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Frontal EEG asymmetry moderates the association between attentional bias towards food and body mass index

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ABSTRACT

High global incidence of obesity has led to efforts to identify factors that may contribute to elevated body mass index (BMI). Studies have shown individuals with obesity tend to display an attentional bias (AB) towards food. Left frontal EEG alpha asymmetry (FA) has been associated with motivation to approach rewards and may heighten reactivity to food cues. The current study thus explored whether the association between AB to food and BMI is moderated by FA. EEG was recorded while 93 female participants watched a video confederate incidentally consume potato chips. Participants subsequently completed a visual-probe task to assess AB towards food. Results revealed that AB was positively associated with BMI when FA was skewed left but not right. Individuals' predisposition to approach appetitive stimuli may interact with a bias to attend to food to facilitate overconsumption in obesogenic food environments. Future studies should examine this interaction in relation to consumption.

1. Introduction

Over half a billion of adults are estimated to be within the obese weight category worldwide (Kemps, Tiggemann, & Hollitt, 2014), and it is projected that by 2025, 18% of males and 21% of females worldwide will be classified as obese (Benton & Young, 2017). Individuals' tendency to overeat may factor into subsequent weight gain and the development of obesity (Ochner, Green, van Steenburgh, Kounios, & Lowe, 2009). It has been suggested that the neurobiological correlates of appetitive drive may account for one's vulnerability to overeat (Ochner et al., 2009). In particular, differences in neural circuitry related to motivational behaviours and reward-seeking, as well as attentional processing, may play a role by increasing food cue reactivity among individuals who are overweight and those with obesity (Hume, Howells, Rauch, Kroff, & Lambert, 2015). Individuals who exhibit hypersensitivity to food cues may be particularly vulnerable to engage in chronic overeating (Brignell, Griffiths, Bradley, & Mogg, 2009), which may lead to elevated body mass index (BMI) over time. The "right brain hypothesis" notably posits that obesity may be related to dysfunction in the right prefrontal cortex (Alonso-Alonso & Pascual-Leone, 2007). Compared to their leaner counterparts, individuals classified as obese tend to display lower gray matter density in the right frontal operculum and frontal gyri (Pannacciulli et al., 2006). In accordance, these individuals may be anticipated to exhibit greater activity within the left frontal regions of the brain.

A longstanding literature has demonstrated that the differential lateralization of frontal cortical activity is associated with opposing motivational propensities (Kelley, Hortensius, Schutter, & Harmon-Jones, 2017; Smith, Reznik, Stewart, & Allen, 2017). In particular, greater relative left frontal activity has been deemed characteristic of an approach-motivated tendency associated with heightened responsivity to appetitive stimuli, whereas greater relative right frontal activity has been associated with the predominance of withdrawal or avoidance of aversive stimuli (Kelley et al., 2017; Pizzagalli, Sherwood, Henriques, & Davidson, 2005; Smith et al., 2017). This relative balance between left and right frontal cortical activity has been referred to as frontal asymmetry (FA). Approach and withdrawal motivation have their foundation within Gray's (1970) theory of motivation. Gray (1970) suggests that the Behavioural Activation System (BAS) is sensitive to signals of conditioned reward and appetitive stimuli. By contrast, the Behavioural Inhibition System (BIS) is posited to inhibit behaviour, with increased sensitivity to signals of conditioned punishment and nonreward (Gray, 1970). One's resting FA is proposed to reflect one's trait motivational response tendency towards either behavioural activation (i.e., approach) or behavioural inhibition (i.e., withdrawal; Kelley et al., 2017; Smith et al., 2017). Using electroencephalography (EEG), FA is defined as the difference in alpha activity between the left and right frontal electrode sites (Smith et al., 2017). Though asymmetries in cortical activity have also been identified across the scalp and within various frequency bands, the present analysis focuses on frontal EEG asymmetry in the alpha band.

Individuals' self-reported BAS has been associated with greater relative left FA (Coan & Allen, 2003). Left FA has also been associated

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with a number of approach-related behaviours, dispositional traits, and affective states. For example, left FA has been associated with positive, approach-based affective states (see Harmon-Jones & Gable, 2016 for a review), decreased cortisol response to stress (Quaedflieg, Meyer, Smulders, & Smeets, 2015), proneness to symptoms of hypomania and mania (Harmon-Jones et al., 2002), aggression (Harmon-Jones & Sigelman, 2001), and emotion regulation (Hannesdóttir, Doxie, Bell, Ollendick, & Wolfe, 2010). Neal and Gable (2016) also found that certain facets of self-reported impulsivity were related to greater left FA. Specifically, both positive and negative urgency (i.e., the tendency to act rashly in response to positive or negative emotion states, respectively), lack of premeditation, and lack of perseverance displayed significant associations to left FA (Neal & Gable, 2016). This reward responsivity may be linked to greater dopamine binding within left frontal regions (Tomer et al., 2013, 2014). By contrast, right FA has been associated with withdrawal motivation (Smith et al., 2017), greater physiological stress arousal (Hannesdóttir et al., 2010), and negative affect (Harmon-Jones & Gable, 2016), among others. FA has also been shown reflect state-based changes in approach motivation (Harmon-Jones & Gable, 2016).

