Introduction

- Research shows structural and functional neurological differences between people who stutter (PWS) and controls (Ingham, 2001).
- Psycholinguistic theories (e.g., Postma & Kolk, 1991; Vasic & Wijnen, 2005) account for stuttering as a deficit in the phonological-encoding stage of speech planning.
- We replicated findings by Sasicelakaran et al. (2006) that PWS have increased reaction times during phoneme monitoring of the internal speech plan (Garnet & Den Ouden, submitted). PWS in our study also made significantly more errors.
- Functional imaging studies show that LH posterior superior temporal gyrus (pSTG) supports phonological encoding (Indeley, 2011) and is involved in monitoring internal speech (Den Ouden et al., 2013).
- Neuroimaging methods alone cannot conclude if specific brain regions are crucial for a task.
- High Definition Transcranial Direct Current Stimulation (HD-tDCS) is a non-invasive, focal method of brain stimulation which provides better information about neural involvement (Dmochowski et al., 2011).
- This study had two purposes:
  - First, can we disrupt or enhance task performance in healthy control participants on a covert phoneme detection task?
  - Second, can we 'normalize' the performance of PWS on the same task?

Method

- 11 PWS (6 females; mean age 25.5 years) and 20 controls (11 females; mean age 23.6 years), all right-handed participated.

Stimulation Location, Materials, and Task

- Target location was based on activation found in a cluster of 0.278 cl., with peak in left pSTG (Den Ouden et al., 2013; Figure 1).
- Electrode montages were configured using Soterix software (HD-Targets™ and HD-Explorer™; Figure 2: Soterix Medical Inc., Dmochowski et al., 2011).
- Two stimulation conditions (left posterior field orientation [LPFO] and right anterior field orientation [RAFO]) were modeled for max focality using 4 active electrodes, and a sham location was modeled separately to ensure adequate blinding (Figure 2).
- After 20 min of stimulation participants completed the monitoring task.
- Participants monitored for the presence of a target phoneme (e.g., /pa/) during silent picture naming (Figure 3).
- 28 bisyllabic words were used, with the target phoneme occurring in one of four positions, CV/CVC/CVC* (e.g., *p*igh*fft*).
- Targets: /pl, vl, kl, bl, dl, gl, lml, inl, isl, ifl, rll, /fl, lfl, lv/ balanced among position within words and across blocks (74 trials/block).

Results

- ANOVAs were conducted separately for accuracy and reaction time to assess effect of stimulation type as well as any potential interactions between stimulation type and group (Figure 4).
- There were no interactions between Stimulation Type and Group for either RT (F = 1.26, p = .292) or accuracy (F = 227, p = .798).
- There was no main effect of Stimulation Type for RT (F = 675, p = .513) or accuracy (F = 247, p = .782).
- A main effect of Group was found for accuracy (F = 6.618, p = .015): PWS were less accurate than controls in all conditions.
- There was no main effect of Group for reaction time (F = 1.35, p = .255).
- As a post-hoc check, we also compared performance in the sham condition alone (i.e., simple behavioral results) and found that PWS did show a strong trend to be slower than controls (p = .0058), and again, were less accurate than controls (p = .037).

Issues in HD-tDCS

- In traditional tDCS, current is turned off after 30-60 seconds. This is an effective sham due to the short-lived sensation of tDCS.
- In HD-tDCS, however, participants can report sensation lasting the entire session (Garnet & Den Ouden, submitted); therefore current cannot be turned off without affecting participant blinding.
- One method of sham modeling is to pass current through pairs of adjacent electrodes, largely bypassing the scalp (Richardson et al., 2014).
- We collected sensation ratings, to assess the blinding quality of this continuous sham-method.
- There were no significant differences in sensation ratings across stimulation types, indicating a) an effective sham, and b) effective participant blinding (Garnet & Den Ouden, submitted; Figure 5).
- Traditional tDCS often uses 2 oppositely charged electrodes, termed ‘anodal’ (excitatory) and ‘cathodal’ (inhibitory).
- HD-tDCS, however, allows for more complex electrode montages using more than 2 electrodes (i.e., in Figure 2).
- Such configurations may not straightforwardly correspond to ‘anodal’ and ‘cathodal’ terminology, nor to excitatory or inhibitory effects.
- A secondary analysis of the above results comparing sham to ‘combined’ stimulation (i.e., LPFO and RAFO combined) yielded the same results.
- Further, the intensity of stimulation may also produce different stimulation effects with regard to excitation vs. inhibition, as traditional tDCS applied at 2mA strength has been shown to reverse directional effects (Batsikadze et al., 2013).
- Electrode montages that use several electrodes likely target a wider brain area, and could potentially stimulate different parts of the neurons than the targeted soma (Batsikadze et al., 2013; Datta et al., 2009) which further complicates hypothesizing neurological effects.
- These issues warrant further research before straightforward interpretations of brain stimulation studies can be made.

Discussion & Conclusion

- The present study is the first to investigate direct cortical stimulation effects on monitoring phonological encoding in PWS.
- Behavioral results support studies and theoretical accounts suggesting a phonological encoding/internal speech monitoring deficit in PWS (Postma & Kolk, 1993; Vasic & Wijnen, 2005; Sasicelakaran et al., 2006), although in the present study, this deficit was reflected in the monitoring accuracy of PWS, rather than the reaction time, which is in contrast to the findings of Sasicelakaran et al. (2006).
- Stimulation of left pSTG does not significantly affect performance in healthy control participants or PWS.
- Although results of this study do not support the role of left pSTG in phonological encoding, current evidence regarding the role of HD-tDCS, especially in speech and language research, limits our ability to conclude or disprove these effects.
- Potentially, the lack of stimulation effects could be due to incorrect stimulation location, or alternatively, ineffective HD-tDCS settings (e.g., electrode montages, current strength, stimulation duration, timing of performance of behavioral task).
- Basic research using HD-tDCS is crucially, however, particularly important due to potential performance on sensitive behavioral tasks.

References