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The influence of the dorsolateral prefrontal cortex on attentional behavior and decision making. A t-DCS study on emotionally vs. functionally designed objects

Barbara Colombo [a,b,*], Stefania Balzarotti [a], Nicla Mazzucchelli [a]

[a] Psychology Department, Catholic University of the Sacred Heart, Largo Gemelli 1, 20123 Milan, Italy
[b] Division of Education and Human Studies, Champlain College, 163 South Willard Street, Burlington, VT 05401, USA

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ABSTRACT

Prior research has shown that right dorsolateral prefrontal cortex may be crucial in cognitive control of affective impulses during decision making. The present study examines whether modulation of r-DLPFC with transcranial direct current stimulation influences attentional behavior and decision-making in a purchase task requiring participants to choose either emotional/attractive or functional/useful objects. 30 participants were shown sixteen pairs of emotionally or functionally designed products while their eye-movements were recorded. Participants were asked to judge aesthetics and usefulness of each object, and to decide which object of each pair they would buy. Results revealed that participants decided to buy the functionally designed objects more often regardless of condition; however, participants receiving anodal stimulation were faster in decision making. Although stimulation of r-DLPFC did not affect the actual purchasing choice and had little effect on visual exploration during decision making, it influenced perceived usefulness and attractiveness, with temporary inhibition of r-DLPFC leading to evaluate functional objects as less attractive. Finally, anodal stimulation led to judge the objects as more useful. The implications of these results are discussed.

1. Introduction

The dorsolateral prefrontal cortex (DLPFC) is commonly thought to play a major role in cognitive control and executive functions (e.g., Barbey, Colom, & Grafman, 2013; Kane & Engle, 2002; Miller, 2000; Owen, 1997; Ridderinkhof, Wery, van den Wildenberg, Segalowitz, & Carter, 2011). Recent research has suggested that the DLPFC may play a pivotal role in decision making as well (Camus et al., 2009; Hadland, Rushworth, Passingham, Jahanshahi, & Rothwell, 2001; Knoch, Pascual-Leone, Meyer, Treyer, & Fehr, 2006; Krawczyk, 2002; van't Wout, Kahn, Sanfey, & Aleman, 2005). Because the DLPFC is responsible for maintaining and manipulating information in working memory, this brain area may subserve the integration and relational processing of multiple sources of information relevant to decision making (Krawczyk, 2002; Kroger et al., 2002), as well as monitor the status of competing options one may consider when making a decision (Krawczyk, 2002). Research, however, has shown that the DLPFC – especially in the right hemisphere – may be also involved in self-regulation and inhibitory cognitive control on affective impulses, being therefore particularly critical to limit the influence of impulses in decision making behavior (Pripfl & Lamm, 2015; Pripfl, Neumann, Kohler, & Lamm, 2013).

A first line of evidence comes from studies reporting that the activation of DLPFC corresponds to the tendency to reduce risk-taking behavior (Cheng & Lee, 2015; Ernst et al., 2002; Fecteau et al., 2007; Pripfl et al., 2013; Schonberg et al., 2012). For instance, Fecteau et al. (2007) found that anodal transcranial direct current stimulation (tDCS) of right DLPFC (together with cathodal-inhibiting stimulation of left DLPFC) decreased risk taking behavior in a risk task, with individuals who received this stimulation choosing more often the safe prospect and being insensitive to the reward associated with the prospects. Other evidence (Cheng & Lee, 2015; Pripfl et al., 2013) has found that stimulating the activity of the right DLPFC increases cognitive control of affective impulses, but that this effect is moderated by individual differences in impulsivity and sensation seeking. In one study (Pripfl et al., 2013), anodal stimulation of right DLPFC led to improved control of risk-seeking temptations and more conservative decisions in a sample of smokers, while it led to riskier choices in a sample of risk-averse non smokers – possibly, strengthened cognitive control may be linked to

* Corresponding author at: Psychology Department, Catholic University of the Sacred Heart, Largo Gemelli 1, 20123 Milan, Italy.
E-mail addresses: barbara.colombo@unicatt.it (B. Colombo), stefania.balzarotti@unicatt.it (S. Balzarotti), nic.mazzu@gmail.com (N. Mazzucchelli).

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increased response confidence during risky decisions in risk-adverse individuals. Similarly, Schonberg et al. (2012) found that right DLPFC activity was positively related to the number of pumps in the Baloon Analog Risk Task, reflecting the engagement of self-control – with each successive pump of the balloons, the risk of potential losses increases (i.e., the balloons explode) until the participant decides to stop pumping.

A second related line of evidence comprises a number of studies examining the role of right DLPFC in the control and suppression of urges and impulsive responses. One study (Fregni et al., 2008) found that stimulation of right DLPFC reduced food craving as well as fixations to food-related pictures. Right DLPFC activity has been also demonstrated while exerting self-control in a task requiring participants to choose healthy over unhealthy food items (Hare, Camerer, & Rangel, 2009). Similarly, other research has found that right stimulation of DLPFC diminishes smoking behavior (Eichhammer et al., 2003), as well as alcohol craving (Boggio et al., 2008). It has been shown that the right DLPFC may subserve and exert modulatory effects on the computation of the goal values during decision making: As compared with a control condition, temporary disruption of the activity of the right DLPFC by means of repetitive transcranial magnetic stimulation (rTMS) led to a decrease in the values assigned to food stimuli in a bidding task (Camus et al., 2009). Similarly, another study (Pripfl & Lamm, 2015) found that right anodal stimulation of DLPFC reduced negative emotional appraisal in a sample of smokers.

