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TRANSCRANIAL DIRECT CURRENT STIMULATION OF THE MEDIAL FRONTAL CORTEX MODULATES CHOICE-INDUCED PREFERENCE CHANGES

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TRANSCRANIAL DIRECT CURRENT STIMULATION OF THE MEDIAL FRONTAL CORTEX MODULATES CHOICE-INDUCED PREFERENCE CHANGES

Cognitive dissonance arises as a reaction to conflict appearing in choices between two equally attractive options. It leads to changes in the desirability of these options. The chosen option becomes more desirable whereas the rejected option is devalued. Despite cognitive dissonance being largely used by social psychologists to explain social conformity and preference re-evaluation, little is known about the neural mechanisms of such choice-induced preference changes. In this study, we modulated the activity of the posterior medial frontal cortex (pMFC), which has been found to be involved in cognitive dissonance in neuroimaging studies. We influenced the activity of the pMFC before individual choices using both cathodal and anodal transcranial Direct Current Stimulation (tDCS) during a revised version of Brehm's free-choice paradigm. Our results showed that cathodal tDCS over the pMFC significantly decreased the typical choice-induced preference change relative to a sham stimulation. On the contrary, no significant effect of anodal tDCS was observed. Our findings of the influence cathodal tDCS on preference re-evaluation highlight the central contribution of the pMFC in cognitive dissonance and provide evidence that pMFC plays a key role in the implementation of subsequent post-decision preference change.

JEL Classification: Z.

Keywords: cognitive dissonance, social psychology, choice-induced preference changes, medial frontal cortex, transcranial direct current stimulation, cathodal tDCS, anodal tDCS

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Introduction

Contrary to the assumptions of normative decision theory, individual preferences are not only driven by attitudes but also by previous choices. As Brehm's original "free choice paradigm" study (1956) demonstrated, after choosing between two similarly attractive options, individuals no longer perceive these options as similar and evaluate the chosen option more positively and devaluate the unchosen option. The devaluation of rejected option has been repeatedly demonstrated using different versions of the free-choice paradigm (Brehm, 1956; Colosio et al., 2017; K. Izuma et al., 2010; Kitayama, Snibbe, Markus, & Suzuki, 2004; Mengarelli, Spoglianti, Avenanti, & di Pellegrino, 2015). Recent neuroimaging studies demonstrated the role of the posterior frontal cortex (pMFC), the posterior cingulate cortex and the dorsolateral prefrontal cortex in post-decisional preference changes (K. Izuma et al., 2010; Kitayama, Chua, Tompson, & Han, 2013). This study focuses on the role of the pMFC in such preference changes.

The phenomenon of post-decision preference change has been explained by the prominent theory of cognitive dissonance (Festinger, 1957). According to this theory, during 'difficult' choices people experience a feeling of aversion or discomfort (dissonance) generated by a discrepancy between their preferences and actions. This discomfort motivates individuals to be consonant with their actions and reduce the dissonance. Thus, the mere act of choosing between similarly preferred options affects individual preferences. In the past decade, functional neuroimaging studies (e.g. Izuma et al., 2010) have explored the neural underpinning of cognitive dissonance predominantly during in the post-decision stage of the free choice paradigm: when subjects rated options again, sometime after difficult choices. Izuma and colleagues (2010) found that choice-induced preference changes are reflected in the activity of the pMFC, which is involved in behavioral monitoring and inconsistency detection. A recent multichannel electroencephalographic (EEG) study demonstrated that the fronto-central resting state activity predicted the individual magnitude of preference change and the strength of cognitive dissonance-related neural activity (Colosio et al., 2017). Thus, activity of the medial frontal cortices at rest may affect the behavioral effects of cognitive dissonance. A recent repetitive transcranial magnetic stimulation (rTMS) study (Izuma et al., 2015) uncovered the causal role of the pMFC in generating and reducing cognitive dissonance. A disruption of pMFC activity by means of 1 Hz rTMS right after the choice stage of the free-choice paradigm significantly reduced the choice-induced preference changes.

