



## UvA-DARE (Digital Academic Repository)

### tDCS of medial prefrontal cortex does not enhance interpersonal trust

Colzato, L.S.; Sellaro, R.; van den Wildenberg, W.P.M.; Hommel, B.

**DOI**

[10.1027/0269-8803/a000144](https://doi.org/10.1027/0269-8803/a000144)

**Publication date**

2015

**Document Version**

Final published version

**Published in**

Journal of Psychophysiology

**License**

Article 25fa Dutch Copyright Act

[Link to publication](#)

**Citation for published version (APA):**

Colzato, L. S., Sellaro, R., van den Wildenberg, W. P. M., & Hommel, B. (2015). tDCS of medial prefrontal cortex does not enhance interpersonal trust. *Journal of Psychophysiology*, 29(4), 131-134. <https://doi.org/10.1027/0269-8803/a000144>

**General rights**

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

**Disclaimer/Complaints regulations**

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: <https://uba.uva.nl/en/contact>, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

# tDCS of Medial Prefrontal Cortex Does Not Enhance Interpersonal Trust

Lorenza S. Colzato,<sup>1</sup> Roberta Sellaro,<sup>1</sup> Wery P. M. van den Wildenberg,<sup>2,3</sup> and Bernhard Hommel<sup>1</sup>

<sup>1</sup>Cognitive Psychology Unit & Leiden Institute for Brain and Cognition, Leiden University, Leiden, The Netherlands, <sup>2</sup>Department of Psychology, University of Amsterdam, Amsterdam, The Netherlands, <sup>3</sup>Amsterdam Brain & Cognition (ABC), University of Amsterdam, Amsterdam, The Netherlands

**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, & Mattingly, 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

are associated with increased activation in the mPFC (Delgado et al., 2005; Krajčich, 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 ( $5 \text{ cm} \times 7 \text{ cm}$ ;  $35 \text{ cm}^2$ ) 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, Ehliş, 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.

## Acknowledgment

This work was supported by research grant from the Netherlands Organization for Scientific Research (NWO) awarded to Lorenza S. Colzato (Vidi Grant No: #452-12-001).

## 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.

## References

- Amodio, D. M., & Frith, C. D. (2006). Meeting of minds: The medial frontal cortex and social cognition. *Nature Reviews Neuroscience*, *7*, 268–277.
- Bellaïche, L., Asthana, M., Ehrlis, A.-C., Polak, T., & Herrmann, M. J. (2013). The modulation of error processing in the medial frontal cortex by transcranial direct current stimulation. *Neuroscience Journal*. Online Publication – Open Access. doi: 10.1155/2013/187692
- Bikson, M., Rahman, A., & Datta, A. (2012). Computational models of transcranial direct current stimulation. *Clinical EEG and Neuroscience*, *43*, 176–183.
- Camerer, C. F., & Weigelt, K. (1988). Experimental tests of a sequential equilibrium reputation model. *Econometrica*, *56*, 1–36.
- Colzato, L. S., Steenbergen, L., de Kwaadsteniet, E. W., Sellaro, R., Liepelt, R., & Hommel, B. (2013). Tryptophan promotes interpersonal trust. *Psychological Science*, *24*, 2575–2577.
- Delgado, M. R., Frank, R. H., & Phelps, E. A. (2005). Perceptions of moral character modulate the neural systems of reward during the trust game. *Nature Neuroscience*, *8*, 1611–1618.

