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Research report

Power of food moderates food craving, perceived control, and brain networks following a short-term post-absorptive state in older adults ☆

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ABSTRACT

The Power of Food Scale (PFS) is a new measure that assesses the drive to consume highly palatable food in an obesogenic food environment. The data reported in this investigation evaluate whether the PFS moderates state cravings, control beliefs, and brain networks of older, obese adults following either a short-term post-absorptive state, in which participants were only allowed to consume water, or a short-term energy surfeit treatment condition, in which they consumed BOOST®. We found that the short-term post-absorptive condition, in which participants consumed water only, was associated with increases in state cravings for desired food, a reduction in participants' confidence related to the control of eating behavior, and shifts in brain networks that parallel what is observed with other addictive behaviors. Furthermore, individuals who scored high on the PFS were at an increased risk for experiencing these effects. Future research is needed to examine the eating behavior of persons who score high on the PFS and to develop interventions that directly target food cravings.

Introduction

With the twofold increase in obesity over the past 20 years (Flegal, 2005) and the fact that older adults have not escaped this epidemic (Villareal, Apovian, Kushner, & Klein, 2005), there is an increased urgency to better understand the etiology of eating behavior in this population. This problem is particularly timely given the *Graying of America* that will occur over the next 15–30 years (Manton & Vaupel, 1995). In response to this need, we examine how either a short-term post-absorptive state, in which participants were only allowed to consume water, or a short-term energy surfeit treatment condition, in which they consumed BOOST®, influence older adults' (a) craving for desired foods, (b) self-regulatory beliefs towards controlling eating behavior, and (c) brain networks. A question of particular interest is whether these responses are moderated by scores on the Power of Food Scale (PFS) (Lowe et al., 2009).

Lowe and colleagues (Lowe et al., 2009) have shown that people differ in the drive to consume highly palatable food within obesogenic food environments; a characteristic assessed using the PFS. These authors found that the PFS was significantly related to the disinhibition ($r = .61$) and hunger scales ($r = .63$) of the three factor eating questionnaire, as well as the emotional and external eating subscales of the Dutch Eating Behavior Questionnaire, $r = .54$ and $r = .66$, respectively. Within the appetite literature, Clark and colleagues (Clark, Abrams, Niaura, Eaton, & Rossi, 1991) have proposed that participants' confidence in their ability to resist eating due to internal states and external circumstances represents an important cognitive dimension of self-regulation. Despite favorable findings with this construct (Linde, Rothman, Baldwin, & Jeffery, 2006; Rejeski, Mihalko, Ambrosius, Bearon, & McClelland, 2011; Richman, Loughnan, Droulers, Steinbeck, & Caterson, 2001), recent work by Nordgren and colleagues has argued that health cognitions are unstable and profoundly influenced by visceral states such as hunger and appetite (Nordgren, van der Pligt, & van, 2008; Nordgren, van, & van der Pligt, 2009). Because our interest was studying responses to two different short-term post-absorptive states, one with water and a surfeit treatment condition with BOOST®, we

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employed a brief state-based measure of confidence for controlling eating behavior ($CCEB_{state}$) that was developed in line with work by Bandura (1986) and a measure of state craving developed by Cepeda-Benito and colleagues (Cepeda-Benito, Gleaves, Williams, & Erath, 2000).

Finally, Alonso-Alonso and Pascual-Leone (Alonso-Alonso & Pascual-Leone, 2007) have proposed that dysfunction in the right prefrontal cortex (PFC) is a root cause of obesity. That is, rather than the appetitive drive per se being the cause of overconsumption, they argue that it is the inability of the right PFC to effectively self-regulate eating behavior. Central to the current investigation is the well documented effect that the craving to consume food increases with exposure to (Kelley, Schiltz, & Landry, 2005) and the active imaging of food cues (Pelchat, Johnson, Chan, Valdez, & Ragland, 2004), increases in craving that were found to be related to activation in the hippocampus, insula, and caudate.

Therefore, in this study, we sought to determine whether scores on the PFS would be related to the $CCEB_{state}$ and state cravings following two different short-term post-absorptive states, one in which participants were allowed to consume water only and a second surfeit treatment condition in which participants consumed BOOST®. Research has shown that liquid meal replacements are an effective strategy for curbing short term hunger (Mattes & Rothacker, 2001). The hypothesis was that individuals scoring high on the PFS would exhibit a substantial increase in food craving and a loss of control related to eating behavior as compared to those scoring low on the PFS, and that this effect would be magnified in the short-term post-absorptive treatment condition in which participants consumed water only.