In the free choice paradigm, participants are typically asked to rate a set of goods (preference task I). Next, they are asked to choose between two of the items in the original set

(choice task). Finally, participants are asked to re-rate the original set of goods (preference task II). Although the above-mentioned neuroimaging studies point out the prominent role of the pMFC during the second rating of the items (preference task II – at the post-decisional stage of the paradigm), the role of the pMFC in the behavioral effects of cognitive dissonance at the earlier decisional stage remains unclear. Whether choice-induced preference changes take place during preference task II or during the choice task remains unclear. An EEG study (Colosio et al., 2017) addressed the temporal aspect of post-decision preference change and further explored the brain dynamics of cognitive dissonance. This study demonstrated that difficult decisions during the choice task, associated with stronger cognitive dissonance, evoked more activity in the pMFC which was reflected in a larger fronto-central error-related negativity (ERN) response compared to easy decisions. Furthermore, the ERN magnitude correlated with the magnitude of choice-induced preference changes. Since ERN activity was manifested during choices, the above-mentioned results suggest that the pMFC may be involved in the cognitive dissonance related preference changes at an earlier stage than previously thought.

In this study, we applied transcranial direct current stimulation (tDCS) over the pMFC to probe the critical role of the pMFC in choice-induced preference change and its contribution to cognitive dissonance during decision-making. The tDCS is a non-invasive, neuromodulation technique that temporally enhances (anodal stimulation) or reduces (cathodal stimulation) cortical excitability by applying a constant weak electrical current through an electrode placed on the surface of the scalp. Importantly, tDCS may result in facilitation of or interference with the targeted brain region activity underlying changes of behavior (Brunoni et al., 2012; Nitsche et al., 2008; Nitsche & Paulus, 2001). This technique has been recently employed to explore the role of the medial-frontal cortex in the modulation of error processing and performance monitoring (i.e. the modulation of the ERN and feedback-related negativity) in both clinical (Reinhart, Zhu, Park, & Woodman, 2015) and healthy populations (Bellaiche et al., 2013; Reinhart & Woodman, 2014).

By applying tDCS at the pre-decision stage of the free choice paradigm, we expected to exert control of the cortical excitability of the pMFC and thus observe either a reduction (after cathodal stimulation) or increase (after anodal stimulation) of the choice-induced preference changes as compared to no stimulation (sham tDCS) condition.

Materials and methods

Participants

Two groups of healthy right-handed volunteers were invited to participate in the study. Participants were recruited through posted advertisements and participated in this experiment in exchange for a small monetary compensation (equivalent to 10 USD). All volunteers had normal or corrected-to-normal vision and took no regular medications. None of the subjects had a history of neurological or psychiatric illness. The study protocol was approved by the local ethics committee. All participants gave informed written consent before entering the study.

For participation in the cathodal tDCS experiment (study 1) we recruited 18 volunteers. One of them was excluded due to distraction during the experiment, so, the data from 17 participants were processed (n = 17, 9 males; mean age = 22.15) For the experiment with anodal stimulation we recorded the data from 24 participants. One male was excluded from the analysis due to technical problems with the software, one female was dropped during the experiment due to unexpected pain during tDCS, 3 subjects were excluded because they reported strong fatigue. Thus, the results of 18 participants were analyzed (n = 18, males = 9, mean age = 23 years).

All participants underwent anodal or cathodal tDCS stimulation and a sham stimulation and were instructed to fast at least three hours before each session. All participants were naïve to tDCS and to the nature of the experiment; they were not informed about the protocol received (i.e. sham or stimulation).

Transcranial direct current stimulation

Each participant received both an active and sham stimulation in two different experimental sessions. Within each group, participants were randomly assigned to receive either tDCS (cathodal tDCS in *Study 1* or anodal tDCS in *Study 2*) or control (sham) stimulation during the first session, whereas the remaining stimulation was delivered during the second session a week later.

