Effects of tDCS over Broca's area coupled with linguistic training are not specific to language

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Introduction

- Transcranial direct current stimulation (tDCS) can enhance language processing:

  - Arguably in healthy speakers (Price et al., 2015)

  - In patients with aphasia: acquired language disorder resulting from focal brain damage (Galletta et al., 2016)

- A promising method for neurorehabilitation because safe, cheap and easy to use.
- However, still little information on the mechanisms and prognosis factors of improvement in aphasia

Research question

To tap into the mechanisms of tDCS-induced enhancement of language processing:

• Are the effects specific to language processing?

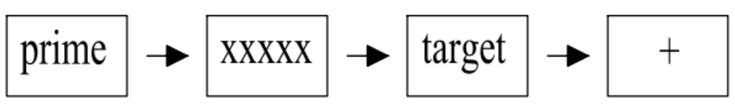
vs.

• Does enhanced language performance result from a general increase in cognitive performance (attention, processing speed, etc.)?

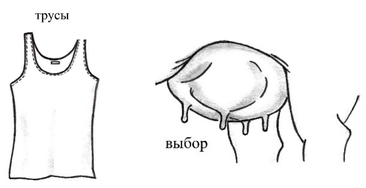
Better understanding of the nature of tDCS effects will inform its application in aphasia therapy.

Stimuli

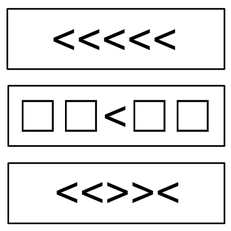
Lexical (word / non-word) decision with masked priming



Object naming



The Flanker task stimuli



Method

Participants

• 24 healthy participants (11 males, age: mean 21.5 years, SD 3.4, range 19-31), right-handed, native speakers of Russian, no reported history of neurological, psychiatric, speech, or language disorders.

Design

• Within-subject design: anodal and sham stimulation on different days, order counterbalanced.

• During stimulation: practice of the two linguistic tasks (see Bikson et al., 2013: active neuronal networks are preferentially modulated by tDCS)

• After stimulation: two linguistic tasks + an untrained unrelated nonlinguistic task to assess generalization to general cognitive performance.

Stimulation

• StarStim. tDCS device. Targeting Broca's area (inferior frontal gyrus): anode at F7 (inferior frontal gyrus), cathode at Oz; electrode size 25 cm2.

• Anodal: 1.5 mA, 20 min. Sham: stimulation turned off after 30 sec.

Materials

• Two linguistic tasks:

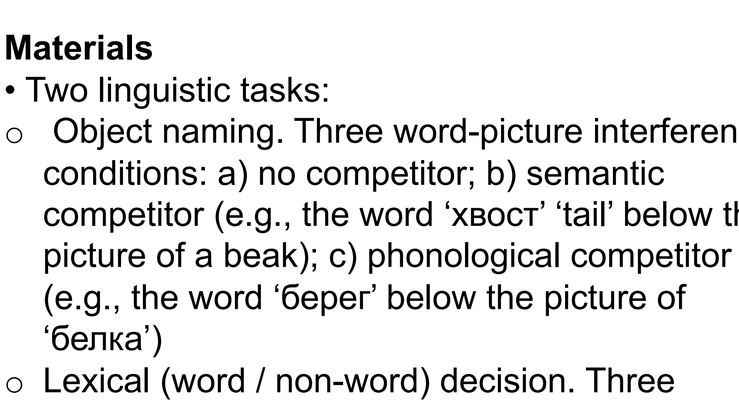
- Object naming. Three word-picture interference conditions: a) no competitor; b) semantic competitor (e.g., the word 'хвост' 'tail' below the picture of a beak); c) phonological competitor (e.g., the word 'берег' below the picture of 'белка')
- Lexical (word / non-word) decision. Three priming conditions: a) repetition priming; b) semantic priming (e.g., prime 'палец' 'finger' – target 'кулак' 'fist'); c) no priming.

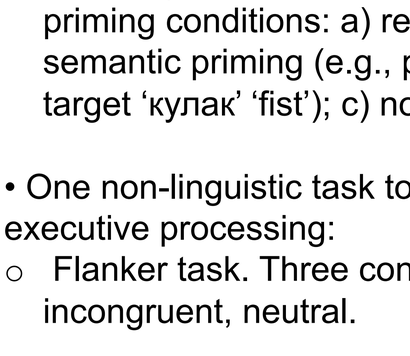
• One non-linguistic task to access general executive processing:

- Flanker task. Three conditions: congruent, incongruent, neutral.

• No stimuli repeated; materials split into two balanced sets, order of sets counterbalanced.

Results





- Accuracy at ceiling in all three tasks
- Participants unable to guess the order of sham and anodal stimulation (42% guessed correctly) → good blinding.

Results (cont.)

Linear mixed-effect model in R, p-values obtained via log likelihood ratios:

- Anodal stimulation: significantly faster reaction times in lexical decision and Flanker task; weak trend in naming.

Naming	Stimulation: $\chi(1) = 2.37$, $p = .12$ Within-task condition: $\chi(2) = .63$, $p = .73$ Session: $\chi(1) = .27$, $p = .61$ Stimulation by Condition: $\chi2(1) = 1.78$, $p = .41$
Lexical decision	* Stimulation: $\chi(1) = 14.15$, $p < .001$ Within-task conditions: * Word/non-word: $\chi(1) = 248.96$, $p < .001$ * Priming: $\chi(2) = 989.74$, $p < .001$ * Session: $\chi(1) = 86.43$, $p < .001$ Stimulation by Condition: By Word/non-word: $\chi(1) = 1.39$, $p = .24$ By Priming: $\chi(1) = 2.09$, $p = .35$
Flanker task	* Stimulation: $\chi(1) = 15.76$, $p < .001$ * Within-task condition: $\chi(2) = 342.33$, $p < .001$ Session: $\chi(1) = 1.58$, $p = .21$ Stimulation x Condition: $\chi2(1) = .77$, $p = .68$

Individual response to tDCS (anodal mean RT minus sham mean RT) significantly correlated between each linguistic task and the non-linguistic task:

- Flanker and Lexical decision: $r = .49$, $p = .01$
- Flanker and Naming: $r = .57$, $p < .001$

Both still significant in multiple regression controlling for session order

Conclusions

- Beneficial effect of anodal tDCS applied to a "speech area" & coupled with online linguistic practice may be **non-specific to language processing**:
  - The effect generalized to an untrained unrelated non-linguistic task.
  - No stimulation x linguistic condition interactions → stimulation did not specifically modulate semantic network strength / orthographic form recognition / etc.
  - Individual response correlated between two linguistic tasks and the non-linguistic task.
- Any reported tDCS-induced improvement in aphasia therapy may be mediated by a general enhancement of executive processing.