Additionally, we examined brain networks after repeated exposure to food cues expecting that the short-term post-absorption state, in which participants consumed water only, would most likely yield changes in the brain regions associated with craving, particularly increased connectivity in the basal ganglia and insula (Pelchat et al., 2004), and that these effects would be accentuated for those scoring high on the PFS. We also predicted that alterations in basal ganglia connectivity would be associated with changes in motor system connectivity as a reflection of food-seeking motivation. Parenthetically, we focused on the sensorimotor cortex because of the conceptual nature of the research question. That is, we manipulated sensory cues (i.e., palatable food) and reasoned that individual difference in the drive to consume palatable food (i.e., the PFS) would increase activity in sensorimotor networks.

Engaging external environmental cues, as promoted by the food cue manipulation employed in the current study, can result in alterations in the activity and connectivity of the default-mode brain network (DMN), since this network represents the resting state of the brain (Gusnard & Raichle, 2001; Raichle et al., 2001). The brain areas that make up the DMN include precuneus/posterior cingulate extending into the medial temporal lobe, anterior cingulate/medial prefrontal cortex, and bilateral occipito-parietal cortices. Furthermore, it has recently been demonstrated that the posterior cingulate/precuneus portion of this network is one of the most highly connected regions in the brain and serves as a brain network hub for the DMN (Hagmann, Cammoun, Gigandet, et al., 2008; Sporns, Honey, & Kotter, 2007). Therefore, the posterior cingulate/precuneus region was selected as the primary region of interest for this sub-network and we anticipated that there would be greater disruption of this region in the short-term post-absorptive state with water only, particularly for those scoring high on the PFS due to a lingering preoccupation with the food cues (Kavanagh, Andrade, & May, 2005).

Methods

Participants

A sample ($n = 22$) of obese (BMI $\geqslant 30\ kg/m^2$ but $\leqslant 40\ kg/m^2$), sedentary older adults (50–80 years of age) was recruited from Forsyth County, NC. All were Caucasians and were excluded if they were either actively dieting or involved in more than 60 min of structured exercise each week. Active dieting was defined as currently involved in a research study of weight loss, participating in a commercial weight loss program, or engaging in a self-directed program to lose weight. Structured exercise was any structured type of aerobic or resistance training performed in bouts lasting $\geqslant 10$ min. Both active dieting and structured exercise habits were assessed via interview. Other exclusion criteria included: (1) the presence of a systemic uncontrolled disease or psychiatric illness determined via self-report, (2) a binge eating disorder, (3) the inability to safely undergo magnetic resonance imaging, (4) currently undergoing active treatment for cancer, or (5) unable to read or speak English. Of the 22 that were randomized to treatment, 3 were unable to complete the study leaving a final n of 19. One individual was lost due to complications from preexisting back-pain, another became claustrophobic during the first day of scanning, and the third had a large artifact in the prefrontal region of the fMRI. Participants received $225 to compensate for their time commitment.

Measures

Power of Food Scale (PFS)

The PFS assesses the drive to consume highly palatable food in an obesogenic food environment (Lowe et al., 2009); higher scores are associated with a higher drive. The total score has been shown to have good test–retest reliability ($r = 0.77$), is internal consistent ($\alpha = 0.91$), and support exists for its construct validity (Cappelleri et al., 2009; Lowe et al., 2009). Three subscale scores can be calculated: food available, food presence, and food tasted. Because the total score has such high internal consistency, we felt justified in restricting our attention to this single score of the PFS. Furthermore, examination of the separate subscales for the PFS fell beyond the scope of the current study.

Food Craving Questionnaire (the FCQ_{state})

The FCQ_{state} assesses state craving for specific foods using a 5-point scale (1 = strongly disagree; 5 = strongly agree) with the mid-point being anchored by the label *neutral*. The FCQ_{state} is based on a unifying construct and has a Cronbach alpha of 0.94. The FCQ_{state} is distinct from the concept of Food Restraint and has been found to exhibit a statistically significantly reduction completed prior to and then following breakfast (Cepeda-Benito et al., 2000).

Confidence for Controlling Eating Behavior ($CCEB_{state}$)

We developed a 4-item measure of self-efficacy for eating behavior for the consumption of favorite foods that is state-based (Bandura, 1986). Participants rate their confidence in being able to resist or control eating their favorite food right now, at this moment. The items are rated on a 10 point scale ranging from 0 "not at all confident" to 10 "very confident", with the anchor "moderately confident" spanning the values from 4 to 6 and centered at 5. The four items include the following: (1) if available, I could resist eating my favorite foods; (2) at the current time, I feel like I have good control over my appetite; (3) at the moment, I feel as if I could restrain myself from eating foods that I enjoy; and (4) currently I feel that I could avoid snacking between meals. In this