The tDCS was applied using a battery-driven 8-channel constant current neuro-stimulator (Startstim 8, Neuroelectrics) and two conductive rubber electrodes hosted in saline-soaked synthetic sponges (active electrode, 19.25 cm²; reference, 52 cm²). The active electrode was placed over medial-frontal cortex (FCz position of the international EEG 10-20 system) and held in place by a neoprene headcap, while the reference electrode was placed diagonally at the center of the right cheek.

For active stimulation, the current was increased over the first 30 seconds. Then cathodal or anodal direct current was delivered constantly for 20 min at an intensity of 1.5 mA. This protocol has been successfully used to down-regulate the medial frontal cortex and associated ERN component (see Reinhart & Woodman, 2014, for details of the current flow model). The impendence was controlled by *Neuroelectrics Instrument Controller* software v1.4, (NIC,

Neuroelectrics) and was kept below 10 kΩ. After 20 minutes of stimulation, the current was ramped down over 30 seconds. The sham tDCS stimulation was administered following the same procedure as the active tDCS stimulation, but stimulation lasted only 30 seconds, ramping up and down at the beginning and at the end of the 20 min period, producing the same tingling sensations associated with active stimulation. Such a sham stimulation protocol has been shown to be a reliable control condition in both naïve and experienced participants (Gandiga, Hummel, & Cohen, 2006).

Stimuli

Two sets of 223 digital (sets A or B), colorful photos of snack foods on a white background (chocolate, chips, a small fruit or vegetable, cheese, etc.) were used as stimuli. To ensure that both sets of stimuli contained similarly attractive items, we used ratings provided by 45 participants (20 males, mean age of 22.17) during our previous experiment (see Colosio et al., 2017, for details) to determine average preference of each item. Then we assigned items to set A or B in such way that both sets would consist of the same number of items and item ratings would show similar distributions and standard deviations (see the results section for statistics). We counterbalanced sets A and B across stimulation conditions.

The photos were projected onto a screen with a visual angle of 4.772^{o} vertically and 7.62^{o} horizontally.

Procedure

Participants underwent a modified version of Brehm's free-choice paradigms (Brehm, 1956) in the stimulation and sham sessions; for detailed and critical discussion of the paradigm see also Chen and Risen (2010) and Izuma and Murayama (2013). The basic free-choice paradigm consisted of three main parts: (1) *preference task I*, (2) *choice task*, and (3) *preference task II*. Figure 1 illustrates the whole experimental design.

