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Research review

Transcranial magnetic stimulation of medial prefrontal cortex modulates implicit attitudes towards food

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ABSTRACT

The medial prefrontal cortex (mPFC) is known to be associated with food representation and monitoring of eating behaviour, but the neural mechanisms underlying attitudes towards food are still unclear. Transcranial magnetic stimulation (TMS) was used in combination with the implicit association test (IAT) to investigate the causal role of mPFC in controlling implicit food evaluation in healthy volunteers. Participants performed an IAT on tasty and tasteless food to test TMS interaction with food evaluation. Moreover, IATs assessing self-related concepts and attitude towards flowers and insects were carried out to control whether TMS could also affect self-representation or, more in general, the cognitive mechanisms required by the IAT. TMS was applied over mPFC; the left parietal cortex (lPA) was also stimulated as control site. Results revealed that mPFC-TMS selectively affected IAT on food, increasing implicit preference for tasty than tasteless food, only in a subgroup of participants who did not show extreme explicit evaluation for tasty and tasteless food. This demonstrates that mPFC has a critical causal role in monitoring food preference and highlights the relevance of considering individual differences in studying food representation and neural mechanisms associated with eating behaviour.

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Introduction

Food consumption is a daily activity essential for life, but in modern society food has become less a question of survival and more a matter of social interaction in which different factors influence personal feelings and behaviour in eating. In this context weight-related diseases and eating disorders are growing problems for health and a field of great interest for researchers and clinicians (Fairburn & Harrison, 2003; Treasure, Claudino, & Zucker, 2010). Taking into account biological factors related with food consumption and linked with the risk to develop eating disorders, recent neuroimaging studies have investigated which brain regions are involved in food representation and which are the neural mechanisms underlying motivations and attitudes towards food. The visual presentation of food images typically produces activation in cortical and subcortical regions including the amygdala, hippocampus, insula, anterior cingulate cortex, orbitofrontal cortex, medial and dorsolateral prefrontal cortex (Frank et al., 2010; Killgore et al., 2003; LaBar et al.,

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2001; van der Laan, de Ridder, Viergever, & Smeets, 2011). These areas seem to be involved in food-related activity because of their role in processing biologically relevant stimuli and part of a brain network recruited during the evaluation of the reward value of the stimuli and monitoring behaviour (Tang et al., 2012). In particular, different variables modulated the activity in the orbitofrontal and prefrontal cortex, namely, hunger or satiety (Führer, Zysset, & Stumvoll, 2008), the calorie content of the food (Killgore et al., 2003) and the request to actively control the desire for food (Hollmann et al., 2012), consistent with the hypothesis that these areas are crucial for reward anticipation and behavioural control. Interestingly, prefrontal regions showed also different food-related activity depending on individual differences in reward drive, emotional eating style and cognitive restraint of eating (Beaver et al., 2006; Blechert, Goltsche, Herbert, & Wilhelm, 2013; Hollmann et al., 2012); finally, the activation of the prefrontal cortex differed when healthy volunteers were compared to participants with eating disorders such as obesity or anorexia (Martin et al., 2010; Uher et al., 2004). These results have led researchers to consider the prefrontal cortex as part of a neural circuit contributing to the pathophysiology of eating disorders (Kaye, Wagner, Fudge, & Paulus, 2011) and therefore an interesting candidate as cortical target for studies aiming at exploring the modulatory effects of non-invasive brain stimulation techniques on food-related behaviour (McClelland, Bozhilova, Campbell, & Schmidt, 2013). Indeed, medial and dorsolateral prefrontal cortices have been selected as target sites in studies with transcranial direct current stimulation (tDCS) or transcranial magnetic stimulation (TMS) showing that stimulation sessions reduced food craving in healthy participants (Fregni et al., 2008; Goldman et al., 2011; Uher et al., 2005) and pathological feelings and behaviour in participants with eating disorders (Downar, Sankar, Giacobbe, Woodside, & Colton, 2012; Van den Eynde et al., 2010; Van den Eynde, Guillaume, Broadbent, Campbell, & Schmidt, 2013). However, the mechanisms underlying the behavioural outcome and how stimulation of specific target areas could modulate attitudes towards food are still poorly understood.

