCS with the anode over the left DLPFC would more likely induce a post-modulatory effect in inhibitory control performance than sham tDCS. We assumed that because of the important role the DLPFC plays in inhibitory control, stimulation of this cortical area would be effective in improving the accuracy measured by the Stroop task. Therefore, we predict that participants who received active tDCS will perform better, as demonstrated by increasing interference scores and lower error rates. As a secondary objective, we tested the effect of the impulsivity of the participants on inhibitory control performance and expected it to be dependent on personality traits (impulsiveness measured by the Abbreviated Impulsiveness Scale).

Materials and Methods

Participants

Twenty-seven healthy participants (16 females, aged 18-24, mean age ± SD: 20.15±1.8) participated in the study. According to the Edinburgh Handedness Inventory, they were all right-handed and had normal or corrected-to-normal vision. Exclusion criteria were diagnosed neurological or psychiatric disorders, metallic implants or tattoos near electrode sites, a cardiac pacemaker, the usage of psychiatric pharmacotherapy (anti-psychotics, hypnotics, sedatives), and Czech language skills lower than CEFR level B2.

All the participants gave their written informed consent to the experiment before the first session. The study was approved by ethics committee of NIMH and was conducted following the Declaration of Helsinki.

Experimental procedure

The study was designed as a double-blind, sham-controlled, cross-over study. All the participants received both types of stimulation – active anodal and sham – in a counter-balanced random order in two separate experimental sessions with a wash-out period of at least one week. Experimental sessions were conducted at the same time of the day. We ask the participants to refrain from caffeine and smoking for at least two hours before the experiment, and not to drink alcohol or use other psychoactive substances within 24 h before the session.

Each participant underwent the same procedure: (1) signing of the informed consent, (2) demographic questionnaire and ABIS (Abbreviated Impulsiveness Scale), (3) pre-tDCS Stroop test, (4) 30 min tDCS application (active or sham), (5) post-tDCS Stroop test, and (6) adverse effects questionnaire. The Stroop test was applied immediately before and after the stimulation, without any interval. The experiment lasted around 60 min.

The flow chart of the protocol can be seen in Figure 1.

Personality questionnaires

Sample characteristics, such as age, were addressed in the personal questionnaire. To evaluate the impulsiveness of the participants, the ABIS was used. The ABIS is a tool for measuring impulsiveness, which is based on the Barratt Impulsiveness Scale version 11 (BIS-11) and represents a shortened and improved variant of it [46]. It is effective in measuring all three components of impulsiveness, i.e. attentional, non-planning, and motor impulsiveness. The participants were instructed to answer the questions rapidly and without overthinking.

Possible adverse effects were reported on a custom adverse effects scale after the stimulation and post-tDCS Stroop task. At the end, blinding was assessed and the participants reported whether they thought they had received a “sham” or “active” stimulation. The questionnaires were provided in their respective Czech versions.

Stroop test

A paper version of a classic Stroop test was used to address inhibitory control. Word stimuli for the Words and Incongruent conditions were Czech translations of the words: RED, BLUE, YELLOW, and GREEN. Following the task instruction, the paper with color words printed in black on white was presented to the participants. The participants heard the sound signal and read the words loudly for 45 s. The time course was