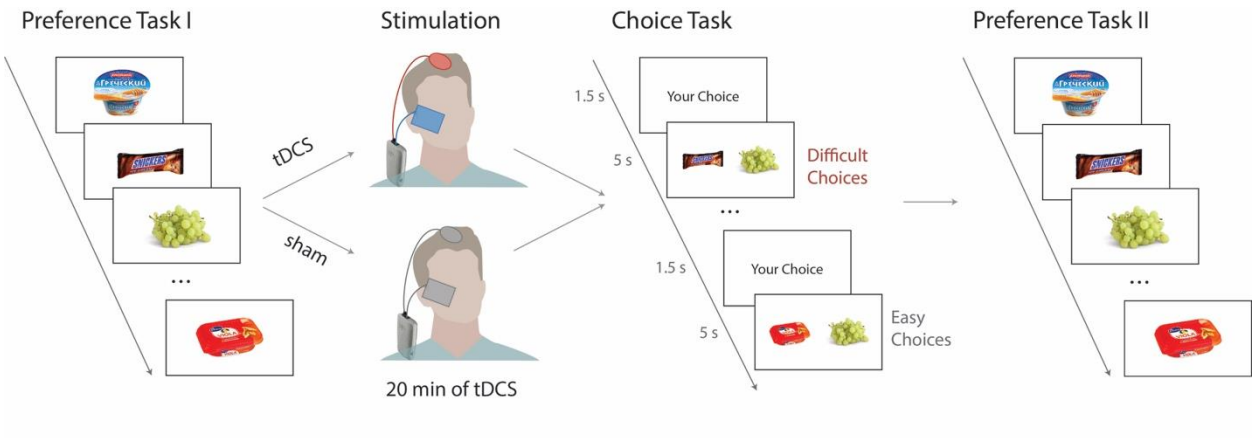

Figure 1. Free-choice paradigm. During preference task I, participants rated food items presented for 3s on the screen. Next, during the choice task, subjects freely selected one of two food items (self-difficult trials evoked strong cognitive dissonance, self-easy trials evoked weak cognitive dissonance), whereas in the computer trials, subjects selected the item that was selected by the computational algorithm (highlighted by a red square). In preference task II, participants rated the same food items again.

During *preference task I*, participants rated a set of 223 food items on a 8-points Likert scale (1 = "I don't like it at all" to 8 = "I like it a lot"). Each item was presented at the center of the screen for 3s. The tDCS montage was set up and active/sham tDCS was administered right after the end of *preference task I* and lasted for 20 minutes during which participants were instructed to sit comfortably on a chair.

During the *choice task*, each trial was formed by a pair of food items presented on the screen for 5s. In *self-trials*, participants were instructed to select the preferred item by pressing the corresponding button on a computer keyboard. To enhance participant motivation to select preferred items, participants were informed that they would receive one of chosen items along with show-up fee at the end of the experiment. Participants were unaware that a computational algorithm used individual ratings provided by *preference task I* to create the *self-trials*. Thus, we modulated choice difficulty by creating *self-difficult trials*, that evoked high cognitive dissonance as pairs were formed by highly preferred food items (rated between 6 and 8) and *self-easy trials*, that evoked low cognitive dissonance since pairs were formed by a highly preferred item and a poorly rated one (rated below 3). In the control conditions, namely *computer trials*, participants were instructed to press the button corresponding to the item randomly selected by the computer (highlighted by a red square). The *computer trials* were formed using the same criterion used to create *self-difficult trials.* All items were used only once during the *choice task.* At the beginning of each trial, participants were informed about the trial type ("your choice" or

"computer choice"). Participants had 5 seconds to either choose an item or to press the keyboard button corresponding to the computer's choice. If there was no answer, a written message prompted participants to respond faster.

During *preference task II*, participants rated the same set of food items. Unlike *preference task I*, an additional message informed the participant about either their choices or computer choices during the *choice task*. Finally, participants attended an additional control condition, namely a *post-ex choice* task (see Izuma et al., 2010 for details). In the *post-ex choice* task, participants actively selected preferred items previously presented in the *computer trials.*

Statistical Analysis

To assess post-decision preference change, we calculated mean ratings of food items in *preference task I* and *preference task II* separately for items rejected or selected in the *Self-difficult, Self-easy, Computer* and *Post-ex choice trials.* Then, we tested the effect of tDCS on post-decision preference change compared to the sham condition by running a 2 (*Rating session*: rating in preference task I or preference task II) x 2 (*Choice*: selected vs. rejected) x 2 (*Stimulation*: sham stimulation vs. real stimulation) repeated measure ANOVA. Thus, we calculated a 2x2x2 ANOVA for *Self-difficult, Self-easy, Computer* and *Post-ex choice* conditions separately. All results were Bonferroni corrected.

In addition, within each stimulation group, a series of paired, sampled t-tests were performed in order to further test whether preference changes for both the selected and rejected items where they were significantly different between sham or tDCS stimulation.

