Effects of high definition transcranial direct current stimulation (HD-tDCS) on motor reaction time during speech production and hand movement

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Introduction

Background:

The ability to generate and control precise motor actions is central to human functioning and day-to-day tasks. The lack of mobility or lack of control of these tasks can be devastating. Yet despite the crucial importance of these tasks, the processing mechanisms behind these basic movements are poorly understood [1]. Previous studies have found evidence for the effectiveness of traditional transcranial Direct Current Stimulation (tDCS) on improving speed and accuracy of speech and hand movement-related functions [1,2].

Experimental data from the Speech Neuroscience lab at the University of South Carolina has demonstrated the significant effects of HD-tDCS on improving speech function during a voice pitch motor control task when cathodal HD-tDCS was applied to the left motor cortex [2]. This data showed that subjects were able to better control their voice pitch and produced smaller deviations in response to alterations (pitch shifts) in their speech auditory feedback after receiving stimulation. This effect was accompanied by increased event-related potential (ERP) and enhanced neural activities in the left motor cortex following HD-tDCS [2].

These findings lay the groundwork for the proposed study to investigate the effects of HD-tDCS on improving speech and hand function as it relates to motor reaction time in healthy subjects.

Objectives:

Our main purpose for this study was to determine whether HD-tDCS would lead to faster speech and hand movement, as indexed by decreased measure of reaction time, and would potentially modulate the underlying neural bases of motor mechanisms in the human brain. The goal was to use objective measures of reaction time in response to temporally-predictable sensory cues to address the following questions:

1. How does temporally-predictable sensory stimuli affect temporal processing during initiation of speech and hand movement in participants receiving cathodal stimulation and participants receiving no neural stimulation?
2. Does HD-tDCS affect neural mechanisms of temporal information processing for movement initiation?

Methods

Subjects:

14 experimental and 14 control participants were recruited in the present study. All participants were recruited based on the specific demographic criteria of the study: healthy, native speaker of English, right-handed, age 18-25 years old, normal speech and hearing with no history of neurological or psychiatric disorders.

Procedure:

Participants were randomly assigned to the cathodal HD-tDCS stimulation or the control (sham) group receiving no neural stimulation.

Event-related potentials (ERPs) were recorded while subjects were visually cued to prepare to produce a steady vocalization of a vowel sound or press a button in a randomized order, and to initiate the cued movement following the onset of a go signal on the screen as well as stop ongoing movement after the stop signal appeared. The time interval between visual cue and go signal as well as between go and stop signal was temporally-predictable (see Figure 1).

For each subject, measures of reaction time and ERP analysis were computed for **initiation** of speech and hand movement.

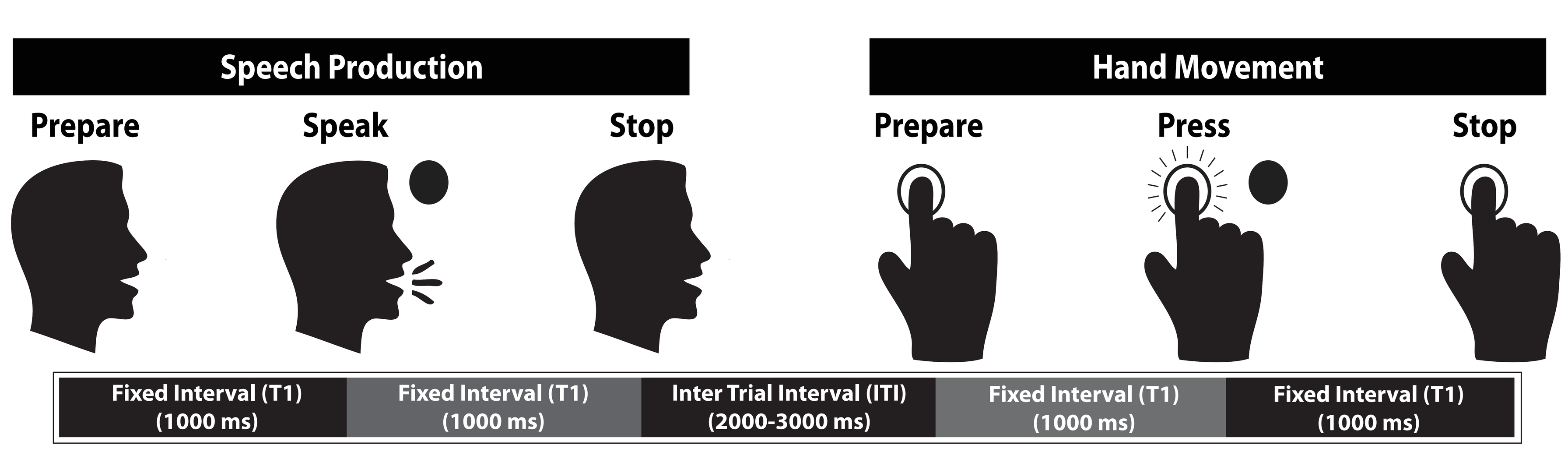

Figure 1: Experimental Design

Results

Behavioral Results:

Cathodal subjects were significantly faster than sham subjects during initiation of speech and hand movement (figure 2).

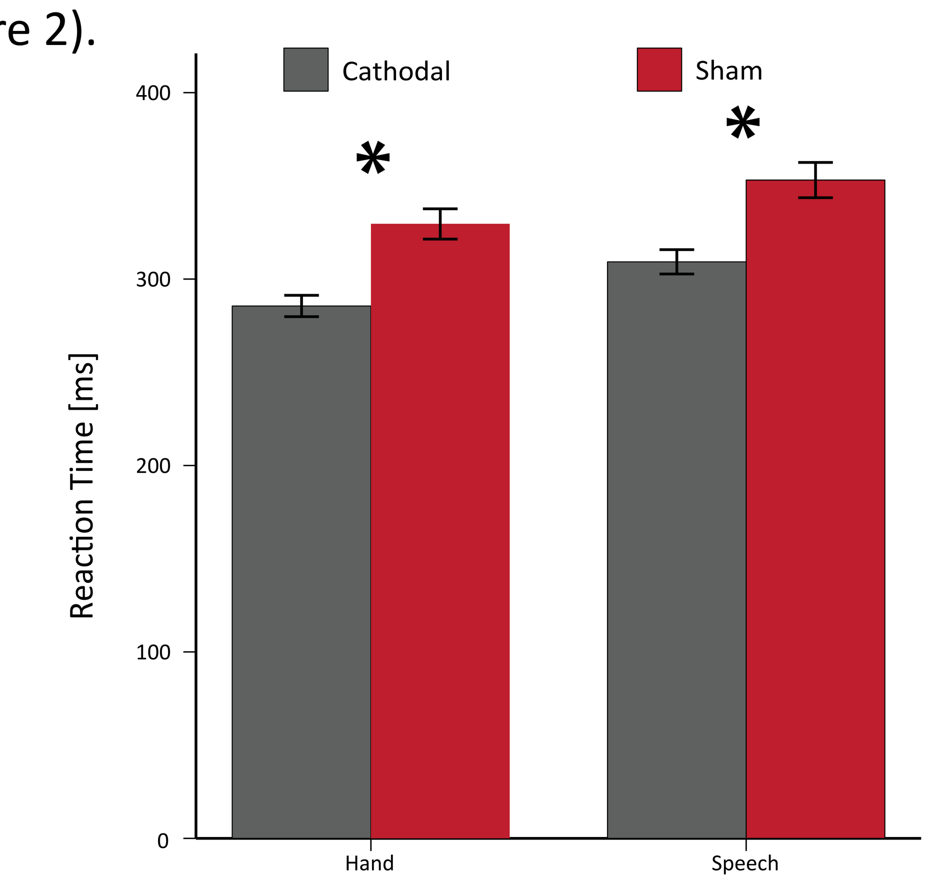

Figure 2: Behavioral response in response to temporally predictable stimuli during initiation of hand and speech movement in both cathodal and sham subjects.

ERP Results:

ERP results showed a significant increase at the time window -150 to 0 ms before speech initiation for the cathodal condition. Thus, explaining the increased reaction time of subjects in the cathodal condition. However, this increase was not as drastic for the sham condition (figure 3A).

There was a slight variation in the ERP amplitudes between the cathodal and sham condition for hand initiation, but it was not significant (figure 3B).

The topographical distribution maps of ERP activies are depicted for speech and hand movement initiation in figures 3A and 3B, respectively.

