Modulating Vocal Pitch Motor Control through Neurostimulation

Keiko Bridwell*, Caroline Hayden*,
Roozbeh Behroozmand & Dirk-Bart den Ouden
Dept. of Communication Sciences and Disorders, University of South Carolina
* Equal author contributions

Introduction

Question: Does High-Definition transcranial Direct Current Stimulation (HD-tDCS) of speech motor areas in the brain improve a participant's ability to control their vocal pitch in response to a change in auditory feedback?

Purpose: To use EEG to record and obtain changes in neural activity prior to and after neural stimulation from HD-tDCS, while human subjects control their voice pitch in response to auditory feedback alterations

Goal: To investigate whether pitch control is affected by neural stimulation, with the long-term goal of facilitating future diagnosis and treatment of neurological diseases resulting in speech motor disorders (e.g. Parkinson's disease)

Background

- Alterations in the pitch of auditory feedback have been shown to cause involuntary vocal pitch shifts in the opposite direction to compensate for the perceived change (Behroozmand et al., 2012; Chen et al., 2007; Larson, 1998).
- Findings in previous studies have shown that HD-tDCS affects functional behavior and neural plasticity (Kuo et al., 2013; Monti et al., 2013; Malyutina & Den Ouden, 2014).
- We aimed to target the ventral motor cortex, because this area in the brain is known to be involved in controlling the movement of speech production muscles (Parkinson et al., 2012).
- The combination of EEG and HD-tDCS has not been utilized in previous studies and therefore is novel to this Magellan Scholar project.

Methods

Participants: Our goal is to recruit 30 right-handed speakers of English with no language, hearing, or other cognitive impairments. This presentation shows the results of our preliminary analysis on the first three participants.

Behavioral Task

- participants directed to produce a steady vowel sound for 2-3 seconds while receiving pitch shift stimuli in the auditory feedback of their own voice
  - Pitch shift magnitude: +/- 100 cents
  - Pitch shift duration: 200 ms
  - Trials: ~200 (~100 shifted up, ~100 shifted down)
- magnitude and speed of compensatory vocal response recorded for analysis

Procedure

- Session 1: participants' brain signals recorded with EEG during behavioral task
- Session 2
  - participants received 20 minutes of HD-tDCS brain stimulation to ventral motor cortex
    - 3 conditions: anodal, cathodal, and sham (control), between subjects
    - behavioral task performed for ~10 minutes during stimulation
  - brain signals then recorded with EEG while performing full-length behavioral task

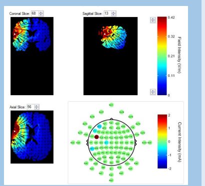
HD-tDCS

a low-current form of brain stimulation, in which a mild electrical current (e.g. 2 mA) is passed through the cortex in order to increase or decrease the excitability of the neurons

Anodal: Increases excitability
Cathodal: Decreases excitability
Sham: Control group; stimulation does not penetrate deeply into cortex, but produces an identical scalp sensation

Figure 1:
Anodal stimulation of motor cortex

Number	Location	Current (mA)
1	FC5	2.0000
2	F7	-0.4110
3	C1	-0.4251
4	TP7	-0.5533
5	AF7	-0.6105

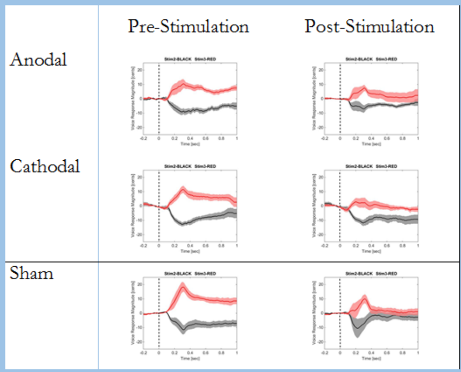


Analysis

- comparison of behavioral and EEG data
  - between upward and downward pitch shifts
  - before and after stimulation
  - between conditions (anodal, cathodal, sham)

Results

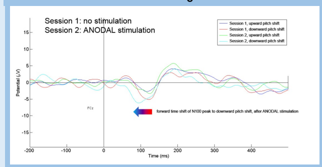
Behavioral

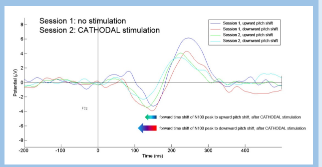


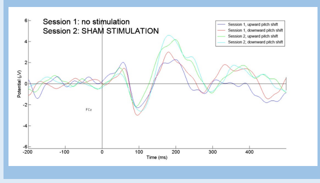
When a shift in pitch is presented, the subjects respond with an automatic shift in pitch in the opposite direction, known as a compensatory response. Red lines represent the vocal response after a downward shift; black lines represent the response after an upward shift.

Neural

Figure 3: Potentials recorded at electrode FCz







In our first three participants, it appears to be the case that anodal and cathodal stimulation result in a forward time shift of the N100 ERP component, associated with the neural response to pitch shift.

Further Study

- Collect data from remaining participants (28 out of 30 complete)
- Perform more detailed analyses of behavioral data
  - Examine speed of compensatory response
- Finish EEG analyses

References

Behroozmand, R., Korzyukov, O., Sattler, L., & Larson, C. R. (2012). Opposing and following vocal responses to pitch-shifted auditory feedback: evidence for different mechanisms of voice pitch control. *The Journal of the Acoustical Society of America*, *132*(4), 2468–77.

Chen, S. H., Liu, H., Xu, Y., & Larson, C. R. (2007). Voice F[sub 0] responses to pitch-shifted voice feedback during English speech. *The Journal of the Acoustical Society of America*, *121*(2), 1157.

Kuo, H. I., Bikson, M., Datta, A., Minhas, P., Paulus, W., Kuo, M. F., & Nitsche, M. A. (2013). Comparing cortical plasticity induced by conventional and high-definition 4 x 1 ring tDCS: a neurophysiological study. *Brain stimulation, 6*(4), 644-648.

Larson, C. R. (1998). Cross-modality influences in speech motor control: the use of pitch shifting for the study of F0 control. *Journal of Communication Disorders*, *31*(6), 489–502; quiz 502–3; 553.

Malyutina, S. & Den Ouden, D.B. (2014). High-definition transcranial direct current stimulation of single word processing [poster], *Annual Meeting of the Society for the Neurobiology of Language 2014*, Amsterdam, The Netherlands, August 27-29.

Monti, A., Ferrucci, R., Fumagalli, M., Mameli, F., Cogiamanian, F., Ardolino, G., & Priori, A. (2013). Transcranial direct current stimulation (tDCS) and language. *Journal of Neurology, Neurosurgery, and Psychiatry*, 84(8), 832-842.

Parkinson, A. L., Flagmeier, S. G., Manes, J. L., Larson, C. R., Rogers, B., & Robin, D. a. (2012). Understanding the neural mechanisms involved in sensory control of voice production. *NeuroImage*, *61*(1), 314–22.