Results

The descriptive analysis of preferences for food items (sets A and B) proved that the sets had similar mean ratings (Set A = 4,70; Set B = 4,69), median ratings (Set A = 4,71; Set B = 4,68), and equal mode ratings (4,62). Similar standard deviations were also observed for both sets (Set A = 0,87; Set B = 0,88). The independent t-test showed no significant difference between preferences for food items in sets A and B ($t_{(222)}$= 0.06275, p = 0,94, *d* = 0.008). The Shapiro-Wilk test for normality showed that the distribution of sets A and B did not significantly differ from normal distributions: set A, W = 0,991, p = 0.215; set B, W = 0,990, p = 0,121.

The effects of tDCS on post-decision preference change

Study 1: Cathodal tDCS of the pMFC. Figure 2 illustrates the behavioral results of Study 1. Participants strongly devalued rejected items particularly in self-difficult trials, which were

associated with strong cognitive dissonance. To test whether the cathodal tDCS influenced post-decision preference changes differently compared to the sham stimulation, a 3-way repetitive measure ANOVA was performed separately for the Self-difficult, Self-easy, Computer, and Post-ex choice trials. Importantly, a significant 3-way interaction *Rating session* x *Choice* x *Stimulation)* was observed only in Self-difficult trials: $F_{(1,16)}$= 4.651, p = 0.047. Thus, the tDCS particularly affected post-decision preference changes in Self-difficult trials, which were associated with stronger cognitive dissonance.

We also ran 2-tailed paired t-tests for the post-decision preference change (calculated as rating 2 minus rating 1) for rejected and selected items separately for Self-difficult, Self-easy, Computer, and Post-ex choice trials, comparing the sham stimulation to the cathodal tDCS. The t-test revealed a selective significant reduction for the post-decision preference change for rejected items in Self-difficult trials ($t_{(16)}$= -3,215, p=0.005), whereas no significant difference between the sham and the tDCS stimulation was observed in other conditions (all p>0.217).

