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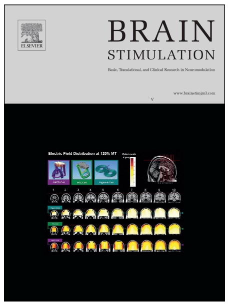

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Everything is (still) illuminated:

dual right cathodal-left anodal tDCS of PPC prevents fatigue on a visual detection task

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Dear Editor,

it is known that transcranial Direct Current Stimulation (tDCS) may affect attentional processing when applied to the right posterior parietal cortex (PPC) in line with current evidence on the neural bases of this cognitive function and their modulation by Transcranial Magnetic Stimulation [1]. However, research results are conflicting: some, in line with the interhemispheric rivalry account of attention [2], indicate that tDCS over PPC biases attention contra- or ipsilaterally depending upon whether (facilitatory) anodal or (inhibitory) cathodal tDCS is applied to PPC, respectively; others suggest that PPC controls attention across the entire visual field. Anodal tDCS of the right PPC boosts orienting of spatial attention leftwards [3] and enhances detection of left-sided visual targets [4], while cathodal tDCS of the right PPC induces a rightward attentional bias on line-length estimation [5]. Coherently, the application of bi-parietal, right anodal-left cathodal tDCS ameliorates detection of left-sided visual stimuli and deteriorates detection of right-sided stimuli [6]. By contrast, other findings show that cathodal stimulation of the right PPC ameliorates attentional selection of visual stimuli across the entire field [7], or that dual tDCS over PPC worsens object-motion tracking, regardless of hemifield and stimulation polarity [8].

To further investigate how modulation of PPC excitability might affect attentional performance, we employed a visual detection task that is very sensitive to attentional modulation [9], before and after bi-parietal tDCS. We asked whether dual tDCS of PPC would affect visual attention in a polarity-specific manner as predicted by the interhemispheric rivalry account of attention [2].

Forty-five right-handed healthy volunteers (24 women, mean age 23±2.7) gave written informed consent to participate in the study that was approved by the ethics committee of the University of Turin. Participants seated in a dark room, 50 cm away from a computer screen. Visual stimuli were 0.4 cm x 0.6 cm rectangles randomly presented for 50 ms (ISI: 2000 to 2500 ms) in 18 different locations distributed along the horizontal (3, 6 and 9 cm to the left or right of the central cross) and vertical (0.5 cm above or below the fixation cross) axes. There were ten possible levels of stimulus luminance, ranging from 0.8% to 1.2% of the screen maximum output. Individual subjective visual thresholds (i.e. detection rate between 40 and 60%) were determined during the training phase. During the experiment, 162 stimuli were presented prior and 162 after 13 minutes of stimulation. Stimuli were flashed at luminance threshold level (1/3), or one level below (1/3) or above (1/3) threshold. Participants pressed the keyboard spacebar, with their right index, as soon as a stimulus was detected while fixating the central cross (Fig. 1A, B). TDCS was applied at 1.5 mA by means of a *Newronika HDCstimulator* (Newronika s.r.l.) for 15 minutes. Electrodes (25 cm^2), covered with conductive rubber and saline-soaked synthetic sponges, were positioned over P4 and P3 (10-20 EEG system). Participants were assigned to one of the following conditions (N=15): 1) Right Anodal-Left Cathodal tDCS (RA-LC); 2) Right Cathodal-Left Anodal tDCS (RC-LA); 3) sham stimulation (ramp-up period: 30 s).

