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Research Report

Neural regulatory mechanism of desire for food: Revealed by magnetoencephalography

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ABSTRACT

Currently, little is known about the brain function that allows individuals to suppress eating behavior. The present study used magnetoencephalography (MEG) to examine changes in neural activity over time that were related to suppression of motivation to eat in 11 healthy males. The MEG experiment consisted of four motivation sessions and four suppression sessions in an alternating and counterbalanced order. During MEG recordings, participants viewed a set of food pictures and mosaic pictures projected onto a screen, and were then asked to rate their motivation to eat and the suppression of the motivation to eat during the recordings. The present study demonstrated a higher β-band (13–25 Hz) event-related synchronization (ERS) level during the suppression sessions relative to the motivation sessions in the left supplementary motor area (SMA) 200–300 ms after the start of food picture presentation. Similar differences were also observed in θ-band (4–8 Hz) event-related desynchronization (ERD) in the left dorsolateral prefrontal cortex (DLPFC) after 500–600 ms. Negative relationships were observed between these levels of MEG responses and the number of food items for which the participants reported the motivation to eat during the MEG recordings. These findings indicate that the left DLPFC and SMA, particularly the DLPFC, play prominent roles in the suppression of motivation to eat. This may help to clarify the temporal aspects of the neural basis of self-control of appetitive motivation as well as aid development of self-control strategies such as cognitive behavioral therapy for patients with disordered appetite.

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1. Introduction

Obesity represents a considerable health threat to modern adults and children worldwide (WHO, 2000), and is an independent risk factor for various common diseases (Must et al., 1999). Excessive weight gain commonly originates from an imbalance between expenditure versus intake of energy. Accordingly, the management of obesity, apart from exercise, mainly involves a calorie restricted diet. Furthermore, it has been reported that calorie restriction has an additional effect on lifetime extension in many animal species (Fontana et al., 2010), suggesting that it may also be beneficial for humans. However, efforts to restrict calorie intake are often hampered in part by distorted appetite (Borer, 2010). In this sense, both mental and physical health might partly depend on the ability to resist gratification by regulating the appetitive impulse to consume a desirable but unhealthy food.

Appetite is controlled not only by homeostatic requirements such as nutritional deficit but also by other factors, including cognition, emotions, and pleasure from food intake (Rolls, 2007). In the homeostatic system, the hypothalamus senses the nutritional state of the body and thereby controls energy intake and expenditure. In contrast, the pleasure obtained from food intake can provide reinforcement for intake exceeding the homeostatic requirements and thereby lead to overindulgence in highly palatable foods. This hedonic component of feeding behavior is mediated by reward-related cortical and sub-cortical systems, including the ventral striatum, the ventral tegmental area, and the orbitofrontal cortex (OFC) (Berthoud, 2002, 2004; Berthoud and Morrison, 2008; Grill and Kaplan, 2002). There is growing evidence suggesting that overeating is related to an imbalance in these homeostatic and hedonic systems. However, little is known about the neural mechanism that allows individuals to consciously suppress eating behavior (Carnell et al., 2012).

In previous research on appetite and eating behavior using psychophysiological parameters, few studies have employed electroencephalography (EEG) and magnetoencephalography (MEG), and those that did employ these modalities focused primarily on the asymmetry of prefrontal cortex activation in response to viewing food pictures or that in relation to subjective scores of an overeating scale (Gable and Harmon-Jones, 2008; Ochner et al., 2009). MEG monitors the electrophysiological rhythms inside the brain by measuring induced electromagnetic fields using electric or magnetic sensors over the scalp surface (Hämäläinen et al., 1993; He, 2004; Nunez and Srinivasan, 2005); it has an intrinsic high temporal resolution that allows tracking of rapid neurophysiologic processes at the neuronal time scale of milliseconds. This high temporal resolution enables determination of the flow of neural circuitry formed among multiple brain areas and the location of particular brain areas related to the regulation of appetitive motivation. To the best of our knowledge, few studies have investigated the neural responses to visual stimuli of food in the state of conscious suppression of motivation to eat by assessing electric or magnetic signal changes, and their association with the intensity of subjective motivation to eat. It is expected that elucidation of the mechanism of suppression of the motivation to eat will facilitate the development of objective tools for assessment and therapeutic strategies for various eating disorders characterized by irresistible impulse of motivation to eat.

In the present study, brain activities were measured using MEG in fasting individuals in response to the presentation of food pictures in the following two settings: (1) when one

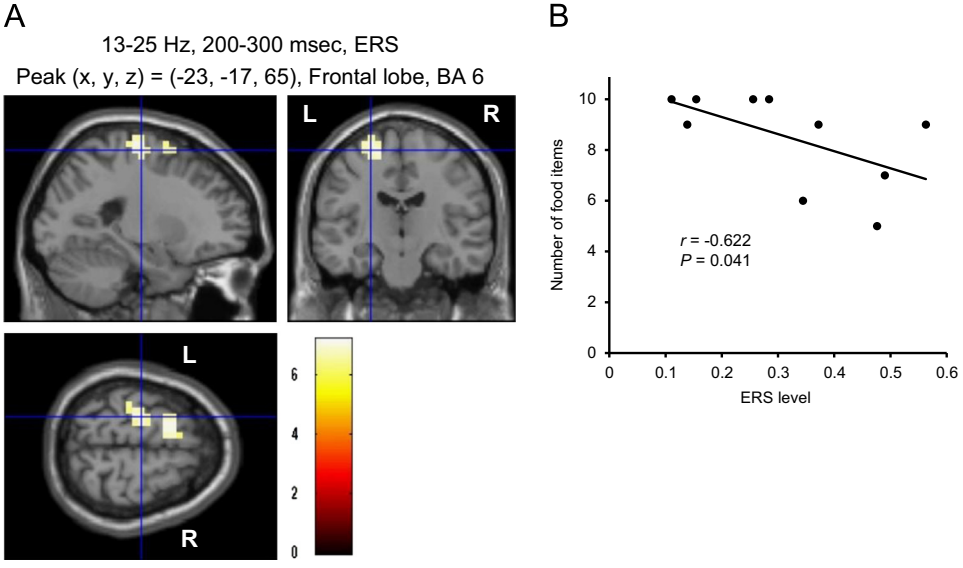

Fig. 1 – Statistical parametric maps of β-band event-related synchronization (ERS) (suppression sessions relative to motivation sessions; random effect analyses of 11 participants, $P<0.05$, corrected for multiple comparisons at voxel level) with the time window of 200–300 ms after the start of food picture presentation (A) and association of the ERS level with number of food items that caused appetitive motivation during MEG recordings (B). Statistical parametric maps are superimposed on high-resolution MRIs. Sagittal (upper left), coronal (upper right), and axial (lower left) sections are shown. Color bar (lower right) indicates ERS levels. BA, Brodmann's area; R, right; L, left. Linear regression line, Pearson's correlation coefficient, and P-value are shown (B).

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