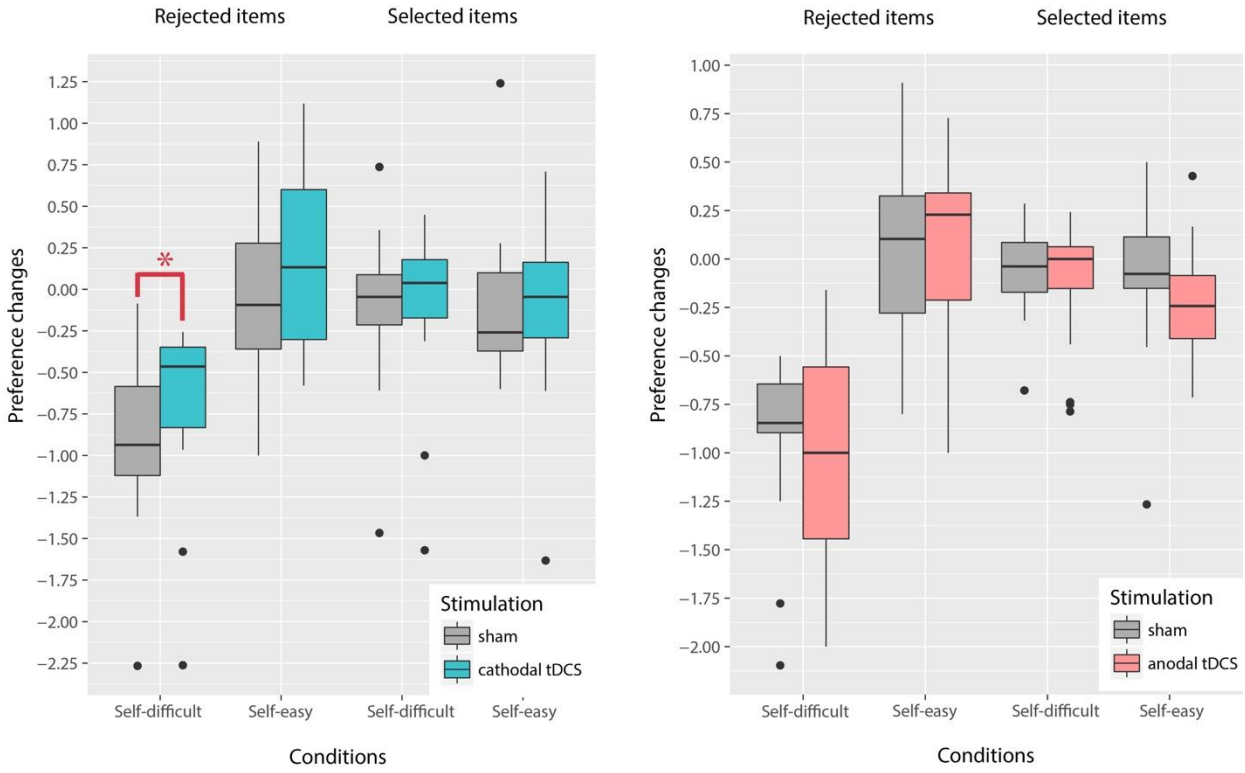

Figure 2. Post-decision preference change for selected and rejected items in Self-difficult and Self-easy trials after the cathodal or the sham tDCS (left) and the anodal or the sham tDCS (right).

We also analyzed the effects of other factors on the post-decision preference change. The ANOVA revealed a significant effect of *Choice* for Self-difficult trials ($F_{(1,16)}$= 101.718, p<0.001), Self-easy trials ($F_{(1,16)}$= 355.792, p< 0.001) and Post-Ex choice trials ($F_{(1,16)}$= 65.685,

p<0.001 and no effect for Computer trials ($F_{(1,16)}$=0.021, p = 0.887). Thus, rejections of options led to a stronger devaluation of food items than the selections of food items. We also found a significant main effect of *Rating session* for Self-difficult trials ($F_{(1,16)}$= 13.333, p = 0.002), Computer trials ($F_{(1,16)}$= 19.278, p<0.001) and Post-Ex choice trials ($F_{(1,16)}$= 19.278, p<0.001), but not for Self-easy trials ($F_{(1,16)}$= 0.027, p=0.871). The ANOVA showed a significant 2-way *Rating session* x *Choice* interaction for Self-difficult trials ($F_{(1,16)}$= 6.313, p<0.001) and post-ex choice trials ($F_{(1,16)}$= 18,138, p<0.001). No other significant main effect or interaction was found (all F<0.7, p>0.63).

Study 2: Anodal tDCS of the pMFC. Figure 2 also demonstrates the behavioral results of Study 2. We found no significant interaction for *Rating session* x *Choice* x *Stimulation*, suggesting no significant difference in post-decision preference changes between the sham and the anodal tDCS stimulation. Thus, contrary to our expectations, anodal tDCS stimulation did not enhance post-decision preference changes.

Similar to Study 1, there was a significant effect of *Choice* for Self-difficult trials ($F_{(1,16)}$= 187.062, p <0.001), Self-easy trials ($F_{(1,16)}$= 403.577, p < 0.001) and Post-ex choice trials ($F_{(1,16)}$= 310.286, p < 0.001) but not for Computer trials ($F_{(1,16)}$= 1.132, p = 0.303). The ANOVA also revealed a significant effect of *Rating session* in Self-difficult trials ($F_{(1,16)}$= 33.902, p < 0.001), Computer trials ($F_{(1,16)}$= 52.487, p < 0.001) and Post-ex choice trials ($F_{(1,16)}$= 52.487, p < 0.001), whereas we found no significant effect for Self-easy trials ($F_{(1,16)}$= 1.914, p = 0.186). The interaction for *Rating session* x *Choice* was significant in Self-difficult trials ($F_{(1,16)}$= 45.925, p < 0.001) and Post-ex choice trials ($F_{(1,16)}$= 111.960, p < 0.001), while no other interactions were significant (all F>1.788, p >154).

