High-definition transcranial direct current stimulation of single word processing
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Introduction
• Verbs occupy pivotal roles in sentence construction, reflecting who is doing what to whom
• Disruption of verb processing might be an underlying cause of sentence comprehension and production deficits in individuals with aphasia (language disorder after focal brain damage such as stroke). Improvement on verbs → improvement on sentences (Thompson et al., 2013).
• Brain areas associated with verb processing: angular / supramarginal gyr (BA 39, 40) (den Ouden et al., 2009; Meltzer-Asscher et al., 2012)
• Brain stimulation can temporarily modify language processing (Monti et al., 2013)
  - In healthy participants: improved verbal fluency, faster naming, etc.
  - In speakers with aphasia: improved picture naming, improved word repetition, etc.
• The present study:
  - Can HD-1DCS brain stimulation modify verb processing speed and accuracy in healthy speakers?
  - Results might inform a follow-up study with speakers with aphasia.

Methods
• High-definition transcranial direct magnetic current stimulation (HD-1DCS)
  - Acts on the resting membrane potential, modulating neuronal excitability (rather than directly causing them to fire)
  - Exceeds TDCS in safety and focality (Kuo et al., 2013)
• 22 healthy participants (mean age 22.2 y.o., 10 m)
• Electrode setups modeled in HD-Targets software
• Stimulation target, 11 participants in each group:
  - Left angular gyrus (area specific to verbs)
  - Broca's area (more general 'speech & language production' area)
• Three stimulation sessions in each participant (on separate days, ~20 min each):
  - Anodal (supposedly 'excitatory')
  - Cathodal (supposedly 'suppressive')
  - Sham (= placebo; novel method: stimulation still applied for the full time but in a setup where the current is modeled to bypass the cortex)
• Participants were asked to rate pain & unpleasantness and to guess which session applied sham stimulation.

Methodological results
• Pain ratings on a 1-10 scale:
  - Mean 2.5 (SD 1.4) at the stimulation start, mean 1.0 (SD 0.0) at the end
• Unpleasantness ratings on a 1-10 scale:
  - Mean 2.7 (SD 2.5) at stimulation start, mean 1.1 (SD 0.3) at the end
• 7 / 22 participants guessed which session applied sham stimulation (close to at-chance level)

Methods (cont.)
• Tasks (administered right after each stimulation session, stimuli not repeated):
  - Lexical decision: 30 verbs (intransitive, transitive, ditransitive), 30 nouns, 120 non-words
  - Picture naming: 20 verbs (intransitive, transitive), 20 nouns (names normed in preliminary survey)
  - Balanced on length, frequency, familiarity, orthographic neighborhood, % homonymic usage, visual complexity, name agreement of pictures
• Data analysis:
  - Done on reaction times, log-transformed accuracy, and number of self-corrections in naming
  - General linear model; SPSS software
  - Independent variables: stimulation type and site; covariate: session order

Naming results
• Accuracy: no significant effects (mean 95.9%)
• Self-corrections: no significant effects (mean 1.4%)
• Reaction times:
  - Condition (p < .001): Nouns (986 ms) < intransitive verbs (1143 ms) < transitive verbs (1283 ms)
  - Site (p = .076): Angular gyrus group (1088 ms) < Broca’s area group (1187 ms)
  - Stimulation (p = .005): Cathodal stimulation (1104 ms) < anodal (1155 ms) or sham (1154 ms)
  - Order x Stimulation (p = .025): Sham < anodal at earlier sessions, anodal < sham at later sessions

Discussion & Future Directions
• HD-1DCS is a safe method with low pain & unpleasantness levels
• New approach to sham stimulation (stimulation applied in a setup modeled to bypass the cortex) is successful in disguising which session is sham. However, trend towards a main effect of stimulation site in naming RTs: due to chance, or sham affecting the cortex?
• The study replicated the verb argument structure complexity effect in naming and lexical decision RTs: verbs with a greater number of arguments are more complex to process.
• No Condition x Stimulation or Site interaction. However, significant Order x Stimulation interactions in naming RTs and lexical decision accuracy. Stimulation effect depending on general task familiarity?
• Future directions:
  - Participants with aphasia
  - Effects of anodal and cathodal stimulation may vary by participant, depending on individual cortical structure (Datta et al., 2012)
  - Individual-level statistical analyses
  - Individualized electrode setup modeling based on individual MRI scans

Lexical decision results
• Accuracy:
  - Condition (p = .027): Intransitive verbs (90.8%), ditransitive verbs (90.1%) < non-words (94.2%)
  - Order x Stimulation (p = .006): Cathodal > sham at earlier sessions, cathodal < sham at later sessions
• Reaction times:
  - Order (p = .004):
    - Session 3 (620 ms) < session 1 (640 ms)
    - Condition (p = .004):
      - Nouns (616 ms) and intransitive verbs (624 ms) < non-words (644 ms);
      - Nouns (616 ms) < ditransitive verbs (634 ms)

References

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