Self-Regulation Ability Modulates Associations between Pre-Frontal Lobe Activity During Food Selection and Body Mass Index: The Use of Functional Near-Infrared Spectroscopy and Virtual Reality

Introduction

Obesity is a pressing global health concern with enormous societal costs (Ng et al., 2014), and the obesity prevalence among U.S. adults was 39.8% in 2015-2016 (CDC, 2017). There is increasing interest in using neuroscientific data to understand how underlying brain characteristics may affect individuals’ susceptibility to food and energy overconsumption, subsequently leading to obesity (Hall et al., 2018). For example, activity in the dorsolateral prefrontal cortex (dlPFC), part of the cognitive control network, in response to food cues has been shown to relate to food choices (Hassenstab et al., 2012; Pignatti et al., & Mauro, 2006; Fregni et al., 2008).

Specifically, greater activation of the dlPFC, a region implicated in cognitive and affective valuation, has been associated with both better (Camus et al., 2009) and poorer food choices (Harding et al., 2018). Thus, additional research to further our understanding of the implications of the dlPFC for BMI, including potential moderators of this association is necessary. Most previous research has primarily relied on food images when examining brain activity and food choices (e.g., Burger et al., 2011). The advent of 3D immersive environments now allows for examinations of brain activity while interacting with more realistic food stimuli. Functional near-infrared spectroscopy (fNIRS) provides a portable way to measure blood oxygenation level-dependent (BOLD) response in immersive virtual environments.

As previous studies have found activity in the dlPFC correlates with food choice, our first aim was to assess if activity in the dlPFC while making food choices in an immersive VR buffet correlates to participants’ body mass index (BMI). We expected a positive association between dlPFC activation during food choice and BMI. Our second aim was to tease apart the complicated association between dlPFC and BMI; specifically, we examined the moderating role of an individual’s regulatory-related abilities. General regulatory skills indicate an one’s ability to establish and execute behavior towards the achievement of goals (Boekaerts et al., 1999) (see Figure 1). Therefore, we hypothesized that higher levels of general self-regulatory skills would modulate the associations between dlPFC activation and BMI by buffering against the negative implications of dlPFC activity for BMI.

Method

Participants. Data collection is ongoing with an expected final sample of 30 participants between the ages of 18 and 25 years recruited from a university campus. In this abstract, we report our preliminary findings from 11 participants (M_{age}=20.45, SD=2.30; 45% female; 4 self-identified as ethnically White, 1 as Black, 5 as Asian, and 1 as Bi-/multi-racial).

Procedures and Measures. Participants reported on their demographics, self-regulation (Short Self-Regulation Questionnaire; Carey, Neal & Collins, 2003) and anxiety (Beck Anxiety Inventory; Steer & Beck, 1997) online via the Qualtrics platform. One week later, participants
completed the VR session during the lunch period (11am-2pm). Participants fasted for 4 hours before the VR session and their BMI was measured and calculated (weight/height^2). An OCTAMON 8 channel fNIRS device was equipped to capture brain activity while participants made food selections within the VR buffet environment. Participants were instructed to make selections of foods as they would in real-life.

**Results**

Correlations and descriptives for study variables were provided in Table 1. Regression analyses revealed that there was a significant main effect of dlPFC activity, \( b=0.93, SE=0.28, t(7)=3.32, p=.013 \), and self-regulation, \( b=-4.56, SE=1.80, t(7)=-2.55, p=.038 \), on BMI. Further, self-regulation moderated the relation between dlPFC activity and BMI, \( b=-1.14, SE=0.44, t(7)=-2.56, p=.037 \). Specifically, at lower, \( b=1.54, SE=0.31, t(7)=4.99, p=.002 \), and mean levels of self-regulation, \( b=0.93, SE=0.28, t(7)=3.32, p=.013 \), dlPFC activity was positively related to BMI. However, at higher levels of self-regulation, the relation between dlPFC activity and BMI was not significant.

**Discussion**

Our results revealed that greater dlPFC activity while making food selection was positively related to BMI. Thus, overall, higher levels of activation in the dlPFC while engaging in the decision-making surrounding food choice may indicate greater attempts to obtain cognitive control during this task. However, greater activation of the dlPFC was a risk factor for higher BMI only for individuals with lower or moderate levels of overall self-regulation abilities. Higher dlPFC activity among individuals with poorer general ability to regulate behavior to achieve their goals may indicate processing inefficiency (Basten et al., 2011). In contrast, individuals with higher self-regulation abilities may be able to inhibit initial impulses to select higher/dense calorie foods and negate the positive association between dlPFC activation and BMI (Lowe et al., 2014). Although preliminary, these findings are promising. With our full sample, we will further examine activation in other regions of the brain previously implicated in obesity and potential moderators, including food-specific regulation, age, and gender. The integration of prefrontal-specific neuroscientific research into the design and development of preventative intervention could guide the development of novel approaches that directly target regions of interest (i.e., those that have been shown to predict obesity), while enabling researchers and clinicians to promote positive behavioral strategies.

**Presentation Brief Summary**

The aims of this study were to: (1) assess the relation between dlPFC activity while making food choices in a Virtual Reality environment and measured BMI; and (2) examine the moderating role of general regulatory abilities in this association. Participants included an ethnically diverse sample of 18- to 25-year-olds (Final projected \( N=30 \); current preliminary sample \( M_{age}=20.45, SD=2.30; 45\% \) female) who reported on their demographics and self-regulation. One week later, participants were equipped with an OCTAMON 8 channel fNIRS device to capture dlPFC activity while making food selections in a VR buffet environment. Results from our preliminary analyses with the current sample of 11 participants revealed that dlPFC activity was related to
higher BMI at lower and mean levels of self-regulation, but not at higher levels of self-regulation. Overall, higher levels of activation in the dIPFC may indicate attempts to obtain cognitive control while making food-related decisions. Coupled with poorer self-regulation, higher dIPFC may indicate processing inefficiency, but higher general self-regulation abilities may enable individuals to inhibit initial impulses to select higher/dense calorie foods and negate the positive association between dIPFC activation and BMI. These findings may inform the integration of prefrontal-specific neuroscientific research into the development of preventative intervention.