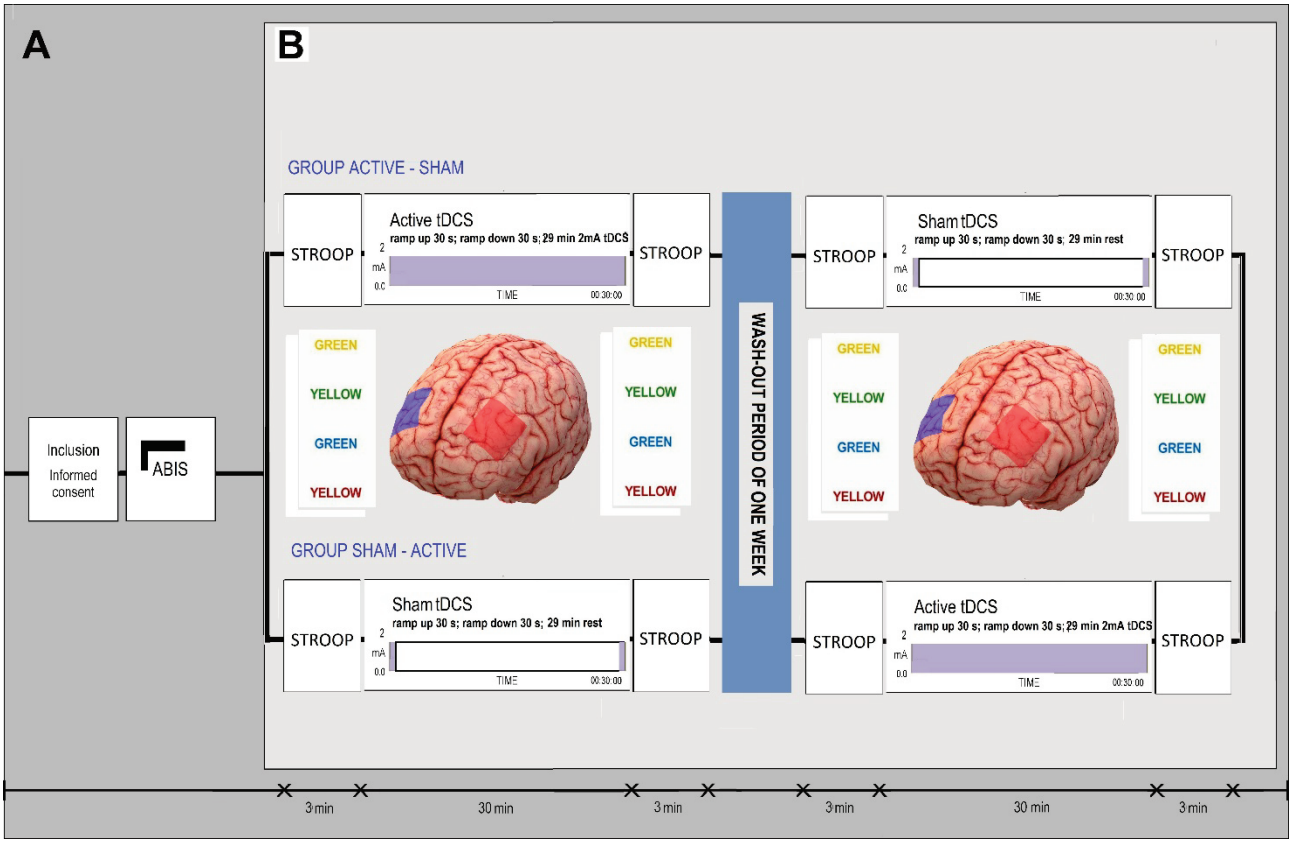

Fig. 1. Flow chart of the protocol. (**A**) Schematic overview of the study. (**B**) Experimental procedure. A double-blind, cross-over study. TDCS sessions (active tDCS and sham tDCS) were carried out randomly with a minimum one-week washout period. The psychometric measurement (Stroop test) was tested immediately before and after the end of each tDCS session. Types of tDCS protocols: active tDCS was targeted over the prefrontal cortex with fixed electrode positions in the F3 (anode) and F4 (cathode) areas; a sham tDCS was administered with identical electrode montage (as used in the active tDCS protocol). Active tDCS sessions comprised a 30 s ramp up, 29 min of 2 mA tDCS, and a 30 s ramp down. Sham stimulation was conducted with only 30 s of tDCS applied at the start and the immediate ramp down.

controlled with the mobile app "Interval Timer". After 45 s, the second signal was presented, the participants stopped and the next paper with colored crosses was presented. During the 15-second break, the participants kept silent and after the signal they began to read the colors of the crosses out loud. After the second break, the paper with incongruent symbols – colored names of colors – was presented and the participants were asked to read them out loud for 45 s. The words were presented in random non-repeating order. The task took three minutes to complete. The researchers recorded the results on the answer sheet, noting any errors.

