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Brain activation during the perception of distorted body images in eating disorders

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Eating disorder (ED) patients have severe disturbances in the perception of body shape and weight. The authors investigated brain activation patterns during the perception of distorted body images in various subtypes of ED. Participants comprised 33 patients with EDs (11 with restricting-type anorexia nervosa (AN-R), 11 with binging–purging type anorexia nervosa (AN-BP), 11 with bulimia nervosa (BN)) and 11 healthy women. Functional magnetic resonance imaging was used to examine cerebral response to morphed images of subjects' own bodies, as well as that of another woman. The amygdala was significantly activated in AN-R patients, AN-BP patients, and healthy women in response to their own fat-image, but this did not occur in BN patients. The prefrontal cortex (PFC) was significantly activated in AN-BP patients and healthy women, but not in AN-R and BN patients. Our results showed that the various EDs are different with respect to significant activation of the amygdala and PFC during the processing of participants' own fat-image. Brain activation pattern differences between the various EDs may underlie cognitive differences with respect to distorted body image, and therefore might reflect a general failure to represent and evaluate one's own body in a realistic fashion.

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1. Introduction

Most women are concerned about their shape and weight (Thompson et al., 1999). Body dissatisfaction is widespread among women in Western societies (Rodin et al., 1993; Tiggemann and Wilson-Barrett, 1998), possibly as a consequence of sociocultural standards of female beauty that emphasize extreme and, for most women, unattainable thinness (Thompson et al., 1999). Such expectations are thought to be a risk factor for the development of eating disorders (EDs).

EDs are an important cause of physical and psychosocial morbidity in young women (Fairburn and Harrison, 2003). EDs are classified primarily into three subtypes, according to specific observable attributes or symptoms (e.g., eating behaviors per se). Anorexia nervosa (AN) and bulimia nervosa (BN) are the two major categories of ED. AN is characterized by the maintenance of an inappropriately low body weight, a relentless pursuit of thinness, and obsessive fears of becoming fat (American Psychiatric Association, 1994). AN is further classified into two subtypes according to specific eating behaviors (American Psychiatric Association, 1994): The restricting type (AN-R; severe restriction of food intake with no associated binging or purging behaviors) and the binge eating/purging type (AN-BP; restriction of food intake coupled with episodes of binge eating/purging). BN is characterized by frequent episodes of uncontrolled overeating (binging). Most EDs are characterized by abnormalities in perception and evaluation of body shape (Uher et al., 2005). Cognitive biases or distortions, particularly about body weight and shape, have been well documented among ED patients. These distortions include biases in the interpretation of body-related information. Related to concerns about weight and shape in EDs is "a disturbance in the way in which one's body weight or shape is experienced" (American Psychiatric Association, 1994). This manifests as systematic overestimation of one's own size, and this bias is stronger in AN than in BN (Cash and Deagle, 1997). Consistent with these cognitive biases, ED patients might have functional abnormalities in those brain systems that are concerned with the processing of body size or image (Grunwald et al., 2001; Smeets and Kosslyn, 2001).

Recently, brain imaging techniques such as functional magnetic resonance imaging (fMRI) have been used to identify specific areas that might underlie abnormal brain functioning in ED patients. The propensity to display specific attributes (drive for thinness, fear of fatness) and behaviors (restricting, binge eating) can be conceptualized as preferential activation of certain neural pathways and circuits (Uher et al., 2005). Several fMRI studies of EDs have investigated brain activation during the presentation of body shape images. Two previous fMRI studies have investigated the neuroanatomical effects of exposing AN patients to morphed images of their own bodies (Seeger et al., 2002; Wagner et al., 2003). Whereas a pilot study of

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three patients reported specific responses in the right amygdala, right fusiform gyrus and brainstem to AN patients' own bodies relative to another woman's (Seeger et al., 2002), a group analysis of 13 patients did not replicate these findings (Wagner et al., 2003). The latter authors explain this discrepancy as a consequence of task design. Brain imaging data on BN are even more limited. One fMRI study found that the lateral fusiform gyrus, inferior parietal cortex, and lateral prefrontal cortex (PFC) were activated in response to line drawings of body shapes (compared with a control condition) in AN patients, BN patients, and healthy women (Uher et al., 2005). One positron emission tomography (PET) study reported that brain serotonin alterations were present after recovery from BN (Kaye et al., 2001). Our previous study reported that healthy women showed activation of the limbic/paralimbic areas and PFC upon viewing distorted images of their own bodies (Kurosaki et al., 2006). These investigations suggest that there is a specific neural network that is involved in the general processing of body shapes (the lateral fusiform, parietal and dorsolateral PFC (DLPFC)) (Uher et al., 2005; Downing et al., 2001), with the emotional (e.g., the amygdala per se) and self-referential areas (medial PFC (MPFC)) (Fossati et al., 2003; Johnson et al., 2002; Zysset et al., 2002) activated when body-shape-related stimuli carry significant emotional or self-related information (Friederich et al., 2007). Further evidence for the notion of a specific neural network for body shape processing comes from lesion studies, in which lesions of the DLPFC and/or parietal cortex are associated with impaired performance on tasks that require on-line coding of body posture (Schwoebel and Coslett, 2005). However, there have been no studies of brain activation differences upon viewing distorted images of one's own body among the three major subtypes of ED (AN-R, AN-BP, and BN). Similarly, little is known about possible functional abnormalities in brain systems that might underlie the cognitive/emotional differences amongst the three subtypes of ED.

