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Bilateral temporal cortex transcranial direct current stimulation worsens male performance in a multisensory integration task

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HIGHLIGHTS

- tDCS induces a polarity, gender and task specific effect in a multisensory integration task.
- Bilateral cathodal temporal cortex tDCS worsens task accuracy in males only.
- Bilateral anodal or cathodal temporal cortex tDCS results in decreased reaction time for both genders.

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ABSTRACT

Somatosensory integration is a critical cognitive function for human social interaction. Though somatosensory integration has been highly explored in cognitive studies; only a few studies have explored focal modulation of cortical excitability using a speech perception paradigm. In the current study, we aimed to investigate the effects of tDCS applied over the temporal cortex of healthy subjects during a go-no-go task in which stimuli were shapes and non-words. Twenty-eight subjects were randomized to receive cathodal, anodal or sham tDCS bilaterally over the superior temporal cortex (the reference electrode was on deltoid) in a counterbalanced order. The effects on judgment of congruency between shapes and non-words in healthy volunteers were measured by a go-no-go task. Our findings show a significant modification of performance according to the polarity of stimulation, task and subject gender. We found that men performed worse on the no-go condition for congruent stimuli during cathodal tDCS. For reaction time, on the other hand, there was a similar effect for anodal and cathodal stimulation. There were significantly faster responses on incongruent trials during both anodal and cathodal tDCS. Along with previous literature showing gender differences in tasks associated with speech perception, the findings of this study provide additional evidence suggesting that men may have a more focal and restricted neural processing in this multisensory integration task.

1. Introduction

Somatosensory integration is a critical component of cognitive processing. It is characterized by dual processing that integrates different sensory inputs such as visual and auditory stimuli in order to provide an adequate response. As these different signals can arise from common external events or objects, the integration between them can be useful [7]. It is a particularly important stage of processing as most of our cognitive computations involve simultaneous processing of more than one type of sensory stimulation.

Theoretical perspectives suggest that brain functions can present interactive distribution of functional systems, e.g. hearing a word is associated with the activation of articulatory motor areas. Thus, there are neural networks combining processing from different inputs. Additionally, inputs from a different modality can activate other areas through processes of association and integration [13].

The motor theory of speech perception suggests that the objects of perception of speech are the “phonetic gestures”, represented in the observer’s brain as a motor command of the signal, characterized by movements of the mouth, lips and tongue [6].

Specific neural networks have been described for different modalities of multisensory integration. For example, specific

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regions of the cortex, including Broca's area and superior temporal sulcus (STS) are likely involved in the integration of shapes and non-words. These regions may underlie the shared representation of the auditory perception of a sound and the motor representation of mouth and larynx movement needed to make the sound [11].

Neuropsychological studies have shown the relationship between motor action and speech production using cognitive tasks of association between images and written non-words where these images have been produced according to the phonetic gestures used to produce the sound of the corresponding non-word, e.g. sounds that need rounded movements of the mouth to be produced have rounded shapes to represent them [8,11].

We therefore hypothesize that a technique – transcranial direct current stimulation (tDCS) – that can alter cognitive processing might be useful to alter performance on a multisensory task. We chose a multisensory task integrating shapes and non-words as we were interested in exploring the effects of tDCS over temporal cortex in speech perception. We expect enhanced performance with anodal tDCS and a decreased performance for cathodal tDCS. Also, based on our preliminary findings, we expected to find a gender effect since language and some tasks associated with crossmodal processing differ in men and women.

2. Materials and methods

We investigated the effects of anodal, cathodal and sham tDCS applied bilaterally over the STS in twenty eight volunteers (14 female and 14 male mean age of 23.2 ± 3.1). All subjects had a similar level of education. This sample is similar to the samples we have been testing in previous cognitive tDCS studies. Subjects were regarded as suitable to participate in this study if they fulfilled the following criteria: (1) age between 20 and 30 years; (2) no clinically significant or unstable medical, or neuropsychiatric disorder; (3) no use of central nervous system-effective medication; (4) no history of brain surgery, tumor, or intracranial metal implantation. All study participants provided written, informed consent. This study was approved by the institutional ethics committee from Mackenzie Presbyterian University, Brazil.

Before starting the experiment, all the participants had to complete successfully a pre-test consisting of visual presentation of pairs of images/non-words. Stimuli were provided from a previous study where neurotypical individuals corrected guessed the matching as expected, at a rate of 88% of trials [11]. Thus, before starting the experiment, all the participants had to complete successfully a pre-test consisting of visual presentation of pairs of images/non-words. Subjects were included in this study if they assigned the correct correspondence between images and non-words with a minimum rate of 80%.