Several different computational methods have been proposed to determine the degree of interference based on rough scores in the subtests "Words", "Colors", and "Color words". The results of the Stroop test may be presented as an interference score based on the theoretical model proposed by Golden [47]. The gross score in subtest CW represents the number of correct answers given within a time limit of 45 s. The interference score is derived from the score in the "Color words" (CW) subtest and the so-called expected score in this subtest (CW'). The degree of interference (IF) expresses the difference between these two values:

$$IF = CW - CW'$$

The expected score in the CW (CW ') subtest was calculated using the number of "Words" (W) and "Colors" (C) using Golden's model:

$$CW' = \frac{W \times C}{W + C}$$

Whereby, a low or negative IF value represents greater difficulty in inhibitory control. We used the interference score as a measure of performance.

Transcranial direct current stimulation (tDCS)

A direct current of 2 mA was delivered by a portable, battery-driven stimulator (HDCstim,

Newronika®, Italy) and applied *via* a pair of 5×5 cm sponge electrodes. The anode was placed over the left DLPFC at F3 according to the international 10-20 system and the cathode was placed over the right DLPFC (F4). The EEG conductive gel (ZERO-GEL®, Ceracarta S.p.A) was applied to the silicone electrodes and the saline-soaked sponges were placed on the electrodes. The position of the electrodes was secured by a fabric cap. The current was equivalent to 0.08 mA/cm^2.

The device varied the voltage to provide a constant current (2 mA).

The stimulation began with a 30-sec ramp up and at the end there was a 30-sec ramp down. Sham stimulation was conducted with the same montage of electrodes, with only 30 s of tDCS applied at the start and the immediate ramp down. Both the experimenter and the participant were blind to the type of stimulation.

During the stimulation (lasting 30 min), the participants engaged in "small talk" about their school life.

Statistical analysis

Data analysis was performed with R version 4.0.5 [48] and the nlme package [49]. The overall alpha level was fixed at 0.05.

A mixed effects model was applied. In the model, IF was used as the dependent variable. The model included the time and type of stimulation and sequence (whether the participant had active or sham stimulation during the first visit) as fixed effects and subject id as a random effect.

Correlation analysis was used for analyzing the effect of impulsivity on the Stroop task outcomes.

Results

Twenty-seven healthy volunteers randomized to treatment sequences completed two treatment conditions. The data obtained from the ABIS and Stroop test were then analyzed.

Sample characteristics

The composition of the two groups (active as first or sham as first) did not differ regarding demographic data. Table 1 provides a detailed overview of group compositions and the respective test statistics.

The primary outcome – the Stroop test

Parameter estimates for fixed effects on the participants' Stroop performance of the mixed-effects model are presented in Table 2. The following section summarizes the most significant main effects and interactions.

Table 1. Demographic data and behavioral data of the Stroop test for the pre- and post-stimulation in the sham and anodal session. According to the sequence of conditions, the participants are divided into Active → Sham or Sham → Active groups. Group mean (± SD) is reported.

	Active → Sham group				**Sham → Active group**			
Gender	9 females, 5 males				7 females, 6 males			
Age	19.79±1.67				20.54±1.94			
ABIS – attentional impulsiveness	1.91±0.39				2.11±0.42			
ABIS – motor impulsiveness	2.09±0.45				2.02±0.48			
ABIS – non-planning impulsiveness	2.02±0.61				2.15±0.61			
	Active		Sham		Active		Sham	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
C (words/45 s)	72.14±6.9	80.86±8.08	80.86±9.49	84.07±9.99	78.08±11.46	83.54±13.7	71.08±10.26	75.77±13.78
CW (words/45 s)	51.57±7.65	59.71±8.91	61.21±8.36	68±10.29	56.69±7.88	63.15±9.97	50.92±9.07	58.08±9.41
IF (words/45 s)	11.97±6.82	15.92±7.35	17.52±6.99	22.79±8.8	13.88±7.46	17.98±5.78	12.65±9.24	16.29±6.18

ABIS – Abbreviated Impulsiveness Scale; C – number of items properly named in 45 s in the color (C) congruous condition; CW – number of items properly named in 45 s in the color-word (CW) incongruous condition; IF – interference score.