A three-way repeated-measures ANOVA was performed on accuracy (ACC, number of detected stimuli) as dependent variable with *Time* (*pre*, *post-tDCS)* and *Side* of presentation (*left, right*) as within-subjects factors, and *Group* as between-subjects factor (*RC-LA*, *RA-LC, Sham*). The ANOVA showed significant effects of *Time* ($F_{1,42}$= 15.02, p< 0.0001, partial η^2= 0.263), with higher ACC pre (94.998±51.264) than post-tDCS (76.182±54.78), and *Side* ($F_{1,42}$= 25.57, p< 0.0001; partial η^2= 0.378), with higher ACC for right (89.376±50.034) than left side (81.264±57.276). Significant interactions *Time x Group* ($F_{2,42}$= 3.814, p= 0.030, partial η^2= 0.154) and *Time x Side* ($F_{1,42}$=4.926, p= 0.032; partial η^2= 0.105) were also observed. Post-hoc analyses (independent-samples t-test) showed that *Time* was significantly different only between *RC-LA* and *RA-LC* (p=0.025). To further analyze the effect of tDCS polarity, separate ANOVAs were performed for each group, with *Time* and *Side* as within-subjects factors (Fig. 1C). The *RA-LC* group showed significant effects of *Time* ($F_{1,14}$= 12.611, p= 0.003, partial η^2= 0.474), with higher detection rate pre than post-tDCS, and a significant interaction *Time x Side* ($F_{1,14}$= 4.709, p= 0.048, partial η^2= 0.252). Post-hoc analyses revealed that pre and post-tDCS ACC differed to a lesser degree for left-sided (left-pre: 45.933±11.689, left-post: 29.467±19.982) than right-sided stimuli (right-pre: 50.8±9.182, right-post: 29.267±19.668; t_{14}= 2.17 p=0.048). The *RC-LA* group showed a significant effect of *Side* ($F_{1,14}$= 5.755, p=0.031, partial η^2= 0.291; i.e. better detection for right-sided than left-sided stimuli), but *Time* was not significant ($F_{1,14}$=0.332, p=0.574, partial η^2= 0.023). The *Sham* group manifested significant effects for *Time* ($F_{1,14}$= 6.91, p= 0.020, partial η^2= 0.330) and *Side* ($F_{1,14}$= 21.931, p<0.0001, partial η^2= 0.610). Participants showed better detection pre than post-tDCS and for right-sided than left-sided stimuli.

Figure 1 about here

Overall, we observed better detection for right-sided stimuli. This rightward bias replicates findings of our previous study [9] and has been previously described in healthy individuals as evidence of the dominance of the left hemisphere in the detection of *transient* visual stimuli [10]. Moreover, we found decreased accuracy bilaterally after *Sham* and *RA-LC* stimulation, likely due to a deterioration of sustained attention during the demanding detection task. Surprisingly, fatigue was prevented by *RC-LA* stimulation. This result, in line with Moos et al.'s finding [16], indicates that 'inhibitory'/cathodal stimulation of right PPC associated with 'facilitatory'/anodal stimulation of left PPC boosts (sustained) attention in both hemifields rather than in the right hemifield only, as expected on the basis of simple predictions of tDCS polarity-dependent effects on interhemispheric attentional control. Future studies with large sample size, including stimulation of a non-parietal site as control condition, are needed to validate these preliminary findings and clarify, using combined neuroimaging, whether they reflects potentiation of left PPC neural activity [10] by anodal stimulation, or reduction of neural noise in right PPC by cathodal tDCS, or both. These findings may have important theoretical implications for translational research.

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Conflict of interests

The authors report no actual or potential conflicts of interests.

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Figure Caption.

Figure 1. Experiment method and results. Panel A shows three examples of the visual stimuli employed in the present experiment (original proportions are not preserved in the figure); in Panel B the experiment timeline; Panel C shows participants' performance (Accuracy) in the detection task. Mean numbers of detected stimuli (out of a total of 162) and relative standard error for the three groups of participants (RC-LA= right cathodal-left anodal, RA-LC= right anodal-left cathodal, SHAM) in pre and post-tDCS conditions are reported. Stars indicate significant differences between pre and post stimulation condition for the RA-LC and the SHAM groups.

