



Trait-based food-cravings are encoded by regional homogeneity in the parahippocampal gyrus



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ARTICLE INFO

Article history:

Received 18 July 2016

Received in revised form

8 February 2017

Accepted 22 March 2017

Available online 23 March 2017

Keywords:

Food-craving trait

Resting-state fMRI

Regional homogeneity

Parahippocampal gyrus

Emotional memory circuits

ABSTRACT

Food cravings can reflect an intense trait-like emotional-motivational desire to eat palatable food, often resulting in the failure of weight loss efforts. Studies have linked trait-based food-cravings to increased risk of overeating. However, little is known about resting-state neural mechanisms that underlie food cravings. We investigated this issue using resting-state functional magnetic resonance imaging (fMRI) to test the extent to which spontaneous neural activity occurs in regions implicated in emotional memory and reward motivation associated with food cravings. Spontaneous regional activity patterns correlating to food cravings were assessed among 65 young healthy women using regional homogeneity analysis to assess temporal synchronization of spontaneous activity. Analyses indicated that women with higher scores on the Food Cravings Questionnaire displayed increased local functional homogeneity in brain regions involved in emotional memory and visual attention processing (i.e., parahippocampal gyrus and fusiform gyrus) but not reward. In view of parahippocampal gyrus involvement in hedonic learning and incentive memory encoding, this study suggests that trait-based food cravings are encoded by emotional memory circuits.

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1. Introduction

As the expression, “Food is the God of the people” implies, eating palatable food is highly pleasurable for most people. The fact that many are overweight in modern obesogenic environments underscores the enticing nature of palatable food (Appelhaus, French, Pagoto, & Sherwood, 2016). Because people often consume more calories than are required physiologically, the tone for eating is usually set by the omnipresence of food or food-related cues rather than physiological deprivation and the pleasure derived from highly palatable foods reinforces such “hedonic” cravings (Lowe & Levine, 2005).

Food craving refers to an intense appetitive motivation for

eating palatable food and is commonly experienced among those who intend to control intake (Cepeda-Benito & Gleaves, 2001; Hill, 2007; Meule, Hermann, & Kübler, 2014). Food cravings are not a simple analogue of hunger which is not necessarily a precondition for food craving; food cravings can arise even when hunger is reduced (Hill, 2007; Pelchat & Schaefer, 2000). Independence of cravings from one's temporary physiological needs is the feature that differentiates trait-based food cravings from state-like cravings (Meule et al., 2014; Pelchat & Schaefer, 2000). Based on the recently proposed goal conflict model of eating (Stroebe, van Koningsbruggen, Papies, & Aarts, 2013), strong trait-based food cravings increase the strength of hedonic eating goals and disrupt the balance between eating enjoyment and weight control. This reinforces associations between food and pleasure experience, thereby contributing to overeating.

Trait-based food cravings are associated with loss of control, overeating, and disturbances such as binge eating, bulimia symptoms, dieting failure, and obesity (Cepeda-Benito, Fernandez, & Moreno, 2003; Innamorati et al., 2014; Meule, Lutz, Vögele, & Kübler, 2012; Potenza & Grilo, 2014). Among dieters, craving of

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palatable foods is thought to interfere with compliance with low-calorie diets, resulting in relapse to initial overeating patterns (Meule, Westenhöfer, & Kübler, 2011).

Researchers have developed various questionnaires to assess food cravings including the Food Craving Inventory and Questionnaire on Craving for Sweet or Rich Foods (Toll, Katulak, Williams-Piehot, & O'Malley, 2008; White, Whisenhunt, Williamson, Greenway, & Netemeyer, 2002). However, the Food Cravings Questionnaire-Trait (FCQ-t) has a unique focus on behavioral, cognitive, and physiological aspects of general food cravings rather than craving of particular foods such as chocolate (Cepeda-Benito et al., 2000; Meule et al., 2014, 2012; Rodríguez-Martín & Meule, 2015). Moreover, the FCQ-t has validity support as trait-based measure of food craving (Hormes & Meule, 2016).

In a series of recent studies, FCQ-t scores were used to evaluate behavioral reactions to food cues in different eating groups. In healthy participants, high cravers were shown to have stronger automatic approach tendencies towards food than low cravers had (Brockmeyer, Hahn, Reetz, Schmidt, & Friederich, 2015). In addition, trait impulsivity and food cravings can jointly affect behavioral inhibition capacities vis a vis food (Meule & Kubler, 2014). Food cravings may distinguish successful from unsuccessful dieters in addition to mediating the relationship between eating control strategies and dieting success (Meule et al., 2011, 2012). Finally, FCQ-t scores are a significant predictor of binge eating symptoms and body dissatisfaction (Moreno, Rodríguez, Fernandez, Tamez, & Cepeda-Benito, 2008; Moreno, Warren, Rodríguez, Fernández, & Cepeda-Benito, 2009). In summary, these studies underscore trait-based food craving as an important consideration, particularly in the current context of life in obesogenic environments.