The mixed effects model revealed a main effect of time ($F_{(75)}$=24.18, p<0.001), demonstrating better performance after the stimulation (both for the active and sham stimulation). The interference score was also influenced by stimulation type ($F_{(75)}$=7.90, p=0.006) and sequence ($F_{(75)}$=20.99, p<0.001). For details of all fixed effects, please refer to Table 2. Our hypotheses were mainly focusing on the two-way interaction of time and tDCS type. No significant interaction was found for time or tDCS type ($F_{(75)}$=0.05, p>0.05). The marginal r^2 for the model was found to be 0.339. The results as boxplots for each time point and stimulation condition are depicted in Figure 2.

Prior to the analysis, the outliers (n=2) were deleted by the Tukey rules on quartiles +/- 1.5 IQR.

We assume, that individual differences could be potentially associated with a musical or dance background (several participants were professional figure skaters), as participants chose a rhythm (slow or fast). Also, the lowest results were found in people for whom the Czech language was not their first language, which was not possibly related to understanding, but rather to the speed of pronunciation.

The secondary outcome – impulsivity and Stroop test results

To test for a correlation between changes in the Stroop test results (IFpost – IFpre) and impulsivity (attentional, motoric, and non-planning), Pearson's R correlation coefficient was calculated. No significant correlation was found for any pair of impulsivity traits and IF change in the active or sham tDCS. Specifically, no significant correlation coefficient emerged either for the active, R=-0.2, p=0.32, or sham stimulation, R=-0.033, p=0.87.

Table 2. Mixed effects model for the outcome variable of the Stroop test.

Parameter	**Estimates**	**CI**	**df**	**F-value**	**p-value**
Intercept	11.49	7.86 – 15.11	75	179.93	<0.001
Time	-3.89	-6.14 – -1.64	75	24.18	<0.001
Type of stimulation	2.38	0.13 – 4.63	75	7.90	0.006
Sequence	3.66	2.07 – 5.25	75	20.99	<0.001
Time × Type	-0.36	-3.54 – 2.82	75	0.05	0.823

df: degree of freedom; CI: confidence interval.

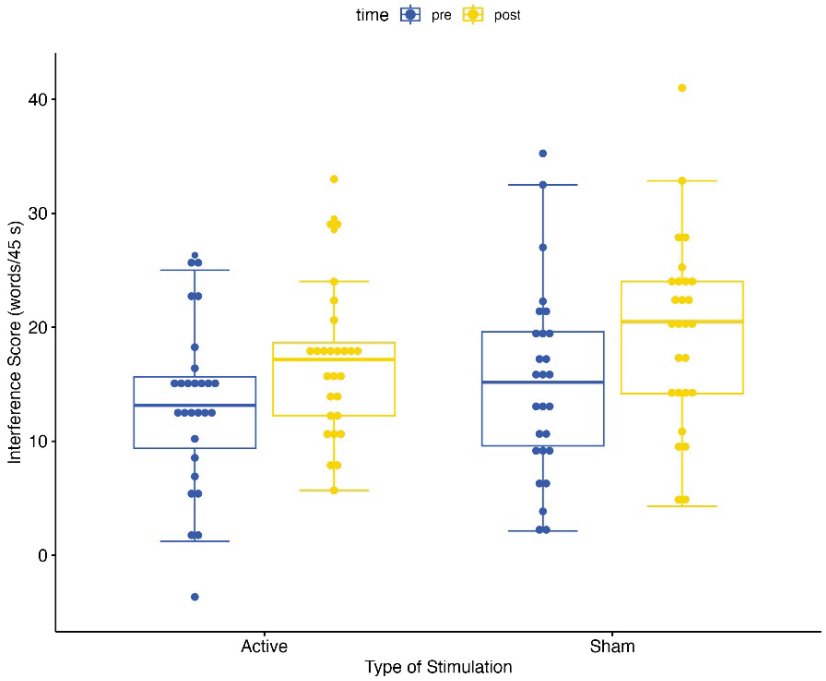

Fig. 2. Boxplot of the Stroop test results. The interference scores of both groups before and after the stimulation. Before the stimulation results are represented by blue color, after by yellow, and each participant is represented by a dot. Subdivision into groups (Active → Sham or Sham → Active) is not pictured here. The boxplot displays the first and third quartiles and the outliers.