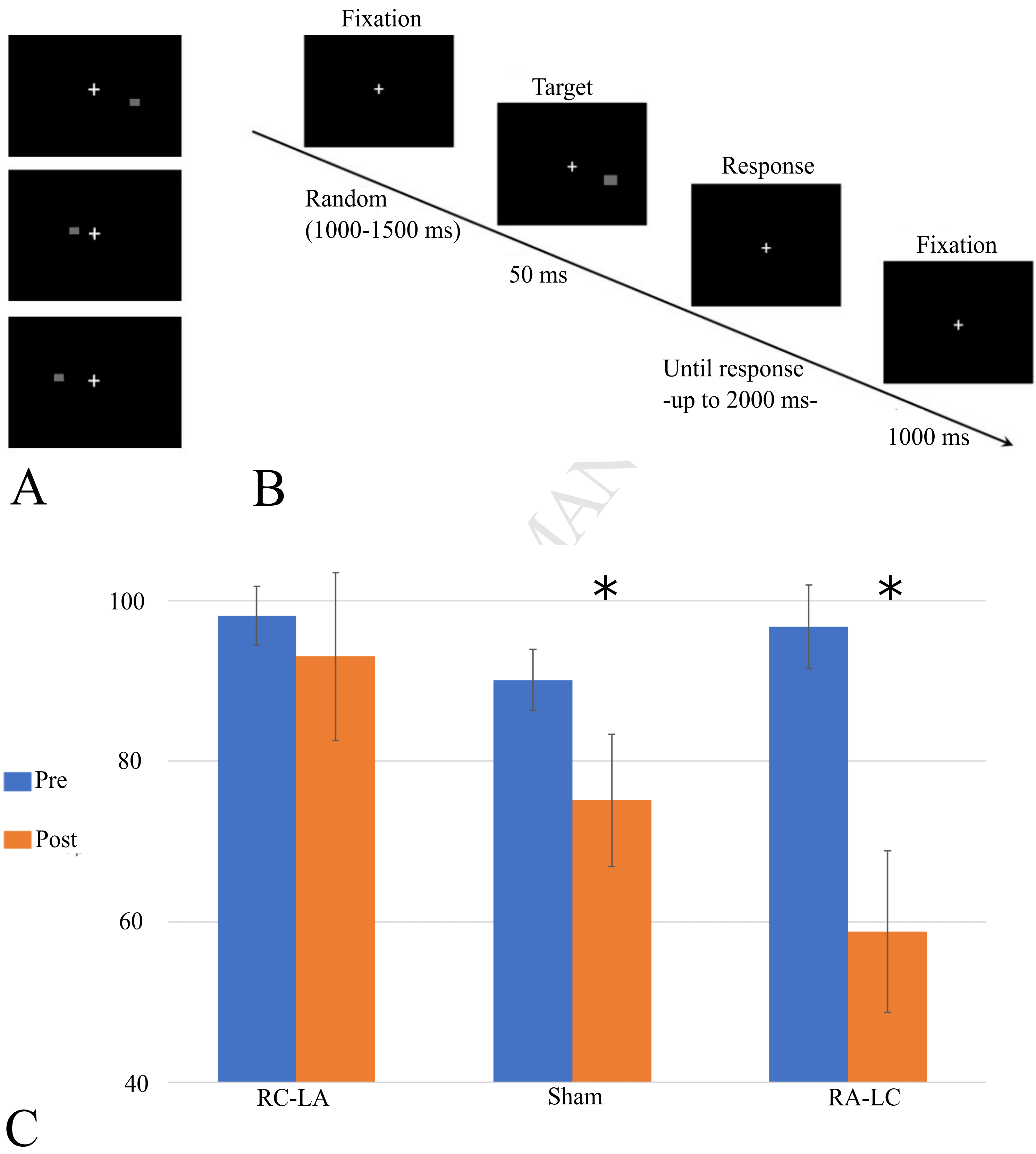
Fixation
Target
Response
Fixation
Random
(1000-1500 ms)
50 ms
Until response
-up to 2000 ms-
1000 ms
A
B
100
80
60
40
Pre
Post
*
*
RC-LA
Sham
RA-LC
C

Figure 1