- Fehr, E. (2009). On the economics and biology of trust. *Journal of the European Economic Association*, 7, 235–266. doi: 10.1162/JEEA.2009.7.2-3.235
- Filmer, H. L., Dux, P. E., & Mattingley, J. B. (2014). Applications of transcranial direct current stimulation for understanding brain function. *Trends in Neurosciences*, 37, 742–753.
- Fiske, S. T., Ames, D. L., Cikara, M., & Harris, L. T. (2013). Scanning for scholars: How neuro-imaging the MPFC provides converging evidence for interpersonal stratification. In B. Derks, D. Scheepers, & N. Ellemers (Eds.), *Neuroscience of prejudice and intergroup relations* (pp. 89–109). New York: Taylor & Francis, Psychology Press.
- Gandiga, P. C., Hummel, F. C., & Cohen, L. G. (2006). Transcranial DC stimulation (tDCS): A tool for double-blind sham-controlled clinical studies in brain stimulation. *Clinical Neurophysiology*, 117, 845–850.
- George, M. S., & Aston-Jones, G. (2009). Noninvasive techniques for probing neurocircuitry and treating illness: vagus nerve stimulation (VNS), transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS). *Neuropsychopharmacology*, 35, 301–316.
- Houser, D., Schunk, D., & Winter, J. (2010). Distinguishing trust from risk: an anatomy of the investment game. *Journal of Economic Behavior & Organization*, 74, 72–81.
- Krajbich, I., Adolphs, R., Tranel, D., Denburg, N. L., & Camerer, C. F. (2009). Economic games quantify diminished sense of guilt in patients with damage to the prefrontal cortex. *The Journal of Neuroscience*, 29, 2188–2192.
- Masson, M. E. J. (2011). A tutorial on a practical Bayesian alternative to Null Hypothesis Significance Testing. *Behavior Research Methods*, 43, 679–690.
- McCabe, K., Houser, D., Ryan, L., Smith, V., & Trouard, T. (2001). A functional imaging study of cooperation in two-person reciprocal exchange. *Proceedings of the National Academy Science of USA*, 98, 11832–11835.
- Meijnders, A., Midden, C., Olofsson, A., Ohman, S., Matthes, J., Bondarenko, O., ... Rusanen, M. (2009). The role of similarity cues in the development of trust in sources of information about GM food. *Risk Analysis*, 29, 1116–1128.
- Moretto, G., Sellitto, M., & di Pellegrino, G. (2013). Investment and repayment in a trust game after ventromedial prefrontal damage. *Frontiers in Human Neuroscience*, 7, 593.
- Nitsche, M. A., Cohen, L. G., Wassermann, E. M., Priori, A., Lang, N., Antal, A., ... Pascual-Leone, A. (2008). Transcranial direct current stimulation: State of the art 2008. *Brain Stimulation*, 1, 206–223.
- Nitsche, M. A., Liebetanz, D., Lang, N., Antal, A., Tergau, F., & Paulus, W. (2003). Safety criteria for transcranial direct current stimulation (tDCS) in humans. *Clinical Neurophysiology*, 114, 2220–2222.
- Nitsche, M. A., & Paulus, W. (2000). Excitability changes induced in the human motor cortex by weak transcranial direct current stimulation. *Journal of Physiology*, 527, 633–639.
- Nozari, N., Woodard, K., & Thompson-Schill, S. L. (2014). Consequences of cathodal stimulation for behavior: when does it help and when does it hurt performance? *PLoS One*, 9, e84338.
- Paulus, W. (2011). Transcranial electrical stimulation (tES - tDCS; tRNS, tACS) methods. *Neuropsychological Rehabilitation*, 21, 602–617.
- Poreisz, C., Boros, K., Antal, A., & Paulus, W. (2007). Safety aspects of transcranial direct current stimulation concerning healthy subjects and patients. *Brain Research Bulletin*, 72, 208–214.
- Pruitt, D. G., & Kimmel, M. J. (1977). Twenty years of experimental gaming: Critique, synthesis, and suggestions for the future. *Annual Review of Psychology*, 28, 363–392.
- Raftery, A. E. (1995). Bayesian model selection in social research. In P. V. Marsden (Ed.), *Sociological methodology 1995* (pp. 111–196). Cambridge, UK: Blackwell.
- Ruff, C. C., Ugazio, G., & Fehr, E. (2013). Changing social norm compliance with noninvasive brain stimulation. *Science*, 342, 482–484.
- Sapienza, P., Toldra, A., & Zingales, L. (2007). *Understanding Trust*. NBER Working Paper No. 13387. Cambridge, UK: National Bureau of Economic Research.
- Sellaro, R., Derks, B., Nitsche, M. A., Hommel, B., van den Wildenberg, W. P. M., van Dam, K., & Colzato, L. S. (2015). *Reducing prejudice through brain stimulation*. Manuscript submitted for publication.
- Sellaro, R., Hommel, B., de Kwaadsteniet, E. W., & Colzato, L. S. (2014). Increasing interpersonal trust through divergent thinking. *Frontiers in Psychology*, 5, 561.
- Wagenmakers, E.-J. (2007). A practical solution to the pervasive problems of p values. *Psychonomic Bulletin & Review*, 14, 779–804.
- Yamagishi, T., & Sato, K. (1986). Motivational bases of the public goods problem. *Journal of Personality and Social Psychology*, 50, 67–73.
- Ziemann, U., & Siebner, H. R. (2008). Modifying motor learning through gating and homeostatic metaplasticity. *Brain Stimulation*, 1, 60–66.

**Accepted for publication:** November 22, 2014

**Published online:** November 20, 2015

Lorenza S. Colzato

Leiden University  
Cognitive Psychology Unit  
Wassenaarseweg 52  
2333 AK Leiden  
The Netherlands  
Tel. +31 71 527-3407  
E-mail colzato@fsw.leidenuniv.nl