Discussion

Our study aimed to increase activity in the left DLPFC, a brain region linked to inhibitory control, decrease activity in the right DLPFC, and influence the balance between the hemispheres. We choose cross hemispheric tDCS montage based on the results of Fecteau *et al.*, which showed that changing the interhemispheric balance of DLPFC activation affects risk-taking [39].

The study was originally inspired by a study by Loftus *et al.*, which showed that following anodal stimulation over the left DLPFC, mean Stroop response times for both neutral and incongruent items were statistically significantly reduced when compared to a sham. However, there was no statistically significant benefit of the tDCS condition regarding error rates [42]. We conducted our study on a larger group and in a cross-over design, the learning effect between the sessions was avoided by a washout period of at least seven days. We expanded our experiment with personal impulsivity characteristics and found no significant deviations from previous studies.

This left prefrontal upregulation by anodal tDCS was expected to enhance the inhibitory control, measured by the Stroop test *via* reducing of interference score. However, our findings did not support the hypothesis that anodal stimulation of the left DLPFC reduces impulsive behavior and boosts inhibitory control in healthy participants.

Inhibitory control

Our study is one of a number of current studies of inhibitory control and the possibilities of influencing it with the help of non-invasive stimulation methods. We chose tDCS as an elegant and safe method of brain stimulation with proven effectiveness. The tDCS method shows significant results in patients but differs in experiments with a healthy population, where the type of stimulation, placement of electrodes, intensity of stimulation [44], and individual factors, such as nicotine intake [31], genetics such as COMT Val158Met polymorphism [50,51], or a potential GABA-A receptor gene polymorphisms [52] may influence the effect of stimulation. Our study aimed to add knowledge of this issue. We conducted the study with healthy young adults with the same level of education and from the same circumstances, which was conceived to reduce the difference in cognitive abilities. However, our approach may lead to a ceiling effect, due to the high intelligence and attention control of the participants. The study was conducted with a cross hemispheric design and relatively high intensity (2 mA) stimulation, as we see now, our results match the current knowledge, i.e. unipolar stimulation with extracephalic electrode placement and lower rather than higher intensity (1 mA rather than 2 mA) shows the best results in experiments with cognitive control [44]. The study presented by Weller *et al.* showed that tDCS has non-linear effects, i.e. higher intensities do not always elicit more noticeable outcomes in a cognitive domain. This effect has previously been demonstrated only for physiological tDCS outcomes [53,54]. The study of Jamil *et al.* showed that for both polarities, the motor-cortical excitability after-effects monitored *via* transcranial magnetic stimulation did not increase linearly with increasing DC intensity. Effects at lower DC intensities (0.5, 1.0 mA) had at least as strong an impact on excitability. Batsikadze *et al.* revealed that tDCS effectiveness does not necessarily increase with longer or more intense stimulation. After both 2 mA anodal and cathodal stimulation, short intracortical inhibition and facilitation were switched towards excitability augmentation, unlike 1 mA cathodal stimulation, which generated cortical inhibition. Therefore, cathodal stimulation loses its classic properties with double intensity. A recent paper by Hassanzahraee *et al.* describes the discovery of a similar effect of duration on the anodal tDCS [55]. The enhancing effect of anodal 1 mA tDCS on corticospinal excitability decreased and even reversed when the stimulation duration increased from 24 to 26, 28, and 30 min. Their results suggest a duration threshold for reversal of the anodal tDCS effect to be 26 min.

A further possible task in DLPFC stimulation may be to harmonize the sides – some of the latter studies focus their attention on the tDCS of the right DLPFC. For example, stop-signal reaction time was elevated after cathodal tDCS and reduced after anodal stimulation [56,57]. These studies consider a different task, which, however, is also related to inhibitory control. The fact that we "inhibited" the right DLPFC may also have influenced the results of our study.

