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BRIEF REPORT

Transcranial direct current stimulation modulates implicit attitudes towards food in eating disorders

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Abstract

Objective: Neuromodulation of regions involved in food processing is increasingly used in studies on eating behaviors, but results are controversial. We assessed the effects of anodal transcranial direct current stimulation (a-tDCS) on food and body implicit preferences in patients with eating disorders (EDs).

Method: Thirty-six ED patients and 36 healthy females completed three sessions with a-tDCS applied to the medial-prefrontal cortex (mPFC), the right extrastriate body area (rEBA) or in sham mode. Each participant then completed three Implicit Association Tests (IATs) on tasty/tasteless food, underweight/overweight body images, flowers versus insects as control. Differences in latency between incongruent and congruent blocks were calculated (D score).

Results: The tDCS by group interaction was significant for the IAT-food D score, with patients showing weaker preference for tasty food than controls in sham, but not a-tDCS sessions. In particular, rEBA stimulation significantly increased patients' D score compared to sham. Moreover, a-tDCS over mPFC and rEBA selectively increased patients' reaction times in the incongruent blocks of the IAT-food.

Discussion: A-tDCS on frontal and occipito-temporal cortices modulated food preferences in ED patients. The effect was specific for food images and selective in patients, but not in healthy participants. These findings suggest that neuromodulation of these regions could affect implicit food attitudes.

KEYWORDS

body image, eating disorder, food preference, implicit attitudes, non-invasive brain stimulation, tDCS

1 | INTRODUCTION

Recent brain-based approaches to eating disorders (EDs) have prompted the use of non-invasive brain stimulation techniques, such as transcranial direct current stimulation (tDCS) and transcranial magnetic stimulation (TMS), to explore the neurobiological mechanisms of eating behavior and possible treatments for EDs (Val-Laillet et al., 2015). Two relevant mechanisms, one concerning food evaluation and the other body image representation, are associated with structural and functional abnormalities in EDs (Amianto et al., 2013). Regarding the network involved in food-related behavior, patterns of hypo- and hyper-responsiveness to food images have been found in the amygdala, the medial-prefrontal cortex (mPFC) and the dorsolateral prefrontal cortex (dlPFC) in patients with anorexia (AN) and bulimia nervosa (BN) compared to healthy controls (Dunlop, Woodside, & Downar, 2016). Studies on body representation in ED patients revealed structural and functional abnormalities in posterior parietal and occipito-temporal regions, including the extrastriate body area (EBA) (Suchan et al., 2010; Uher et al., 2005), which is considered a specialized neural system for the visual perception of bodies (Downing et al., 2001). Thus, the neuromodulation of these networks represents a potential tool for clinical and experimental studies on EDs. Single sessions of tDCS or repetitive TMS (rTMS) to the dlPFC have been reported to improve symptoms in BN and AN patients (Kekic et al., 2017; Van den Eynde, Guillaume, Broadbent, Campbell, & Schmidt, 2013). However, clinical trials applying multi-session tDCS or rTMS protocols to the dlPFC yielded inconsistent findings (Gay et al., 2016; Khedr, Elfetoh, Ali, & Noamany, 2014; McClelland, Kekic, Campbell, & Schmidt, 2016). On the other hand, improvements in binge-purge behavior have been reported applying rTMS to the mPFC (Dunlop et al., 2015). It is worth mentioning that these studies used questionnaires or explicit scales on food behavior to evaluate the outcome of treatments. These measures are vulnerable to social desirability (Higgs, 2015) and may not represent a good index of overall symptoms improvement (McClelland et al., 2016). On the contrary, implicit attitudes and affective evaluation of food and body weight may represent a distinctive feature of ED patients (Rudolph & Hilbert, 2015; Spring & Bulik, 2014). Thus, implicit measures such as the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) might prove more useful to define patients' characteristics and evaluate treatment effects. Moreover, to the best of our knowledge, no studies on ED patients applied neuromodulation to the occipito-temporal regions involved in body processing.