All subjects received in different days with an interval between sessions of at least 48 h, sham, anodal and cathodal temporal cortex tDCS. In order to prevent learning effects, the tDCS sessions were randomized using the Latin Square method. As the number of subjects was not a multiple of 3, the final distribution was not fully counterbalanced. Two pairs of surface sponge electrodes ($35\,cm^2$) were soaked in saline solution and applied to the scalp at the desired areas of stimulation and to the right deltoid muscle as the reference electrode. We used this bi-temporal extracephalic montage before in other studies and obtained significant behavioral changes [5]. Rubber bandages were used to hold the electrodes in place for the duration of stimulation. For anodal stimulation anodal electrodes were placed over T3 and T4 (according to the 10–20 system for EEG electrode placement) and cathodal electrodes on the right arm; for cathodal stimulation the cathodal electrodes were placed over T3 and T4 and anodal electrodes on the right arm; for sham stimulation we adopted the same position as for active stimulation, however, subjects only received stimulation in this condition for 20 s. Participants in the active conditions received a constant current of 1 mA for 14 min (5 min of tDCS only followed by 9 min of tDCS during the go-no-go task of congruency between shapes and non-words).

The task is composed of 10 images, each having a corresponding written non-word. We created 10 stimuli which were 10 congruent and 10 incongruent pairs of images/non-word randomly presented. The shapes and written non-words were presented visually at the screen, side by side. The experiment was composed of 6 blocks of 40 trials. In half of blocks, subjects were instructed to press a button when the stimulus was congruent and in the other half when it was incongruent (Fig. 1). The blocks were presented alternately. At the first testing day, all subjects performed a training test composed by one go-congruent and one nogo-congruent blocks, each one containing 12 trials. Therefore most of the learning effect was achieved during this phase.

Analyses were done with Statistica software (version 8.0, StatSoft Inc.). We performed repeated measures ANOVAs in which the dependent variables were number of correct responses on Go trials, number of correct responses on NoGo trials, and reaction time (for correct responses on Go trials) and the independent variables were condition of stimulation (anodal, cathodal or sham), gender (male or female), and congruency (congruent or incongruent stimuli). Despite previous tDCS go-nogo studies have performed analyses not separating go and nogo conditions, we performed separated analyses for both conditions as recent electrophysiological data suggest that the neural network associated with failure to press following go stimulus is different than that associated with pressing following nogo stimulus [12]. We also considered the interaction of gender vs. tDCS, congruency vs. tDCS, congruency vs. gender, and tDCS vs. gender vs. congruency. When appropriate, post hoc comparisons were carried out using Fisher's LSD. Unless stated otherwise, all results are presented as means, confidence intervals, and standard errors. Statistical significance refers to a p value <0.05.

3. Results

All subjects completed the entire experiment. All subjects tolerated the stimulation well and no side effects were reported. Also, bilateral stimulation was not associated with additional discomfort in any subject.

Initially, we performed a repeated measures ANOVA in which the dependent variable was correct responses on Go trials ('pressing a button' responses). The ANOVA did not reveal significant effects for gender ($F_{1,26} = 3.8$; $p = 0.1$), tDCS ($F_{2,52} = 0.6$; $p = 0.6$), gender * tDCS ($F_{2,52} = 0.2$; $p = 0.8$), congruency * tDCS ($F_{2,52} = 0.5$; $p = 0.6$) or congruency * gender * tDCS ($F_{2,52} = 0.9$; $p = 0.4$). However, the ANOVA did reveal significant effects for congruency ($F_{1,26} = 35.7$; $p = 0.000003$, $\eta_p{}^2 = 0.58$) and for the interaction term congruency * gender ($F_{1.26} = 7.5$; $p = 0.01$, $\eta_p{}^2 = 0.22$. These significant effects, as it can be observed in Fig. 2, were due to a better performance of both genders on congruent trials as compared to incongruent ones. With regard to the interaction congruency * gender, Fischer LSD showed significant differences between congruent and incongruent correct responses for women ($p = 0.000001$) and for men ($p = 0.04$). Post hoc comparisons also revealed significant difference between women and men accuracy for incongruent trials ($p = 0.03$), but not for congruent trials ($p = 0.7$). As it can be seen in Fig. 2, women had poorer performance on incongruent trials as compared to men, but both presented similar performance for congruent trials.