Stimulation of deeply located subcortical regions such as the ACC should also attract our attention, assuming that the inhibitory control is not induced by one brain region, but represented by a network, which may be activated *via* the ACC. Stimulation of the ACC may be achieved by non-standard placing of electrodes (with the

cathode on the cheek) [58] or by the use of high-definition neurostimulation systems with several electrodes [59]. However, this branch of research also shows dissimilar results.

The results show the effect of time of Stroop task application (pre and post the tDCS) – the IS was improved after both types of stimulation (active and sham), which may be explained by the learning effect expected from tests like Stroop [10]. Conducting of the test may also be seen as a limitation of our study. We used the old classic paper version, where the reaction times of individual answers cannot be calculated. The decision for such a version was made taking into account the ease of conducting this test and the portability that we had to resort to due to the COVID-19 pandemic. On the other hand, we had the opportunity to study the error rates and derived interference score, which is considered to be a reflection of inhibitory control [47].

Impulsivity

As a secondary objective, we were interested in studying the effect of personal impulsivity on inhibitory control and tDCS efficiency. Our study showed no significant effect of impulsivity traits on inhibitory control performance in healthy subjects. In the latest study by Weidler *et al.*, active but not sham tDCS increased response inhibition in alcohol-dependent patients and chronic tobacco users [60]. However, there were no differences between stimulation protocols in healthy controls. Interestingly, all the groups performed similarly in response inhibition during the baseline testing, but chronic tobacco and alcohol users presented with higher impulsive features than matched controls. Therefore, the findings agreed with the previous study and showed that higher impulsivity may facilitate tDCS results [61]. At the same time, our experiment also showed that in healthy young people with a low level of impulsivity, this trait does not have a significant effect on the results of stimulation.

Limitations of the study

- The use of high-intensity (2 mA) anodal stimulation may lead to a reverse, inhibiting effect. Also, unipolar stimulation with extracephalic electrode placement showed the most convincing results in studies with cognitive control.
- The chosen method of stimulation could influence not only the DLPFC but also other cortical structures, such as mPFC.
- One of the main limitations of our study is that we did not include another active stimulation (e.g. with different electrode positions or with anode and cathode swapping) to verify the effect/non-effect demonstrated by tDCS.
- We used no electrophysiological measures to prove the actuality of stimulation.
- There is the possibility that results in behavioral tasks show the same pattern as electrophysiological measures, i.e. reversal effect of longer duration (30 min) may be found.
- We cannot exclude the learning effect, which is expected from tests like Stroop.
- The Stroop task performance – the card version of the Stroop test could be replaced by a computer one since the card version of Stroop does not allow us to measure reaction times (the most sensitive and reliable result from the Stroop). The error rate, which we used as an outcome, is an insensitive marker, due to the ceiling effect. We tested healthy participants with high “before” results; reaction times may show a difference between active and sham stimulation.
- The lack of “actual” impulsivity measurement *via* impulsivity-focused tasks (such as the Stop Signal task or CPT test). This could then better show the effect of the used neurostimulation protocol on impulsivity and the relationship between change in inhibitory control performance and change in impulsive behavior.

Conclusions

Studies show that tDCS can enhance inhibitory control in healthy individuals and individuals with various clinical conditions, such as attention deficit hyperactivity disorder (ADHD) or substance use disorders.

However, it is important to note that the effects of tDCS on inhibitory control may vary depending on factors such as the stimulation parameters, the individual's baseline level of inhibitory control, and the specific task being used to measure it.

Despite the limitations of the study, we believe that it adds to the question of whether or not tDCS may affect cognitive functions. Our study showed that cross-hemispheric DLPFC tDCS does not affect the inhibitory control measured by the Stroop task. We see consistency with the results of other studies related to this issue.

Research with a healthy population should aim to further refine the methodology of tDCS application and transfer and compare the results with the patient population.

Conflict of Interest

There is no conflict of interest.

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