This study tested the possibility of modulating implicit attitudes towards food and body images with anodal tDCS (a-tDCS) in ED patients and healthy participants. A-tDCS was applied in separate sessions to the mPFC, the right EBA (rEBA), or in a sham mode. Immediately after stimulation, implicit attitudes towards tasty versus tasteless food and underweight versus overweight body images were measured with IATs. A third IAT on flowers versus insects was included as control, to test the general effect of stimulation on the task cognitive mechanism, since the association of positive attributes to flowers rather than insects can be considered a near-universal evaluative difference (Greenwald et al., 1998).

2 | METHOD

2.1 | Participants

The ED group included 36 female patients meeting DSM-5 criteria for AN (n = 21), BN (n = 13), or ED not otherwise specified (EDNOS, n = 2). Patients were recruited and tested at the Psychiatric Unit of the San Paolo Hospital of Milan. Thirty-six healthy females participated as control group and were tested at the Department of Psychology of the University Milano-Bicocca (see Table 1 for demographic variables and Supporting Information material for sample details). All participants were right handed. Institutional ethics approval was obtained and the experiment was conducted in accordance with the Declaration of Helsinki.

2.2 | Material and procedure

The IAT (Greenwald et al., 1998) was used to measure implicit attitudes towards tasty and high-fat food versus tasteless and low-fat food (IAT-food), underweight versus overweight body images (IAT-body), flowers versus insects (IAT-flowers). Stimuli details are reported in Supporting Information material. At the beginning of the first session participants were asked to rate on a six-points Likert scale the food images as not tasty at all—very tasty, the body images as underweight–overweight and the valence words as negative–positive. They also rated attractiveness and negative or positive valence of being underweight and overweight. Then, saline-soaked sponge electrodes were applied to deliver a-tDCS with a battery-driven stimulator (BrainStim, EMS, Bologna, Italy). Based on the 10/20 international system the anode was placed between FZ and F3 or between O2 and PO8 to target mPFC (Dunlop et al., 2015; Mattavelli et al., 2015) or rEBA (Downing et al., 2001; Mancini, Bolognini, Haggard, & Vallar, 2012), respectively; the cathode was placed over the contralateral supraorbital region. The protocol consisted in 20 min stimulation (1 mA intensity, 10 s of fade-in/out phase), with a 4 × 4 anode (0.062 mA/cm2 current density) and a 7 × 5 cathode (0.028 mA/cm^2 current density). In the sham session electrodes montage was the same as mPFC/rEBA session, but the stimulation was active only for 40 s at the beginning and 30 s at the end of the 20 min. The three sessions occurred at least 48 hr apart with the order of the three tDCS conditions, the electrodes montage for sham, and the order of the three IATs within each session counterbalanced across participants. To keep equal condition across sessions and participants, a cartoon movie was shown during stimulation (Pisoni, Cerciello, Cattaneo, & Papagno, 2017). The three IATs were presented following stimulation on a computer screen using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). Each IAT consisted of seven blocks. Two different versions were created (version A: first congruent blocks, version B: first incongruent blocks) to balance across participants the order of presentation of congruent (e.g., tasty food—positive attributes) and incongruent (tasty food—negative attributes) blocks (Supporting Information Table S1, Greenwald, Nosek, & Banaji, 2003). At the end of each session a questionnaire on tDCS-induced sensations was administered (Fertonani, Ferrari, & Miniussi, 2015); finally, at the end of the last session, all participants completed the Eating Disorder Inventory (EDI-3, Garner, 2004) and Symptom Checklist questionnaire (SCL-90-R, Prunas, Sarno, Preti, Madeddu, & Perugini, 2012).

