Article

tDCS of Medial Prefrontal Cortex Does Not Enhance Interpersonal Trust

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Abstract. Interpersonal trust is an essential ingredient of many social relationships. Previous research has suggested that the medial Prefrontal Cortex (mPFC) may be a critical component in mediating the degree to which people trust others. Here we assessed the role of the mPFC in modulating interpersonal trust by means of transcranial direct current stimulation (tDCS). Participants (n = 60) were randomly and equally assigned to receive anodal, cathodal, or sham stimulation while performing the Trust Game, an index of interpersonal trust that assesses the money units one participant (the trustor) transfers to another (the trustee). Results showed that neither anodal stimulation (brain stimulation that increases cortical excitability of the area being stimulated) nor cathodal stimulation (brain stimulation that decreases cortical excitability) affected the degree of interpersonal trust as compared to sham stimulation. We conclude that noninvasive electrical stimulation over the mPFC does not modulate the degree to which people trust others.

Keywords: medial prefrontal cortex, transcranial direct current stimulation, interpersonal trust, Trust Game

Convergent evidence has revealed that the medial prefrontal cortex (mPFC) is important for social decision-making (Amodio & Frith, 2006) as in, for example, social stereotyping (Fiske, Ames, Cikara, & Harris, 2013) and trust-related decisions (Delgado, Frank, & Phelps, 2005; McCabe, Houser, Ryan, Smith, & Trouard, 2001). Very recently, we showed that that increased activation in the mPFC, via transcranial direct current stimulation (tDCS), reduces implicit biased attitudes toward out-group members (Sellaro et al., 2015). tDCS is a non-invasive brain stimulation technique known to modulate several cognitive functions (Paulus, 2011). tDCS applies a weak electric current by means of surface electrodes placed on the scalp. Depending on the current polarity, neural excitability is either increased (anodal stimulation) or decreased (cathodal stimulation) (Nitsche et al., 2008). tDCS is considered to be a promising tool to infer causal relationships between activity in a particular brain region and a specific cognitive function (see Filmer, Dux, & Mattingley, 2014; George & Aston-Jones, 2009; Nitsche et al., 2008). Besides social stereotyping, fMRI studies have suggested that the mPFC is the brain region associated with decisions involving trustiness (Delgado et al., 2005; McCabe et al., 2001). Interpersonal trust is a fundamental component of social life (Pruitt & Kimmel, 1977) and lesions to the ventromedial prefrontal cortex (vmPFC) seem to make patients less trustworthy (Moretto, Sellitto, & di Pellegrino, 2013). Moreover, mPFC seems to be involved in attentional control, which has been shown to affect the degree of trust in others (Sellaro, Hommel, de Kwaadsteniet, & Colzato, 2014). However, given the correlational nature of fMRI studies, it is hard to infer the exact causal role of the mPFC in mediating the degree to which people trust others.

Here we directly assessed whether the mPFC plays a modulatory role in interpersonal trust by using tDCS. In the present study, we used exactly the same method that was successful in reducing implicit negative biases toward out-group members in Sellaro et al. (2015), in exactly the same participants, but now combined with the Trust Game (Camerer & Weigelt, 1988), a task widely used in behavioral economics to measure interpersonal trust. This task assesses the number of money units one participant (the trustor) transfers to another (the trustee). Based on previous findings suggesting that higher levels of interpersonal trust

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are associated with increased activation in the mPFC (Delgado et al., 2005; Krajbich, Adolphs, Tranel, Denburg, & Camerer, 2009; McCabe et al., 2001) we expected anodal stimulation of the mPFC, which increases cortical excitability of the area being stimulated, to enhance interpersonal trust compared to the cathodal stimulation, which decreases cortical excitability, and to sham stimulation.