A third line of evidence has examined the hypothesis that DLPFC is connected to the tendency to maximize profits and utility in strategic decision making, as well as to the ability to suppress tempting responses by using the Ultimatum Game task (Guth, Schmittberger, & Schwarze, 1982). In this game (a form of economic social dilemma), a proposer offers a fair or unfair division of a sum of money to a responder who decides to accept or reject this offer. Although according to standard economic theories (Edwards, 1954) participants in the role of the responder would be expected to go for the maximum utility (i.e., accepting all offers as any offer is better than receiving no money), research has shown that responders typically tend to reject unfair offers and prefer to earn nothing rather than accept offers that are judged as unequal (Nowak, Page, & Sigmund, 2000). The right DLPFC has been shown to be activated during unfair offers and it is thought to subserve cognitive control or goal maintenance in the task (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003; van't Wout et al., 2005).

Some studies have shown that when right DLPFC is disrupted, individuals tend to be unable to resist the attraction for personal reward. For instance, in a study conducted by van't Wout et al. (2005), participants received repetitive transcranial magnetic stimulation (rTMS) over the right DLPFC and were subsequently asked to play the role of responders in the Ultimatum Game task. Results demonstrated that the temporary disruption of the right DLPFC led participants to take more time to reject unfair offers, as well as to greater acceptance of the unfair offers compared to sham stimulation. In a similar way, Knoch et al. (2006) found that after inhibition of the right DLPFC by means of rTMS, participants rejected unfair offers less often compared to sham stimulation, even though their judgments about the fairness/unfairness of the offers remained unchanged. Thus, although participants clearly recognized the proposer's unfair intention, they could not resist the (selfish) impulse to maximize their income. Similarly, Tassy et al. (2011) found that transitory disruption of right DLPFC activity altered decision making in the context of moral dilemmas leading to increased probability of utilitarian responses. Overall, these results seem to suggest that DLPFC may be involved in the cognitive control of self-interest impulses on the individual's decision making.

The present study adds to and extends prior literature examining the role of right DLPFC in cognitive control during a purchase decision task. When faced with a choice between two (or more) objects – as it happens when deliberating about a purchase – a very common dilemma is whether to buy something useful/functional or rather cave in the temptation of buying an emotional/attractive product. In this study, we use transcranial direct stimulation (tDCS) of right DLPFC while participants are asked to observe couples of either emotionally or functionally designed objects and to decide which one they would like to buy. Emotionally-designed products have been defined as attractive, aesthetically pleasing objects that are able to elicit emotional responses (e.g., interest, awe, fascination) in consumers (Demirbilek & Sener, 2003; Norman, 2004). By contrast, functionally designed products allow the consumer to immediately understand their specific function/use. Overall, research has suggested that although aesthetics influences consumers' preference and preferred products tend to be judged as both functional and attractive, low usability diminishes product liking and purchase intention (Lee & Koubek, 2010; Sonderegger & Sauer, 2010; Tuch, Roth, Hornbæk, Opwis, & Bargas-Avila, 2012). The current study examines whether stimulation (vs. disruption) of right DLPFC leads to an increase in the probability to purchase functionally designed objects – resisting the temptation of attractive, emotionally designed products.

1.1. Goals of the present study

The main aim of the current study is to explore the role of right DLPFC in influencing participants' attentional and cognitive behavior in a purchase task involving emotionally-designed and functionally-designed objects. More specifically, we tested whether modulation of right DLPFC with a technique of noninvasive brain stimulation (i.e., tDCS) influences (a) how long it takes to decide whether to purchase either a functionally-designed or an emotionally-designed object (i.e., response time, RT), (b) the purchasing choice, and (c) the visual exploration of the objects. We chose this technique because it modulates brain activity significantly in a safe, powerful and painless way and its effects can last for more than an hour (Nitsche & Paulus, 2000).

We expected to find significant differences in participants' behavior depending on the type of stimulation condition. First, we hypothesized that participants in the anodal condition (i.e., transitory increased activity and excitability) would choose to buy functionally-designed objects significantly more often than participants in the other conditions. Also, we expected right anodal stimulation to accelerate response times compared with cathodal and sham conditions. In other terms, consistently with prior literature, we hypothesized that stimulation of r-DLPFC should lead to a quicker decision in favor of the more "useful" object – resisting the temptation of the emotional (or beautifully designed) one. Conversely, we expected that after cathodal stimulation (i.e., transitory disruption or inhibition of brain activity) participants would take more time to decide which object to buy being tempted by the emotionally-designed objects.

Second, we analyze participants' attentional behavior while visually exploring the emotionally or functionally-designed objects by recording their eye-movements (i.e., observation and fixation length, number of fixations). The number and duration of fixations are generally used as valid indirect measures of either attention or interest toward a visually presented stimulus (Rayner, 1998). In this study, participants were presented with both images of the objects and short textual descriptions (Rayner, Rotello, Stewart, Keir, & Duffy, 2001). We expected that that participants in the anodal condition would fixate textual information longer than participants in the other conditions – in search of information on the use of objects, while that cathodal stimulation would lead to more fixations at the pictures of emotionally-designed objects.