3 | RESULTS

3.1 | Questionnaires and explicit ratings

Analyses were performed in the statistical programming environment R (R Development Core Team, 2014; Version 3.4.4). ED and control groups were compared with Welch's t-test with adjusted number of degrees of freedom for unequal variances when required (Table 1). Results showed higher scores for ED patients in all the considered clinical subscales. Compared to the control group, ED patients assigned significantly lower values to tasty food and higher values to the weight of

TABLE 1 Descriptive measures and differences between groups in demographic and clinical variables and explicit ratings

Variables	Control	ED	Statistic
Age	24.03 (3.48)	25.53 (8.09)	$t(47.5) = -1.02, P = .31$
Education	14.36 (1.85)	13.22 (3.14)	$t(56.8) = 1.87, P = .06$
BMI	20.47 (1.7)	18.48 (2.72)	$t(58.7) = 3.73, P < .001$
Questionnaires			
EDI-3 DT	7.03 (7.46)	17.31 (9.96)	$t(70) = -4.96, P < .001$
EDI-3 B	3.97 (5.02)	11.83 (10.23)	$t(50.95) = -4.14, P < .001$
EDI-3 BD	14.14 (10.03)	22.81 (12.24)	$t(70) = -3.29, P = .002$
EDI-3 EDRC	25.14 (19.13)	51.94 (28.31)	$t(61.45) = -4.71, P < .001$
EDI-3 GPMC	48.00 (30.04)	106.11 (47.85)	$t(58.87) = -6.17, P < .001$
SCL-90	0.56 (0.38)	1.64 (0.86)	$t(48.27) = -6.92, P < .001$
Explicit ratings of stimuli			
Tasty food	5.15 (0.8)	4.05 (1.1)	$t(70) = 4.87, P < .001$
Tasteless food	2.63 (0.87)	2.85 (0.97)	$t(70) = -0.98, P = .33$
Underweight bodies	1.87 (0.5)	2.91 (0.77)	$t(58.79) = -6.42, P < .001$
Overweight bodies	4.93 (0.98)	5.56 (0.47)	$t(31.77) = -2.98, P = .005$
Positive words	5.7 (0.34)	5.42 (0.57)	$t(56.87) = 2.59, P = .012$
Negative words	1.13 (0.25)	1.37 (0.6)	$t(47) = -2.11, P = .04$
Questions			
Valence of being underweight	2 (0.98)	3.6 (1.78)	$t(56.33) = -4.51, P < .001$
Attractiveness of being underweight	2.08 (1.21)	3.72 (1.7)	$t(58) = -4.08, P < .001$
Valence of being overweight	2.08 (1.38)	1.53 (0.84)	$t(34.5) = 1.76, P = .09$
Attractiveness of being overweight	1.75 (0.61)	1.53 (0.91)	$t(58) = 1.05, P = .3$

DT = drive for thinness; B = bulimia; BD = body dissatisfaction; EDRC = eating disorder risk composite; GPMC = Global Psychological Maladjustment Composite.

body images for both underweight and overweight categories. ED patients also rated positive words as less positive and negative words as less negative than controls. Moreover, scores on valence and attractiveness dimensions for being underweight were lower for the control group compared to ED patients. Conversely, valence and attractiveness ratings of being overweight did not differ between groups.

Questionnaire on the tDCS-induced sensations revealed that the majority of participants believed to have received three real stimulations in the three sessions. The proportion of correct guess for real versus sham stimulation in the three sessions was not significantly different between groups ($P > .05$) as the proportion of correct guess in mPFC compared to rEBA session in each group ($P > .05$). None reported pain or high values for different sensations for tDCS (Supporting Information Table S2).

3.2 | IATs

The D score, namely differences in latency between incongruent and congruent blocks, was computed as index of strength of automatic associations (Greenwald et al., 2003). For each IAT, mixed effects analyses were run to test the effects of tDCS, group, IAT version and their interactions.

Figure 1a depicts D scores in each group and tDCS session. For the IAT-food the main effects of tDCS ($P = .35$) and group ($P = .054$) were not significant, whereas the main effect of IAT version was significant ($P = .015$), being D score higher in IAT version A ($M = 0.74$, $SD = 0.26$) than B ($M = 0.62$, $SD = 0.3$). Crucially, the tDCS by group interaction was significant ($P = .028$). Post hoc tests showed that D scores of the control and ED groups significantly differed in sham session ($P = .016$), but not in mPFC and rEBA sessions ($P > .05$). Indeed, in ED patients D score significantly increased when tDCS was applied to rEBA compared to sham session ($P = .04$).