Materials and Methods

The task investigated in this study was part of a broader study on various aspects of social decision-making. Participants performed the Trust Game before being tested on another task assessing implicit biased attitudes toward out-group members (results reported in Sellaro et al., 2015). Sixty native Dutch students of the University of Amsterdam took part in the study. Participants were recruited via an online recruiting system and offered course credits or a financial reward (€10) for participating in a study on the effects of brain stimulation on decision-making. Inclusion criteria to participate in this study were the following: (1) no history of neurological or psychiatric disorders; (2) no history of substance abuse or dependence; (3) no history of brain surgery, tumor, or intracranial metal implantation; (4) no chronic or acute medications; (5) no pregnancy; (6) no susceptibility to seizures or migraine; (7) no pacemaker or other implanted devices. The study followed a single-blinded, sham-controlled, between-group design. Participants were randomly assigned to one of the three following experimental groups: anodal stimulation ($N = 20$; 8 male; mean age = 22.5 years; age range: 18–27 years), cathodal stimulation ($N = 20$; 6 male; mean age = 22.10 years; age range: 18–30 years), and sham stimulation ($N = 20$; 7 male; mean age = 21.10 years; age range: 18–27 years). All participants received a verbal and written explanation of the procedure and gave their written informed consent to participate in the study. The protocol was approved by the local Ethics Review Board of the University of Amsterdam.

tDCS was administered via a saline-soaked pair of surface sponge electrodes (5 cm × 7 cm; 35 cm^2) that were placed on the scalp. tDCS was delivered by means of a DC Brain Stimulator Plus (NeuroConn, Ilmenau, Germany). One electrode was placed over mPFC, at the Fpz position in the 10–20 EEG system, while the other electrode was placed over Oz (c.f., Bellaïche, Asthana, Ehlis, Polak, & Herrmann, 2013). Following safety limits (Nitsche et al., 2003; Poreisz, Boros, Antal, & Paulus, 2007), for the active stimulation (either anodal or cathodal), a constant current of 1 mA was delivered for 20 min with a linear fade-in/fade-out of 10 s. For the sham stimulation, the same procedure was applied as in the active tDCS but the stimulation was automatically turned off after 35 s, without the participants' knowledge. By doing so, participants experienced the typical short-lasting skin sensation (i.e., itching and/or tingling) in both the sham and active conditions (Gandiga, Hummel, & Cohen, 2006). All participants were blind to the type of stimulation and the placement of the anode electrode for the sham condition either over Fpz or over Oz was counterbalanced across participants.

Participants performed a single one-shot Trust Game 10 min after the onset of the stimulation. Afterwards, they were required to perform another task aimed at assessing implicit attitudes toward out-group members (results reported in Sellaro et al., 2015). The two tasks lasted for 10 min. Hence, tDCS was applied during the whole task and had 10 min forerun to maximize its effects (Nitsche & Paulus, 2000). The Trust Game task assesses the extent to which one person (the trustor) trusts another person (the trustee), as indicated by the number of money units transferred from trustor to trustee (Camerer & Weigelt, 1988). To emphasize the social-game aspect, participants were led to believe to play with a trustee seated in a separate cubicle (Colzato et al., 2013). Trustors were endowed with €5 and could decide how much of this amount to transfer to the trustee. Transferred money would be multiplied by three, after which the trustee could reciprocate by giving part of this tripled amount back to the trustor. Thus, by transferring eurocents to the trustee, the trustor could gain extra endowments, but only if the trustee would give enough money back – which makes the amount transferred by the trustor an indicator of interpersonal trust (Meijnders et al., 2009). The dependent measures were the trust score (computed as the amount of money transferred to the trustee) and reaction times (RT: the time it took the participant to make his/her decision) in seconds for each experimental condition (anodal, cathodal, sham). To assess the effect of tDCS, trust scores and RT were submitted to a one-way analysis of variance (ANOVA) with stimulation type (anodal, cathodal, sham) as between-subjects factor. A significance level of $p < .05$ was adopted for all statistical tests.

Additionally, we calculated posterior Bayesian probabilities associated with the occurrence of the null (H_0) and alternative (H_1) hypotheses, given the observed data (Masson, 2011; Wagenmakers, 2007). This method allows making inferences about both significant and nonsignificant effects by providing the exact probability of their occurrence.