One relevant issue to consider is that these studies used self-report and explicit measures which can be vulnerable to social desirability and motivation to adhere to social norms, whereas it has been shown that taste preference and attitudes towards food are a kind of automatic evaluation related to implicit affect towards different types of food, which could vary in groups with different dietary restraints and can also be seen as contradictory with respect to actual eating behaviour of these people in daily life (Papies, Stroebe, & Aarts, 2009; Roefs & Jansen, 2002; Spring & Bulik, 2014). Moreover, Hofmann, Rauch, and Gawronski (2007) showed that the behaviour of candy consumption in an experimental setting depended on automatic evaluation of candies and participants' dietary standards with a significant modulatory effect of self-regulation resources manipulated with an emotion suppression task, a result that highlighted how explicit and implicit attitudes are both relevant to determine food-related behaviour but with different impact depending on personal resources of cognitive control.

The implicit association test (IAT; Greenwald, McGhee, & Schwartz, 1998) is one of the most used tools to measure implicit attitudes. It consists in a double categorization task of two opposite categories associated with two opposite valence attributes. Participants are asked to sort a set of stimuli pressing two response buttons; stimuli belonging to opposite categories (e.g. palatable/unpalatable foods) and valence attributes (e.g. positive/negative words) are first presented separately, then categories and attributes are associated in pairs which can be congruent (e.g. palatable foods – positive words) or incongruent (e.g. unpalatable food – positive words) relative to the dominant thoughts for each specific category. The IAT assumes that a stronger association between categories and attributes causes increased difficulty in categorizing stimuli in the incongruent condition; therefore, differences in accuracy and reaction times between congruent and incongruent conditions are considered an index of the automatic evaluation of the categories. Applied to preference for food IAT has been used to investigate valence for food as a function of deprivation and attitudes towards high-fat and low-fat food in normal weight and obese participants (Roefs & Jansen, 2002; Seibt, Ha, & Deutsch, 2007); moreover, Richetin, Perugini, Prestwich, and O'Gorman (2007) showed that with a large sample of participants IAT predicted behavioural preference for fruit or snacks.

In the present study we combined IAT and TMS in order to investigate the causal role of medial prefrontal cortex (mPFC) in controlling implicit attitudes for tasty and tasteless food. As mentioned above, mPFC showed abnormal responses to images of food in patients with eating disorders and obesity as compared to healthy participants (Martin et al., 2010; Uher et al., 2004); in addition, a case report of Downar et al. (2012) showed remission of symptoms in a bulimic patient following a treatment with rTMS on mPFC. In our study TMS was applied while participants performed an IAT with tasty and tasteless food associated with positive and negative valence words, with the aim to clarify the neural mechanisms responsible for implicit food representation in a healthy population. A different IAT assessing positive and negative valence towards self and others was also included in the experiment in the light of previous neuroimaging findings showing that cortical midline structures, including the mPFC, are involved in explicit and implicit self-related concepts (Moran, Heatherton, & Kelley, 2009) and psychological studies which highlighted a relation between eating behaviour and self-esteem (Bevelander, Anschütz, Creemers, Kleinjan, & Engels, 2013; Vohs et al., 2001). The analysis of the TMS effect on different IAT performances would allow clarification whether the mPFC, for which we expected a causal role in food evaluation, is causally involved also in implicit self-esteem. Finally, in order to check the site specificity of mPFC stimulation and to control whether the IAT-TMS interaction did not depend on a general effect of TMS on IAT cognitive mechanisms, the experimental design included stimulation of the left parietal cortex (lPA) as control site and a third IAT on valence for insects and flowers as control task.

Methods

Participants

Thirty-six (15 males, 21 females, mean age = 23.25 years, s.d. = 2.88, mean years of education = 14.5, s.d. = 1.75) healthy volunteers participated in the experiment, which took place in the TMS laboratory of the University of Milano-Bicocca with the approval of the local Ethic Committee. All participants were right-handed, had normal or corrected to normal vision, no clinical history of neurological or psychiatric disorders, including eating disorders, or other specific contraindications to TMS. Written informed consent was obtained prior to participation.

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), self versus others related concepts (IAT-self), flowers versus insects (IAT-flowers). For each IAT six words for every category of interest, six words with positive valence and six words with negative valence were selected as stimuli. The positive and negative words were the same across the three IATs. Foods and positive/negative valence words were selected throughout a pilot rating submitted to 40 subjects (20 males, 20 females, mean age = 27.2 years, s.d. = 5.3, mean educational level = 15.8 years, s.d. = 2.4) who did not take part in the TMS experiment. From two lists of 45 foods and 45 positive/negative valence words rated on a six-point Likert scale (very tasteless – very tasty food, very negative – very positive word), the six foods with the highest and the lowest score on the tasty scale and the six words with the highest and lowest score on the valence scale were selected.