For the IAT-body results showed significant effects of group ($P = .022$) and group by IAT version interaction ($P = .027$). ED patients ($M = 0.18$, $SD = 0.37$) had higher D scores than controls ($M = 0.03$, $SD = 0.37$). Other effects were not significant ($P > .05$). Post hoc tests for the significant group by IAT version interaction showed that controls' D scores were higher in the IAT version A ($M = 0.13$, $SD = 0.36$) compared to version B ($M = -0.08$, $SD = 0.36$, $P = .04$), whereas ED patients' D scores did not significantly differ between IAT versions (A: $M = 0.14$, $SD = 0.39$; B: $M = 0.22$, $SD = 0.35$; $P = .76$).

For the IAT-flower D score only the main effect of IAT version was significant ($P < .001$), being D scores higher in version A ($M = 0.64$, $SD = .27$) than in version B ($M = 0.39$, $SD = .26$), whereas the effects of tDCS, group and their interaction were not significant ($P > .05$).

Modulation of tDCS on IAT-food D score could depend on the selective effect on congruent or incongruent trials (Cattaneo, Mattavelli, Platania, & Papagno, 2011; Mattavelli et al., 2015); thus, response latencies (RTs) were analysed with mixed model testing the effects of factors tDCS, group and block type. Crucially, the three-way tDCS by group by block type interaction was significant ($P = .02$), since only in ED patients RTs of incongruent blocks were longer in mPFC and rEBA sessions compared to sham ($P = .002$ and $P < .001$, respectively; Figure 1b).