In contrast to numerous behavioral studies, few researchers have directly examined neural mechanisms underlying trait-based food cravings. One early functional magnetic resonance imaging (fMRI) study found craving-related activation was isolated from activation related to hunger or liking (Pelchat, Johnson, Chan, Valdez, & Ragland, 2004). Three brain areas were linked to stronger craving-specific activation: the hippocampus, insula, and caudate, all of which are also involved in drug cravings (Volkow, Wang, Fowler, Tomasi, & Baler, 2012, pp. 1–24). Other conceptually-relevant studies have focused on the pleasantness or desirability for food stimuli. Areas activated by food cues include the orbitofrontal cortex (Small et al., 2007), parahippocampal gyrus (Brooks, Cedernaes, & Schiöth, 2013), fusiform gyrus (LaBar et al., 2001), and striatum (Kober et al., 2010). However, in these studies, participants were required to engage in different tasks while viewing food stimuli and neural correlates of trait-based food cravings were not a specific focus.

Though task-based fMRI studies have been the main thrust of eating-related neuroimaging research (Van der Laan, De Ridder, Viergever, & Smeets, 2011), resting-state fMRI (RS-fMRI) is a promising alternative for elucidating neural correlates of trait-based food cravings (Fox, Snyder, Vincent, & Raichle, 2007). To date, RS-fMRI studies have indicated obese groups show alterations of intrinsic activity in default mode, temporal lobe, and salience networks during resting states (Garcia-Garcia et al., 2013; Kullmann et al., 2012).

Regional properties of intrinsic brain dynamics can be assessed via regional homogeneity (ReHo) analysis, a robust, reliable index of resting-state brain activity (Zang, Jiang, Lu, He, & Tian, 2004). Based on the underlying assumption that brain activity is more likely to occur in clusters than in single voxels, ReHo evaluates similarities of neural activation patterns between the time series of a given voxel and its nearest neighbors, as calculated by Kendall's coefficient of concordance (KCC) (Kendall & Gibbons, 1990). Recent work

contends that ReHo is one of the most efficient, reliable, and widely used indices for detecting local functional coherence (Jiang & Zuo, 2015; Zuo et al., 2013) and has potential utility in predicting weight changes over time among restrained eaters (Dong, Jackson, Wang, & Chen, 2015). To elaborate, women with higher restrained eating levels also have stronger ReHo values in regions implicated in reward processing (Dong et al., 2014). Furthermore, elevated spontaneous reward region activity can predict future weight gain in this group (Dong et al., 2015). While these RS-fMRI studies point to the potential utility of examining intrinsic neural activity associated with specific eating behaviors, extensions have yet to investigate trait-based food cravings.

Towards addressing this gap, we examined specific neural mechanisms related to food cravings using RS-fMRI. Based on evidence that high cravers more frequently experience the desire for food and recollect previous pleasurable food experiences (May, Andrade, Panabokke, & Kavanagh, 2004; Tiggemann & Kemp, 2005), we hypothesized that stronger trait-based food cravings would be associated with higher levels of spontaneous activity in motivational-memory and somatosensory regions, especially the hippocampus /parahippocampal gyrus, caudate nucleus, fusiform gyrus, and insula.

2. Methods and materials

2.1. Participants and procedure

Participants were 65 healthy undergraduate women from Southwest University, Chongqing. Only women were recruited because men and women differ in how and why they gain and lose weight as well as brain anatomy and function (Frank et al., 2010; Holm-Denoma, Joiner, Vohs, & Heatherton, 2008; Luders, Gaser, Narr, & Toga, 2009). Open-ended queries assessed exclusion criteria including current neurological disease (i.e., central and peripheral nervous system diseases such as epilepsy, migraine and other headache disorders, multiple sclerosis, or brain trauma). Obese participants (body mass index [BMI] ≥ 30 kg/m²) were also excluded because of potential neuro-anatomical differences based on BMI (Gunstad et al., 2008). Smokers, alcohol users, and women taking medication known to affect fMRI signals were excluded. Finally, none of the women reported a formal eating disorder diagnosis or history of such symptoms, although 30 reported the use of dieting to maintain or lose weight. Table 1 summarizes sample characteristics.

The research was approved by the Southwest University human research ethics committee. All participants provided written, informed consent prior to participation. Eligible women were instructed to refrain from eating and drinking any liquids except water for three hours before their scans. All scans were conducted between 9:30 and 11:30 a.m. Fasting status was confirmed by self-reports upon arrival. During the scan, participants were instructed to keep their eyes closed, to not think of anything in particular, and to remain awake. Following the RS-fMRI scan, participants completed demographic questions (i.e., age, smoking status,

Table 1
Demographic and psychological characteristics of sample (N = 65).

Variable	Range	M (SD)
FCQ-T-r	15–73	43.12 (10.42)
Age (years)	18–27	21.52 (1.55)
BMI	17.16–24.56	20.45 (1.99)
Fast Time (hours)	2–9	4.72 (1.99)
Positive Affect	14–43	27.20 (7.19)
Negative Affect	14–41	24.23 (6.49)
Menstrual Phase (days)	2–50	20.04 (8.53)

Note. FCQ= Food Cravings Questionnaire-Trait-revised; BMI = body mass index.

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