Core regions for syntactic processing? A tDCS study on the language network.

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Introduction

Many questions are still open for language processing (Hagoort, 2014), such as the role of specific language properties (phonology, syntax and semantics) for the definition of the language network and if processing language properties requires focal activation of a specific area. In the past years several techniques have been allowed a deeper investigation to further detail the brain network relevant for language processing. In this study, we used transcranial direct current stimulation (tDCS) to temporarily inhibit Broca's area (BA 44/45) in a group of healthy participants, while a sentences comprehension task was carried out. A second group of participants received the same stimulation in the temporal area (BA 22) of the left hemisphere, during the same comprehension task. The main aim of this study was to clarify the role of these two language network hubs, Broca's area and BA 22, for syntactic processing, focusing on the impact of its disruption for comprehension of sentences with different degrees of syntactic complexities.

Methods

Participants and materials

33 English-speaking adults (MCA 22, sd. 2.37) participated in the study. All participants were tested prior to the stimulation on both grammatical comprehension (TROG-2; Bishop, 2003) and verbal digit span (Wechsler, 2010) to control for differences in language abilities in the two groups and to guarantee a standard performance on grammatical reception. After completing these measures, participants were randomly allocated to one of the two active experimental conditions. Group A received cathodal stimulation on Broca's area and the reference electrode was positioned on the temporal area, while group B had the same montage with opposite polarities. Areas for bicephalic unilateral montage were identified through the EEG 10-20 system (Jasper H.H., 1958). All participants also participated in a sham (control) session. Order of cathodal-sham sessions was randomized.

tDCS was delivered through a TCT Research tDCS 1ch stimulator (2012 TCT Research Limited, Hong Kong) and 2 5 by 5 cm rubber-sponge electrodes. Parameters were set at: 2mA intensity, 10 minutes duration, with a 15 second ramping up/down period at the start and end of the stimulation (cathodal stimulation) (Fregni et al. 2014). The sham condition uses the same parameters but the stimulator automatically turns off current after 30 seconds.

During both stimulation conditions (online stimulation), participants performed a true value sentence-picture comprehension task. The test was developed with Psychopy and comprised

40 reversible sentences divided in 4 syntactic structures, with increasingly syntactic complexity:

Simple active: The boy is chasing the grandma.

Long coordination: The boy eats a banana and the cat drinks some milk.

Peripheral object relatives: The girl hits the boy that the mum is kissing.

Centre embedded object relatives: The girl that the boy is pushing is looking at the dog.

Items and pictures were adapted to English from the Italian sentence comprehension standardised battery “Comprendo” (Cecchetto, C. et al., 2012). Time for each session was adapted to tDCS duration and fixed. The Serial Visual Presentation formula was used to calculate fixed reading times for each sentence (Otten & Van Berkum, 2008).

After presentation of a sentence within the fixed time, a blank screen with a fixation cross lasting 500ms was displayed, followed by the picture (6 seconds fixed interval) with correct or reversed roles. Total time of the session was 10 minutes during both experimental conditions and sham conditions.

Results

Both accuracy and reaction times (RTs) were collected. We did not expect differences in accuracy in relation to stimulation, given the sample composed by healthy participants and the task difficulty. As such, accuracy is used to confirm task reliability, while RTs are used to test the experimental hypothesis. All participants performed accordingly to the syntactic complexity, with active sentences being characterized by less errors and the center-embedded object relatives sentences being presenting with a higher number of errors. A mixed ANOVA was performed on RT with the Group (cathodal Broca, cathodal Temporal) as between subjects factor and Type of Sentence (simple active, long coordination, peripheral object relative and center-embedded object relative) and Type of Stimulation (sham vs tDCS) as within subjects factors. Effect size was computed as partial eta squared ($\square 2_p$). We found a main effect of Type of Sentence ($F_{(3,93)} = 191.391$; $p < .001$, $\square 2_p = .86$) and a significant interaction between Group and Type of Stimulation ($F_{(3,93)} = 5.005$; $p = .033$, $\square 2_p = .14$) (Fig. 1).

