Neuromodulation (tDCS) of the left dorsolateral prefrontal cortex (L-DLPFC) flattens gender differences in the sensitivity to facial expressions

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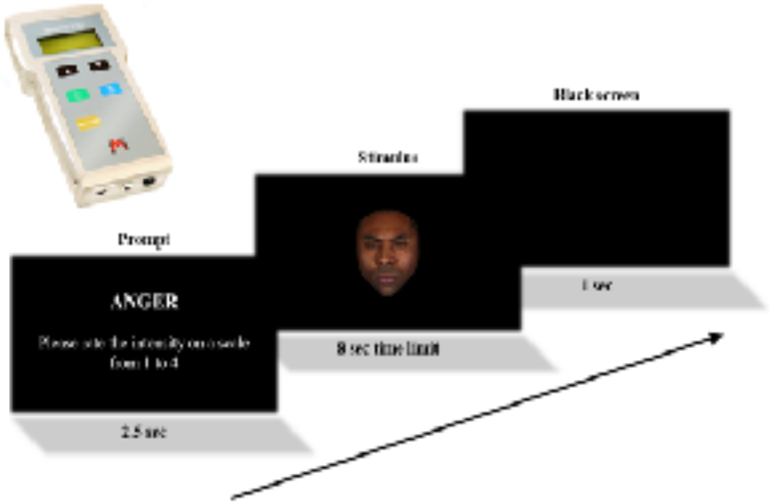
INTRODUCTION & OBJECTIVE

Due to its key role in high-order processes related to emotional content, the DLPFC has often been chosen as target for tES protocols (Costantino et al., 2017). Albeit tDCS over the L-DLPFC seems to modulate facial expression recognition (Nitsche et al., 2012; Tremblay et at., 2014), there are two main issues that still require proper investigation, and thus were investigated in this study: (i) whether and to what extent the neuromodulation of L-DLPFC affects emotion intensity judgments; (ii) whether L-DLPFC is involved in gender bias and implicit attitudes toward other race faces.

MATERIALS & METHODS

Participants: Sixty-nine volunteers (36 females, mean age 23.24 ± 3.76 SD)

Experimental design: participants were assigned to one of three groups: Group-1 (“Sham”; N = 23), Group-2 (“tDCS_1mA”; N = 23), and Group-3 (“tDCS_2mA”; N = 23). They completed the Emotions Rating Task (Figure 1), which was administered immediately after tDCS (i.e., *offline*). The task stimuli were pictures of facial expressions selected from the Binghamton University 3D Facial Expression Database (BU-3DFE) (Yin et al., 2006). A total of 192 photos of Black/White people were chosen. Pictures showing happy, sad, fearful and angry faces were selected including different levels of intensity for each emotion (25%, 50%, 75%, 100%). Participants were instructed to rate the emotion intensity of each face on a Likert-like scale of 1 (very low intensity) to 4 (very high intensity).



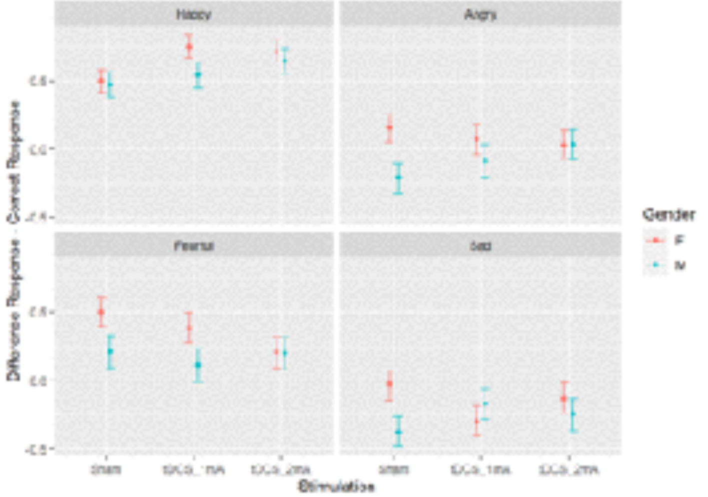
tDCS. Electrodes delivered a 20 min constant anodal current of 1 mA (tDCS_1mA), 2 mA (tDCS_2mA) and placebo (Sham). We adopted a “unilateral-monopolar-montage”, with the anode located over F3 (the electrode traditionally adopted to target the L-DLPFC), and the cathode over the right deltoid muscle.

Statistical analyses. A stepwise multiple regression mixed model was adopted to test for tDCS effects on participant’s emotions rating. For each trial, a rating index was calculated as the difference between participants’ responses and the correct emotion intensity.

