**Introduction**

- Brain stimulation can temporarily modify language processing (reviews: Monti et al., 2013; Holland & Crinion, 2012)
  - In healthy speakers: improved verbal fluency, faster naming, etc.
  - In speakers with aphasia (acquired language disorder following brain damage): improved picture naming, improved word repetition, etc.

- Thus, it can complement behavioral language therapy for aphasia.

- So far, studies of language processing have used TMS and tDCS.

- HD-tDCS (high-definition transcranial direct current stimulation)
  - Like TDCS, applies electric current in order to modulate neuronal excitability by short-term depolarization of the resting membrane potential.
  - Unlike TDCS, it uses small high-definition electrodes.
  - High safety and tolerability (Borckardt et al., 2012)
  - Increased focality (Datta et al., 2009; Kuo et al., 2013)

- Goals of the present study:
  1. To investigate if HD-tDCS can modify word processing in healthy speakers. Results may inform a follow-up study with speakers with aphasia.
  2. To obtain more methodological information about the novel HD-tDCS method.

**Methods**

- 27 healthy participants (mean age 22.1 ± 4.14)
- Electrode setups modeled in HD-TDCS software

- **Stimulation target, 13 & 14 participants in each group:**
  - Left Broca’s area (area generally involved in speech & language production)
  - Left angular gyrus (area involved in verb processing; Thompson et al., 2013 – hypothesized to specifically affect verb processing)

- **Three stimulation sessions** in each participant (on separate days, 20 min each):
  - Anodal (traditionally considered ‘excitatory’)
  - Cathodal (traditionally considered ‘suppressive’)
  - Sham (placebo): novel method; stimulation applied for full time but in a setup where the current is modeled to bypass the cortex (Richardson et al., 2014)

- **Task results**
  - **Naming:**
    - No significant effects.
  - **Reaction times:**
    - Analysis of all sessions: Stimulation Type x Session Number interaction in Broca’s area (F(4, 68.8) = 5.04, p = .002) and angular gyrus (F(4, 47.2) = 3.45, p = .029) group.
    - Analysis of first session only: effect of Stimulation Type in Broca’s area (F(2, 27) = 7.50, p = .002): anodal is slower than cathodal and sham. No effects in angular gyrus group.
  - **Lexical decision:**
    - No significant effects.

- **Methods (cont.)**
  - Participants were asked to rate pain & unpleasantness at 0.5, 10.0 and 19.5 minutes after stimulation start to guess which session applied sham stimulation.

- **Tasks** (administered right after each stimulation session, stimuli not repeated):
  - **Picture naming:**
    - 20 verbs, 20 nouns
  - **Lexical (word/non-word) decision:**
    - 30 verbs, 30 nouns, 120 non-words

- **Data analysis:**
  - Done on reaction times and log-transformed accuracy in SPSS software
  - Analysis of data from all sessions (GLM, with session order as a covariate), followed up by analysis of each participant’s first session only, which is not subject to any carry-over effects (Kruskal-Wallis test)

**Methodological results**

<table>
<thead>
<tr>
<th>Stimulation target</th>
<th>Pain &amp; unpleasantness ratings, mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broca’s area</td>
<td></td>
</tr>
<tr>
<td>Anodal</td>
<td>0.94 ± 0.00</td>
</tr>
<tr>
<td>Cathodal</td>
<td>1.14 ± 0.36</td>
</tr>
<tr>
<td>Sham</td>
<td>1.07 ± 0.27</td>
</tr>
</tbody>
</table>

- **Pain and unpleasantness ratings, mean (SD)**
  - Both pain (F(2, 24) = 18.26, p = .002) and unpleasantness (F(2, 25) = 37.23, p = .001) subsided within session, with significant reduction from 1st to 2nd and from 2nd to 3rd time points.
  - No significant effects of stimulation target or type.
  - 8/27 of participants guessed correctly which session was sham (chance level: 9/27)

**Discussion & Future Directions**

- **Low pain & unpleasantness levels, gradually subsiding within session.**
- **New approach to sham stimulation (applied in a setup modeled to bypass the cortex) is successful in masking which session is sham.**
- **Anodal stimulation over Broca’s area made naming slower:**
  - Inconsistent with previous findings (Iyer et al. 2005; Fertonani et al. 2011; Cattaneo et al. 2011, etc.)
  - Inconsistency may be due to specific tasks, stimulation target, electrode montage and stimulation intensity (it may not make sense to make predictions about “anodal” and “cathodal” stimulation in general), as well as to a possible difference between conventional TDCS and HD-TDCS.
- **Contrary to the initial hypothesis, stimulation of angular gyrus did not induce verb-specific effects.**
- **Stimulation effects depended on the order of stimulation administration:**
  - Effects of task novelty?
  - Physiological carry-over effects? – Within-subject designs may not be ideal in future research.
- **Future directions:**
  - Participants with aphasia;
  - Individualized electrode setup modeling based on individual MRI scans.

**References:**