To test whether the anodal tDCS had a different effect on post-decision preference change compared to the sham stimulation, we ran a 2x2x2 repeated measure ANOVA as in the cathodal stimulation. We found a significant effect of *Rating session* for Self-difficult trials ($F_{(1,16)}$= 63.819, p < 0.001), Computer trials ($F_{(1,16)}$= 52.476, p < 0.001) and Post-ex choice trials ($F_{(1,16)}$= 52.476, p < 0.001). A significant effect of *Choice* was found in Self-difficult trials ($F_{(1,16)}$= 209.621, p < 0.001), Self-easy trials ($F_{(1,16)}$= 311.352, p < 0.001) and Post-ex choice trials ($F_{(1,16)}$= 185.602, p < 0.001). We found also a significant interaction of *Rating session* x *Choice* in Self-difficult trials ($F_{(1,16)}$ = 73.605, p < 0.001) and Post-ex choice trials ($F_{(1,16)}$= 77.886, p < 0.001). We found no other significant interactions.

Overall, a selective modulation of post-decision preference change was observed only for rejected items in Self-difficult trials following the cathodal, but not the anodal, tDCS.

Discussion

In the current study, in both experiments, we replicated a general behavioral effect of cognitive dissonance: the preferences for items rejected during difficult choices significantly decreased compared to the preferences for items rejected during easy choices. Figure 2 shows preference changes for rejected items are located in the negative area. This effect is observed for both the active tDCS (cathodal or anodal) and the sham. Next, we influenced the activity of the pMFC to investigate its causal role in the generation of cognitive dissonance and subsequent preference re-evaluation. We applied tDCS over the pMFC and observed whether there were any changes in the choice-induced preference changes. We found that preference changes following difficult decisions were significantly reduced by cathodal tDCS over the pMFC compared to the control stimulation (sham). We found no significant behavioral effect of anodal tDCS.

Importantly, we modulated pMFC activity during the early stage of the free choice paradigm contrary to majority of previous studies. We applied tDCS right after *preference task I*, before the *choice task*. A pioneering neuroimaging study demonstrated that more conflicted decisions were associated with heightened pMFC activity during *preference task II* compared to less conflicted decisions (Izuma & Adolphs, 2013). In other words, it indicated neural correlates of cognitive dissonance at the post-decision stages of the free choice paradigm Although many follow-up neuroimaging studies suggest that the pMFC plays a central role in cognitive dissonance and preference change, although little is known about the causal role of the pMFC in preference changes following conflicted decisions. A previous TMS study employing a modified version of the "free-choice paradigm" (Izuma et al., 2015) showed that offline down-regulation of the pMFC right after the *choice task* decreased the magnitude of post-decision preference change, providing the first strong evidence for the causal role of the pMFC in preference changes. Our study confirmed the previous results: Post-decision preference changes were significantly reduced by the cathodal tDCS over the pMFC compared with the control stimulation. Interestingly, we modulated pMFC activity before the *choice task* and our results may suggest a role of the pMFC in post-decision preference change already during conflicted decisions.

Our findings have however an important limitation. We were not able to control the duration of the effect of tDCS. The duration of tDCS after-effects is still under discussion: some studies reported that a 20 min, 1.5 mA stimulation can generate a modulatory effect for up to few hours (Nitsche & Paulus, 2001; Nitsche et al., 2003; Reinhart & Woodman, 2014). Thus, in our study cathodal tDCS could inhibit cortical activity during both the *choice task* and *preference*

task II. Further experiments could employ other inhibitory protocols, that better control for stimulation after effects.

