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Effects of left dlPFC modulation on social cognitive processes following food sampling

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ABSTRACT

Background: The dorsolateral prefrontal cortex (dlPFC) plays a central role in the inhibition of eating, but also the modulation of conscious thought processes that might precede, accompany or follow initial food tasting. The latter might be particularly important to the extent that post-tasting cognitions may drive prolonged eating beyond the satiety point. However, we know very little about the effect of the dlPFC on conation following initial food sampling. This investigation compared the effects of dlPFC attenuation using repetitive transcranial magnetic stimulation (rTMS) on social cognition following (Study 1) and prior to (Study 2) a food consumption opportunity.

Methods: In Study 1, participants ($N = 21$; $M_{age} = 21$ years) were randomized to active or sham continuous theta-burst stimulation (cTBS; an inhibitory variant of rTMS) targeting the left dlPFC followed by an interference task. Participants subsequently completed measures of attitudes, norms and perceived control following a mock taste test. In Study 2, ($N = 36$, $M_{age} = 21$ years) a second sample of right handed participants ($N = 37$; $M_{age} = 21$ years) were assigned to active or sham cTBS, followed by an interference task and two measures of attitudes (implicit and explicit), both assessed prior to the same taste test paradigm.

Results: In Study 1, findings revealed a reliable effect of cTBS on post-tasting attitudes ($t(1,19) = 3.055$, $p = .007$; $d = 1.34$), such that attitudes towards calorie dense snack foods were significantly more positive following active stimulation than following sham stimulation. Similar effects were found for social norms ($t(1,19) = 3.024$, $p = .007$, $d = 1.31$) and perceived control ($t(1,20) = 19.247$, $p < .001$, $d = 0.50$). In Study 2, no effects of cTBS were observed on pre-consumption attitudes, despite reliable effects on interference scores and subsequent consumption.

Conclusions: The left dlPFC may selectively modulate facilitative social cognition following initial food sampling (but not pre-consumption).

1. Introduction

Within a single encounter with food, initial sampling and subsequent overindulgence may be very different phenomena, with equally divergent causal determinants. Although a great deal of attention is directed toward understanding thought patterns that predict initiation of eating, less may be known about cognition that accompanies the first few bites of food. Such processes, however, might be germane to understanding why initial tasting escalates into a full blown eating binge. Post-tasting cognition might be best understood with reference to interactions among neurobiological and social cognitive processes.

With respect to the latter, within the social psychological literature, attitudes, normative beliefs and perceptions of controllability form the proximal predictor network of several of the most highly cited models of eating behavior (Ajzen, 1991; Godin & Kok, 1996; Madden, Ellen, & Ajzen, 1992; Montano & Kasprzyk, 2015). Theorizing suggests that all three variables influence intention to consume and/or consumption itself, all in a facilitative direction. Primary shortcomings of these pure social psychological models is that they are not perfectly predictive of behavior (McEachan, Conner, Taylor, & Lawton, 2011), and they may be missing some critical variables (Sniehotta, Presseau, & Araujo-Soares, 2014), including those that involve neurobiological substrates that might regulate self-control processes. The latter may be a particularly critical omission in relation to calorie dense food consumption (Dohle, Diel, & Hofmann, 2017; Hall, 2016; Hofmann, Schmeichel, & Baddeley, 2012).

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More recent models of eating behavior from the field of social neuroscience have increasingly integrated interactions between social cognitive variables and biologically-based executive control processes (Dohle et al., 2017; Hall, 2016; W.; Hofmann, Friese, & Strack, 2009), the latter often identified as being rooted in the operation of the prefrontal cortex (Cohen, 2005; Miller & Cohen, 2001; Miller, 2000). The lateral PFC, and particularly the dorsolateral PFC (dlPFC), is implicated in self-control (W. Hofmann et al., 2012; Miller & Cohen, 2001); structural connectivity between the lateral PFC and reward regions predict less susceptibility to the allure of immediate rewards in place of larger, later ones (W. Van den Bos, Rodriguez, Schweitzer, & McClure, 2015; W. Van den Bos, Rodriguez, Schweitzer, & McClure, 2014). Studies involving experimental manipulation of the dlPFC show reliable modulation of craving responses to foods (Lowe, Vincent, & Hall, 2017), as well as to appetitive food consumption (P. A. Hall, Lowe, & Vincent, 2017).

Theoretical perspectives on the PFC frequently emphasize its role in maintaining neural representations of goals and goal-consistent action as a means for biasing perceptual motor systems in the service of target goals (Miller & Cohen, 2001). In the case of eating, restraint goals might be maintained in working memory within the PFC, and outcompete more dominant influences such as perceived pleasure of eating. However, primed visceral drives may be more difficult to reign in when the dlPFC is attenuated, yielding more attention and motivational power to the indulgent qualities of appetitive foods. This is a different account of excess consumption than implied by models that, for example, emphasize the role of the dlPFC only in the avoidance of initiation of eating appetitive calorie dense food options. Yet, no prior study has tested the effects of dlPFC attenuation on social cognitive processes following food sampling.