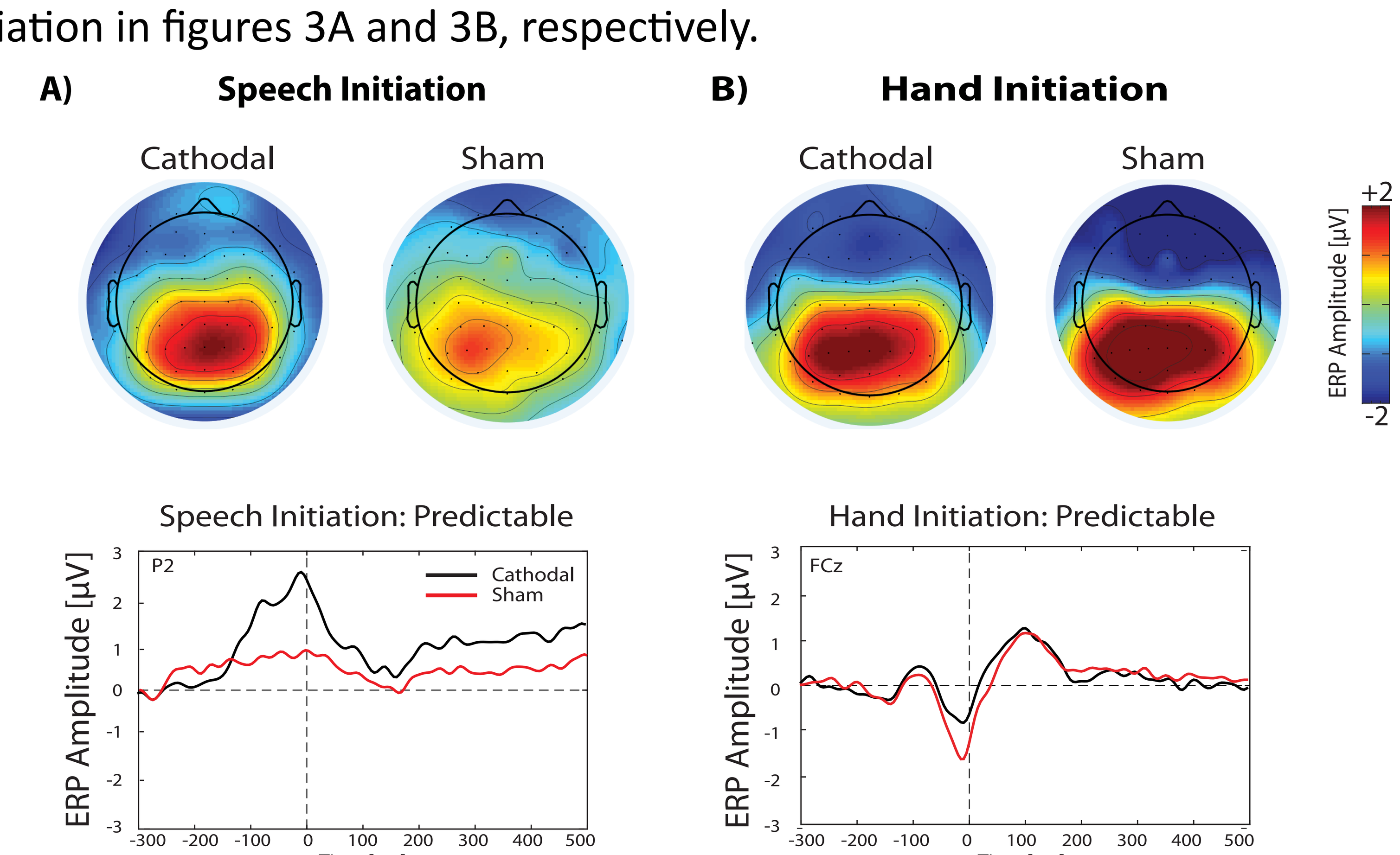

Figure 3: ERP response plots for the initiation of speech and hand movement

Discussion

Our findings indicate that the cathodal stimulation modulated neural activities over bilateral frontal and parietal electrodes in response to speech production and hand movement.

Further analyses revealed that ERP activities over frontal and parietal electrodes emerged earlier for cathodal vs. sham stimulation.

Our findings suggest that cathodal stimulation over the left ventral motor cortex enhance underlying neural mechanisms that drive speech production. and hand movement.

References

[1] Douglas, Z. H., Maniscalco, B., Hallett, M., Wassermann, E. M., & He, B. J. (2015). Modulating conscious movement intention by noninvasive brain stimulation and the underlying neural mechanisms. *The Journal of Neuroscience, 35*(18), 7239–7255.

[2] Ouden, D. B, Johari, K., Bridwell, K., Hayden, C., Behroozmand, R. (2017). Modulation of the speech motor control network through high-definition transcranial direct stimulation. *Research Gate, 22,* 48.