RESULTS

Significant *interactions*: (i) group x gender x emotion [F(6, 13121) = 7.1, $p < .001$], (ii) group x gender x race [F(2, 13121) = 4.5, $p = .01$]

Post-hoc contrasts based on gender performed on the (i) group x gender x emotion interaction highlight that males, as compare to females, underestimate the emotions of anger ($p = .006$), fear ($p = .029$) and sadness ($p = .008$) in the Sham condition only. With the exception of fear ($p = .04$), the difference between genders was not statistically significant in tDCS_1mA, and it completely disappeared in tDCS_2mA (Figure 2).



Post-hoc contrasts based on gender on the (ii) group x gender x race interaction showed, in Sham only, a statistically significant overestimation in female compared to male participants for black faces ($p = .03$).

DISCUSSION

Our results :

- Confirm the efficacy of an anodal stimulation of the L-DLPFC in modulating emotional processing: the target area is part of the network for facial expressions’ judgement.
- Show that tDCS exerts a differential effect on male versus female participants: L-DLPFC might have a role in the gender-related dimorphism for facial expressions’ judgement. Only a few studies investigated gender differences in emotional processing through brain stimulation before. Specifically for the DLPFC, Conson et al. (2015) found that females were significantly more accurate than males in recognizing all expressions, but only in males anodal right/cathodal left stimulation enhanced processing of fearful faces. The literature on activation patterns during facial recognition shows that females generally demonstrate activation in both frontal and temporal regions, whereas males exhibit frontal but not temporal activity (Weisenbach et al., 2014). Thus, we can hypothesize that the prevalent involvement of frontal areas in males contributed to the gender-specific effect of stimulation over the L-DLPFC.
- Confirm the complex interaction between gender and racial factors in facial emotions’ perception. We found significant gender differences in the interaction between stimulation and race, with female participants overestimating black faces more than the male counterparts; this might suggest a higher “*other-race like*” bias in women that was mitigated by the stimulation at both 1 and 2 mA. This supports the role of the L-DLPFC in biased cognition, and further investigation is needed to unveil the mechanisms involved in racial-biased judgements in combination with affective aspects of face processing.

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. **Discussion**

The aim of the current study was to investigate whether 20 minutes of 1 and 2 mA offline anodal-tDCS over the L-DLPFC could result in a change in intensity judgement of emotional faces in neurotypical subjects. Participants' performance was tested on a rating task with faces showing anger, happiness, fear and sadness at different intensity levels. We found that gender significantly modulated tDCS effects on the task, with a flattening of differences between men and women in over- and under-rating performances.

Previous research on gender differences showed that women are more accurate than men in judging emotional meaning from nonverbal information. According to the *emotional sensitivity hypothesis*, women would be better in recognizing subtle cues of emotional expressions (Hall & Matsumoto, 2004; Hoffman et al., 2010; Montagne et al., 2005). However, recent studies have not always replicated this difference, even adopting emotional intensity judgment paradigms (Fisher et al., 2018). The origin of gender differences in emotional processing is under theoretical debate, specifically in relation to biologically driven factors as opposed to different socialisation processes (McClure, 2000).

In our study men and women differed in the sham group, with female participants being less accurate (even if the gender main effect was not significant) with a tendency to overestimate emotion intensity; this gender difference was attenuated in the tDCS_1mA group and, even more clearly, in the tDCS_2mA group. It seems that the stimulation mitigated the gender gap, bringing both groups to a slight overestimation of the emotional intensity. This effect demonstrates the efficacy of the stimulation protocol over the L-DLPFC in modulating emotional processing, and, for female participants only, corroborates previous findings showing changes in emotional judgement as a result of anodal tDCS over this area (Nitsche et al., 2012; Peña-Gómez et al., 2011). In line with other studies adopting behavioural parameters, we did not find a lack of emotional sensitivity in males. In fact, support to the *emotional sensitivity hypothesis* is mainly found in the neural networks that underlie emotional processing, with males and females showing activation diversity in both frontal regions and subcortical areas (e.g., Kemp et al., 2004; Lee et al., 2002; Lee et al., 2005).

In spite of this, when considering the emotion displayed by the stimuli, we found a gender bias with males, but not females, showing a tendency to underestimate negative emotions (i.e., anger, fear, and sadness) in the Sham condition only. This might be linked to women' higher sensitivity to emotionally negative stimuli irrespectively of valence intensity. In fact, it is often seen in life settings that males show fewer emotional responses to the negative events that, however, generally elicit strong emotional reactivity in females (Li et al., 2008; Yuan et al., 2007). We could have expected males to be less sensitive to negative stimuli of lower valence intensity relative to females; however, we did not find any significant interaction between gender and intensity.

Previous literature has revealed a gender-related dimorphism during the processing of emotional stimuli, demonstrating a female advantage for negative stimuli, e.g. in labelling task and affective priming paradigms (Gohier et al., 2013, Li et al., 2008). Specifically