Results

No significant differences were found among Stimulation type with respect to Age ($F = 1.29$, $p = .28$), and Sex, $\chi^2 = .44$, $p = .80$. ANOVA did not show a significant main effect of Stimulation type on Trust scores, $F(2, 57) = 0.08$, $p = .93$, $\eta^2 = .003$, or RT, $F(2, 57) = 1.86$, $p = .17$, $\eta^2 = .06$. Participants who underwent anodal stimulation transferred about the same amount of money and took the same time to decide (€3.03, $SD = 1.34$; 73 s, $SD = 23$) as participants in both the cathodal (€2.89, $SD = 1.52$; 61 s, $SD = 15$) and the sham conditions (€3.08, $SD = 1.71$; 66 s, $SD = 24$). Bayesian analysis revealed that, based on our data, the posterior probability of H_0 was .98 (Trust scores) and .90 (RT), which represents strong evidence for H_0 (Raftery, 1995).

Discussion

Our results, corroborated by Bayesian inference, suggest that mPFC tDCS does not directly influence the degree to which people trust others. Given that vmPFC damage seems to mediate social transaction with other individuals (Moretto et al., 2013) and that mPFC modulates attentional control, a function that has been shown to affect the degree of trust into others (Sellaro et al., 2014), we expected anodal stimulation to increase Trust scores. While electrode montage placement over a cortical region of interest is not necessarily an arrangement that maximizes the current density at the area of interest (Bikson, Rahman, & Datta, 2012), previous literature suggest that tDCS over the mPFC is effective in modulating the underlying cognitive functions (Bellaïche et al., 2013). Hence, the nonsignificant effect on trust scores we observed may cast some doubts on the assumed critical role of the mPFC in mediating interpersonal trust, at least, as indexed by the Trust Game (Camerer & Weigelt, 1988). One may argue that the trustor simply has a desire to increase his/her own gains, and – by transferring money to the trustee – may be willing to take the risk to achieve this (see e.g., Fehr, 2009; Sapienza, Toldra, & Zingales, 2007). If this were the case, the Trust Game may be taken to measure both interpersonal trust and the trustor's risk attitude. However, Houser, Schunk, and Winter (2010) showed that people's risk attitudes did predict behavior in individual investment decisions, but not in the Trust Game. As Houser et al. point out, these results support the "trust" interpretation of decisions in the Trust Game over the "risk-taking" interpretation.

Given that within the same experimental session we were able to successfully reduce implicit biased attitudes toward members of an out-group (Sellaro et al., 2015), this may indicate that our manipulation of increasing cortical excitability in the mPFC during anodal stimulation worked.

We can only speculate what the reasons for this outcome pattern are. First, we considered just one index of interpersonal trust. Even though this index is frequently used and well established, it remains to be seen whether other measurements of mutual or general trust will yield similar findings. One interesting example to consider would be the general trust questionnaire (Yamagishi & Sato, 1986), which assesses two of the main factors that form general trust: the belief that other people are basically honest and the belief that trusting others is risky.

Second, in our study we used a constant current of 1 mA. While this intensity was sufficient to reduce intergroup bias in Sellaro et al. (2015), changing trust may require greater intensities.

Third, in our study tDCS was applied throughout the entire Trust Game. Given that the temporal relationship between the cognitive task and the stimulation has been found to contribute to the likelihood to observe stimulation effects on behavior (Nozari, Woodard, & Thompson-Schill, 2014; Ziemann & Siebner, 2008), it would be worthwhile to measure interpersonal trust after tDCS stimulation.

Finally, a recent study by Ruff, Ugazio, and Fehr (2013) has shown that tDCS stimulation of the right lateral prefrontal cortex (rLPFC) modulates the compliance in the context of socially constituted sanctions. Given that sanction-induced social norm compliance may support mutual trust, it is not to exclude that stimulating the same areas may modulate trust scores as well.

In sum, our results may thus help to determine the precise effects of mPFC stimulation on interpersonal trust, and hence also help understand the precise function of mPFC itself. Future studies may also assess current density distributions due to the electrode montage to ascertain the stimulation of the intended area. Further, follow-up studies might consider a more thorough exploration of trust through repeated trials and by having participants assume both roles.

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Ethics and Disclosure Statements

Informed consent was obtained from all participants. The study conformed to the declaration of Helsinki and was approved by the Ethics Committee of the University of Amsterdam. All authors disclose no actual or potential conflicts of interest including any financial, personal, or other relationships with other people or organizations that could inappropriately influence (bias) their work.

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