The capability model of frontal EEG asymmetry advanced by Coan, Allen, and McKnight (2006) suggests that rather than reflecting a static disposition regardless of the situation, individual differences in FA may more aptly reflect an interaction between the demands of a situation and the traits or abilities that an individual brings to a given situation. The capability model therefore hypothesizes that motivational challenges will elicit more pronounced individual differences that will be more resistant to measurement error. Furthermore, it is suggested that individual differences in FA assessed during motivationally- or emotionally-relevant challenges will be more stable over time than those derived from resting states, and will exhibit stronger associations with important criterion variables (Coan et al., 2006). Corroborating this notion, Coan et al. (2006) found approximately 50% of FA variance across emotional state manipulations reflected an individual by condition interaction, whereas only 26% represented stable individual differences. FA in response to food exposure may be particularly relevant to real-world behavioural response tendencies. As left FA reflects a motivational orientation prone to respond to rewards, left FA to food exposure may reflect a tendency to gratify one's appetitive desires, which may manifest in hedonic eating.

Hedonic eating refers to the consumption of food that occurs in the absence of metabolically-driven need (Berthoud, 2011; van Bochove et al., 2016). Rather than metabolic need, hedonic eating is driven by the reinforcing impact of eating elicited by the activation of reward-related regions in the brain (Berthoud, 2011). Hedonic eating has been implicated as a risk factor for the development of obesity (van Bochove et al., 2016), and may be one of many factors that can contribute to an elevated BMI. Left FA has been related to self-reported hedonic hunger among those with a BMI in the normal to overweight range (Winter et al., 2016), and with hedonic hunger, behavioural disinhibition, and appetitive responsivity to food among individuals with obesity (Ochner et al., 2009). Left FA may thus be involved in prompting hedonic eating, which may lead to overeating.

van Bochove et al. (2016) also examined the association between cortical asymmetries across the scalp during resting state EEG and hedonic valuation of food. Participants' self-reported hedonic valuation of food on the Dutch version of the Health and Taste Attitudes Scales (Roininen & Tuorila, 1999; Roininen et al., 2001) was found to be associated with greater relative left posterior alpha, reflecting the combined activity of the parieto-occipital sites. However, no association was found with anterior fronto-central EEG asymmetries in the alpha band (van Bochove et al., 2016). It was proposed that this may reflect the fact that hedonic valuation of food reflects a combination of sensory perceptions integrated across visual, olfactory, and gustatory systems (van Bochove et al., 2016). The posterior parietal cortex may have greater relevance for holistic food perception and self-reported hedonic valuation (van Bochove et al., 2016). However, van Bochove et al. (2016) did not examine FA in response to perceiving food stimuli. In light of the capability model of frontal EEG asymmetry, it is plausible that left FA may be more apparent when cues in one's environment signal the presence of reward. Viewing food-related stimuli may be more capable of prompting an associated motivational appetitive drive. Moreover, the use of a pooled index of frontal and central regions may have diluted the association.

Preliminary evidence suggests left FA may also enhance approach behaviour related to one's food consumption. The primary study from which the current analysis was derived (i.e., McGeown & Davis, 2018) examined a social modeling of eating paradigm. The social modeling of eating effect refers to the demonstration that individuals exhibit a robust tendency to match the quantity of their food consumption with that of their eating companion (Cruwys, Bevelander, & Hermans, 2015; Vartanian, Spanos, Herman, & Polivy, 2015). McGeown & Davis (2018) found that left FA in response to viewing a confederate consume food strengthened the association between an individuals' food intake and subsequent potato chip consumption as mediated by mirror neuron activity (McGeown & Davis, 2018). Left FA has also been associated with attentional narrowing, referring to a more narrowed, local scope of attentional focus on details compared to a broader, global focus of attention (Gable & Harmon-Jones, 2010a). This narrowing of attention has been proposed to confer an advantage in responding to motivational stimuli by filtering out irrelevant stimuli and facilitating acquisition of desired objects (Gable & Harmon-Jones, 2010a). As a result, it is possible that left FA may enhance an individuals' pre-existing attentional bias (AB) to food. This combination may create a particularly potent force that may encourage appetitive consumption.

AB towards food has been proposed to index individuals' differential reactivity to food reward (Hou et al., 2011). Notably, BMI has been positively correlated with AB towards food via visual-probe tasks (Kemps et al., 2014; Nijs, Muris, Euser, & Franken, 2010; Yokum, Ng, & Stice, 2011), as well as with activation in attention-related brain regions during initial orienting to food (Yokum et al., 2011). However, AB towards food does not necessarily predict food intake (Nijs et al., 2010). Associations between AB towards food and BMI may depend upon presence of an underlying motivation to act that may play a part in prompting overconsumption for these individuals. To date, no studies have examined whether the association between AB towards food and BMI may be moderated by FA as a proxy for one's motivational orientation. However, a study by Karhunen et al. (2000) found that exposure to food images led to a greater increase in regional cerebral blood flow (rCBF) to the left frontal and prefrontal regions among women with obesity who engaged in binge eating compared to women with obesity and of normal weight who did not binge eat. Karhunen et al. (2000) also reported that greater rCBF to the left frontal and prefrontal regions was associated with elevated feelings of hunger during exposure to food. It was suggested left hemispheric frontal regions may play a role in binge eating (Karhunen et al., 2000). Ergo, previous research seems to implicate left FA as a potentially potent force that may prompt excessive approach-related behaviour when in the presence of food. This may be conducive to patterns of chronic overeating, which may contribute to variation in one's weight. This exploratory analysis thus examined whether FA and AB towards food interact in strengthening associations with BMI.

2. Method

The data reported here are part of a larger study initially reported by McGeown & Davis (2018). The participants are identical to those previously described and do not reflect a new sample of individuals. However, the results of the present analysis have not been published elsewhere.