The main effect of Type of Sentence confirmed a significant increase of times in each sentence types independently form the type of stimulation received and the area stimulated. The interaction, further explored by means of estimated marginal means comparisons Bonferroni corrected, revealed that the effect is driven by a significant increase in all sentence types in the group receiving cathodal stimulation to Broca’s area (mean difference: = .304 seconds, p = .022), while no differences emerged in the two groups during sham stimulation (mean difference: = .019 seconds, p = .886).

Discussion

A variety of research has demonstrated that Broca’s area (particularly pars opercularis. BA 44) is activate during verbal working memory tasks, with some research suggesting that Broca’s area does not have any language specific functions instead supporting language processing in non-specific ways (Thompson-Schill SL, Bedny M, Goldberg RF., 2005). In this study, we show that inhibiting Broca’s area during a syntactic comprehension task has a general effect on sentences even of different difficulty, causing an increase in the time required to map grammatical roles compared to the same inhibition on the temporal area.

Our results are in agreement with studies showing how Broca's Area is involved in processing of grammatical knowledge, in line with what reported also for implicit grammar tasks (De Vries, et al., 2010). Furthermore, the study supported the specificity of these effects to Broca's area and its core functional engagement for supporting syntactic processing with no involvement of the left temporal area for core processing of syntax. We conclude that Broca's area is specifically involved in syntactic based processing, and here with pejorative effect of detecting grammatical roles.

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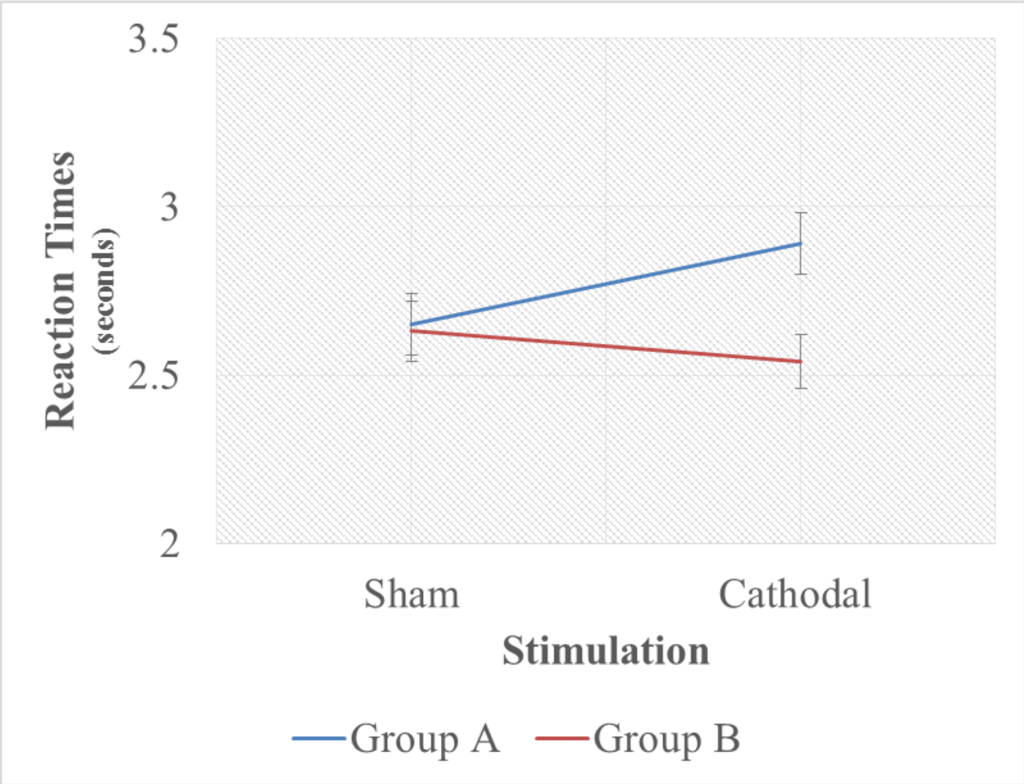

Figure 1. RT (seconds) for Group A (Broca's cathodal) and Group B (Temporal cathodal) as a function of stimulation type (sham versus active). Error bars show standard error of the mean. The figure shows how performance changes dramatically when Broca's area is inhibited.