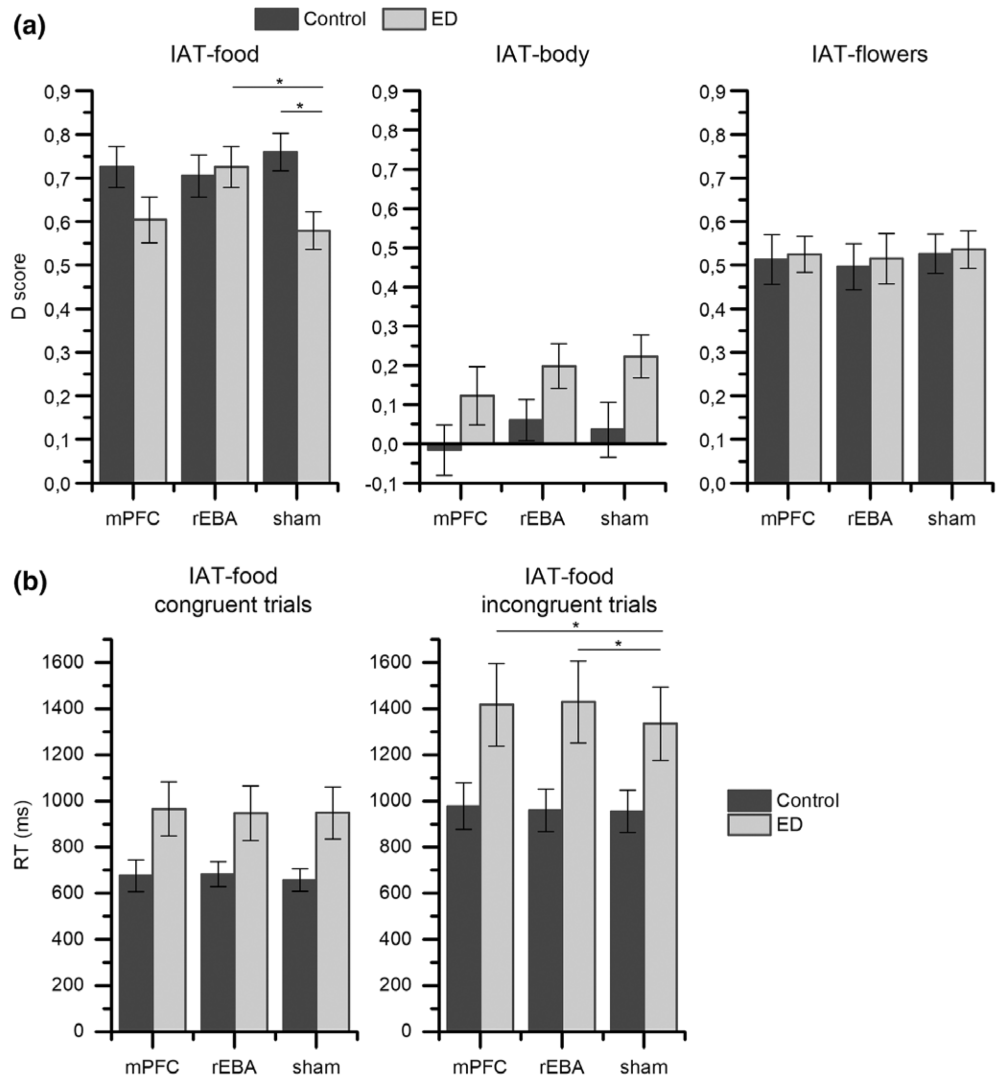

FIGURE 1 (a) Mean D score of control and ED groups at the IATs. Error bars represent standard error of the means. Asterisks indicate significant pairwise comparisons ($P < .05$) for the tDCS by group interaction. (b) Mean RTs in congruent and incongruent trials of control and ED groups at the IAT-food. Error bars represent standard error of the means. Asterisks indicate significant pairwise comparisons ($P < .05$) for the tDCS by group by block type interaction

4 | DISCUSSION

This study provides preliminary evidence that tDCS modulates implicit attitudes towards food in ED patients. Indeed, ED patients had significantly lower D score than controls in sham condition, that is, weaker implicit preference for tasty food at baseline, whereas the two groups did not differ in the a-tDCS sessions. In particular, rEBA stimulation significantly increased patients' D score compared to sham session. Analyses on congruent and incongruent blocks revealed that a-tDCS, both on mPFC and rEBA, selectively increased RTs of incongruent trials in ED patients, suggesting a reduction of patients' automatic association of negative attributes to tasty food and positive attributes to tasteless food.

The tDCS effect on mPFC supports the hypothesis that food preference can be affected by modulating cortical excitability of this area (Mattavelli et al., 2015). Previous studies that applied tDCS to dlPFC reported effects on craving (Fregni et al., 2008), whereas improvement in binge-purge behavior has been observed with rTMS of mPFC (Dunlop et al., 2015). Our results confirm that a-tDCS over mPFC can modify implicit food preference in ED patients, including both AN and BN patients. Future studies with larger and more homogenous samples could clarify tDCS effect on diagnostic groups separately.

The effect of rEBA stimulation on the IAT-food was, in fact, unexpected, but can be explained with the widespread effect of tDCS in areas connected to the target site (Romero Lauro et al., 2014). In particular, rEBA stimulation may have modulated regions between the anode and the cathode, as the cingulate or the frontal cortices, involved in monitoring food preference. On the other hand, previous studies suggest that responses to food images in the visual cortex and temporo-parietal junction can be related to cognitive strategies that control food desire and self-reflection (Brooks et al., 2011; Hollmann et al., 2012). In our study, a-tDCS over rEBA could have modulated patients' cognitive control on the IAT-food. Crucially, the effect was specific for implicit attitudes towards food and did not concern general cognitive mechanisms required by the IAT, since the IAT-flower and IAT-body were not affected by tDCS. The selective effect in the ED patients, but not in healthy controls, supports the hypothesis that tDCS modulatory effect depends on the network functional status (Huang et al., 2017).

Implicit attitudes towards food can predict eating behavior (Richetin, Perugini, Prestwich, & O'Gorman, 2007). Therefore, our data are relevant for future studies testing the effect of tDCS on ED patients. A better understanding of neuromodulation effects in EDs is critical to inform the neurobiological approach for treating dysfunctional eating behavior. This study suggests the possibility of stimulating frontal areas, but also the previously unexplored posterior occipito-temporal regions, to modulate food preferences.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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