The purpose of the present study was to examine the causal significance of the dlPFC in modulating food preoccupation—operationalized as active social cognitions favoring continued consumption—following food sampling in an experimental paradigm. In order to experimentally manipulate dlPFC function, an inhibitory variant of repetitive transcranial magnetic stimulation (rTMS)—continuous theta burst stimulation (cTBS)—was employed. It was hypothesized that experimental attenuation of the dlPFC would allow consumption-facilitating social cognitions to become magnified following initial sampling of such foods (Study 1). It was further hypothesized that such effects would not be attributable solely to the amount consumed during initial sampling (Study 1), and that dlPFC modulation effects on consumption-facilitating social-cognition would not occur to the same degree pre-consumption (Study 2).

2. Study 1

2.1. Methods

2.1.1. Participants

A sample of 21 right-handed young adult female volunteers participated in the current study.[1] Mean age of the sample was 21 years. Participants were predominantly Caucasian (62%), single (91%) with BMI predominantly in the “normal” range ($M = 23.35$, $SD = 4.70$; 29% overweight or obese). All were pre-screened using an adapted version of Food Craving Scale (Hill, Weaver, & Blundell, 1991), such that only those whom identified “frequent” and strong cravings for potato chips and chocolate (i.e., a value of 7 or higher subjective units on a scale of 10) were eligible to participate. All participants were blind to experimental condition allocation and were naïve to the precise objectives of the study. All participants were also required to fast for a minimum of 3 h prior to the start of the study, with compliance checked upon arrival to the laboratory.

2.1.2. Procedures

Participants were randomized to receive active or sham cTBS, and subsequently were exposed to attractive images of high calorie snack foods, and were given an opportunity to consume three appetitive foods and two control foods. Experimental foods (appetitive) included plain (salted) potato chips, flavoured potato chips, and milk chocolate portions; control foods consisted of unsalted soda crackers and dark chocolate. Following the taste test, participants completed measures of explicit attitudes towards calorie dense foods, subjective norms and perceived control over eating. All experimental sessions were conducted at the same window of time each day (between 2pm and 3pm), in order to control for the possibility of diurnal effects on appetite. All participants were informed initially that the taste test was for the purpose of examining the effect of cTBS on taste perception. Informed consent was obtained prior to study participation. Participants were debriefed and given an opportunity to withdraw their data if they so choose, after being informed of the full purpose of the study. All study procedures received clearance from the institutional ethical review board.

2.1.3. Measures and experimental manipulations

Neuromodulation Methods. Continuous TBS was delivered by a Magstim ×100 stimulator (Medtronic, MN) using a 75 cm (outer diameter) figure-8 coil (MCF-B65). Resting motor threshold (RMT) was determined using electromyography measured from the right abductor pollicus brevis (APB) muscle of the hand. Stimulation was applied to the contralateral motor cortex (M1) and gradually increased until a peak-to-peak motor evoked potential (MEP) amplitude of more than 50 μV was reached on 5 of 10 consecutive trials. The international 10–20 system was used to localize the left dlPFC in each participant. For active stimulation, the body of coil was held at a 90° angle from the mid-sagittal line with its apex centred over F3. Stimulation was applied according to the protocol outlined in Huang, Edwards, Rounis, Bhatia, and Rothwell (2005) in that a continuous train of magnetic pulses were delivered in the theta burst pattern (triplet bursts at 50 Hz, repeated every 200 ms) for 40 s; stimulation intensity was set at 80% RMT. Prior studies have shown that cTBS reliably decreases cortical excitability for 50 min with a peak effect occurring in the 30–40 min post-stimulation period (Huang, Rothwell, Chen, Lu, & Chuang, 2011; Suppa et al., 2016; Wischnewski & Schutter, 2015). Sham stimulation involved rotating the coil 90°, such that it was perpendicular to the scalp, with the round edge against the head. Participants were blind to stimulation condition (active vs. sham).

Attitudes. Explicit attitudes toward calorie dense foods were assessed via a 16-item semantic differential scale, constructed in accordance with recommended practise (Ajzen, 2006). The internal consistency estimate of the scale—following the removal of two items with low ($r < 0.50$) item-total correlations—was high (Cronbach's alpha = .946). For each item, participants were asked to respond to the query “for me to eat [calorie dense] foods frequently would be …”, followed by a 1 to 7 response scale, with the mid-point (4) being neutral, and the extremes (1, 7) representing either of the adjective pairs (“unpleasant”; “pleasant”). Six items were reverse scored, such that total scores on the measure reflected more favorable attitudes toward consumption of high-calorie foods.

Perceived Control. Perceived control was assessed via a four-item measure, with higher scores indicating higher perceptions of control over consumption of high calorie foods (e.g., “I am in complete control over the number of times that I eat fatty foods in the next month.”), with responses given on a 1 to 7 scale, where 1 = disagree completely, and 7 = agree completely. The 4-item measure was moderately reliable

[1] Findings from the taste test are published in a prior report (Lowe, Hall, & Staines, 2014), excluding the social cognitive outcomes reported here for the first time. In this prior analysis, active cTBS resulted in increased consumption relative to sham stimulation, as predicted. This secondary analysis involves only the manipulation effects on social cognitive outcomes, which were measured only following the taste test following the second session.