The pMFC is known to be involved performance monitoring, action monitoring and reinforcement learning (Bellebaum & Colosio, 2014; Botvinick, 2007; Cohen & Ranganath, 2007; Hardstone et al., 2012; Holroyd & Coles, 2002; Nieuwenhuis, Holroyd, Mol, & Coles, 2004; Rushworth, Buckley, Behrens, Walton, & Bannerman, 2007). It has been suggested that when the outcome differs from a person's expectations, the pMFC generates a learning signal that updates the action values and guides future action (Niv, 2009). In a previous EEG study we recorded a stronger ERN component during self-difficult trials (choice task), than in self-easy trials (Colosio et al., 2017). Since the ERN has been previously associated with error and conflict detection, conflict monitoring, observational learning and cognitive control (Bellebaum & Colosio, 2014; Holroyd & Coles, 2002; Luu, Tucker, & Makeig, 2004; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004; Yeung & Sanfey, 2004), our results suggested that the neural mechanisms of cognitive dissonance share temporal and special characteristics with more general reinforcement learning mechanisms.

We found no effect of the anodal tDCS on preference changes. Contrary to our study, previous tDCS studies efficiently modulated learning related activity of the pMFC by either excitatory or inhibitory protocols. For instance, Reinhart and Woodman (2014) measured the efficiency of 20 min, 1.5 mA cathodal and anodal tDCS of the FCz by recording ERN and FRN. The study demonstrated both a change in the amplitude of these electrophysiological signatures of pMFC activity and the modulation of the accuracy during a two-alternative forced-choice target discrimination task. In a follow-up study, Reinhart and colleagues (2015) combined an anodal tDCS over the medial frontal cortex with an EEG to increase ERN in healthy subjects and patients with schizophrenia. Further studies are clearly needed to reconcile these findings with our results. Follow-up studies should also focus on the optimal location of brain stimulation since the cathodal tDCS of the slightly more anterior subregion of the MFC (FPz site) resulted in no modulatory effect on the ERN (Bellaïche et al., 2013).

Several previous studies have shown heterogenous effects of anodal (Fregni et al., 2005) and cathodal (Karim et al., 2010; Mengarelli et al., 2015) stimulation (for a meta-analysis see: Jacobson, Koslowsky, & Lavidor, 2012). Some studies observed no significant behavioral modulatory effect of anodal tDCS (Conley, Fulham, Marquez, Parsons, & Karayanidis, 2016; Fagerlund, Freili, Danielsen, & Aslaksen, 2015; Karim et al., 2010). It is also possible that the behavioral effects of the anodal tDCS in our study were compensated for by the unaffected brain

areas, e.g. by dorsolateral prefrontal cortex (DLPFC) which could "apply" cognitive control to regulate effects of conflict-related neural signal at the pMFC.

Some studies indicate an important role for the DLPFC in cognitive dissonance (Harmon-Jones & Harmon-Jones, 2008; Harmon-Jones, Harmon-Jones, Serra, & Gable, 2011; Mengarelli et al., 2015). Mengarelli and colleagues (2015) down-regulated the DLPFC by a 15 min, 1 mA cathodal tDCS. Offline stimulation of the left DLPFC delivered before *preference task II* (of a modified version of the free choice paradigm) significantly reduced the post-decision preference changes and hence suggest that the left DLPFC plays an important role in the behavioral effects of cognitive dissonance. The role of the DLPFC in cognitive dissonance is still debated but its contribution is thought to be related to more general cognitive control mechanisms regardless the presence of conflicts (Izuma et al. 2015, Harmon-jones et al. 2011). Interestingly, Ridderinkhof and colleagues (2004) suggested the existence of a functional pMFC-DLPFC network which supervises performance monitoring and performance executions. Further studies could focus on the pMFC-DLPFC interaction during cognitive dissonance.

Overall, we found that the cathodal tDCS of the pMFC reduced post-decision preference changes. Our results suggest a causal role of the pMFC in the generation of cognitive dissonance during conflicted choices. Secondly, it is important to better determine the contribution of the pMFC and DLFC in cognitive dissonance.

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