In the present study, we investigated the neural correlates of body-image perception in three subtypes of EDs and healthy women, examining cerebral responses to morphed images of subjects' own bodies as well as that of another woman. We hypothesized that brain activation differences during the processing of body-image stimuli across the groups would involve discrepancies in activation of the limbic area including the amygdala, and the PFC. We used fMRI to capture brain activation while participants engaged in a "body-image task" that required them to perceive distorted images and real images of their own (and others') bodies.

2. Methods

2.1. Participants

Forty-two patients with EDs were recruited. Exclusion criteria were metallic implants, claustrophobia, and presence of an Axis I or II psychiatric diagnosis other than an ED. A total of nine possible patients were excluded, because of an incidental MRI finding ($n=1$), movement artifacts ($n=3$), dental plates ($n=1$) and the presence of an Axis I or II psychiatric diagnosis other than an ED ($n=4$). Thirty-three patients with EDs participated in this study. All patients fulfilled DSM-IV diagnostic criteria for EDs (11 with AN-R, 11 with AN-BP and 11 with BN), and none of the BN patients had a history of AN. Eleven healthy women were recruited via community announcement, and none of the healthy women had a history of psychiatric or neurological illness. All participants were right-handed Japanese women and outpatients. Handedness was determined using the Edinburgh Handedness Inventory (Oldfield, 1971). The experiment was performed while patients received treatment. They were being treated with medical management, psychological education and supportive psychotherapy. Although 11 patients were taking antidepressant medications to control obsessive–compulsive symptoms, affective symptoms, and bulimic symptoms (two with AN-R, five with AN-BP, and four with BN), the patients did not have any other Axis I or II comorbidities, as assessed via the Structured Clinical Interview for DSM-IV. They were not treated using a particular psychotherapy such as behavioral therapy, cognitive behavioral therapy, or psychodynamic treatment at least 6 months before the time of scanning. Clinical characteristics of the participants were averaged, and multiple comparisons across the groups were made using Bonferroni corrections. This study was conducted using a protocol approved by the ethics committee of the Hiroshima University School of Medicine. All participants gave their informed written consent prior to their participation.

2.2. Measures

The Structured Clinical Interview for DSM-IV Axis I and II Disorders (First et al., 1997a,b) was conducted with all participants. At least two senior psychiatrists interviewed the patients to ensure that they met DSM-IV diagnostic criteria for relevant ED subtypes. The Eating Disorder Inventory-2 (EDI-2) was also used to further examine our participants' eating problems (Garner, 1991).

2.3. Stimuli and task

To investigate neuronal processing of body images, we used the emotional decision task developed by Kurosaki et al. (2006), with some modifications. Before the fMRI examination, we took digital photographs of each participant's whole body against a monotone, light-colored background. The participant wore a white T-shirt and blue jeans and was in the standing position. We changed the width of the image from −25 to +25% of the width of the original, using Paint Shop Pro Version 8.02 (Jasc Software, Inc., Eden Prairie, Minnesota), thereby obtaining 10 distorted images with different degrees of thinness or fatness. Body-image stimuli fell into one of two categories: participant's own body image (self body image) or another healthy woman's body image (other body image). For each participant, we used the following images: undistorted original image, fat-body images (width at +5, +10, +15, +20, or +25% of the original width), undistorted original image with a black cross on the body, and thin-body images (width at −5, −10, −15, −20, or −25% of the original width). Using these distorted and original images, we created image sets which consisted of three types of image pair for each category: 1) pairs consisting of a fat-body image ("gaining weight" image) and a real image (undistorted original image); 2) pairs consisting of a real image and a real-image with a black cross; and 3) pairs consisting of a thin-body image ("losing weight" image) and a real image (see Fig. 1a).

We used a block-designed fMRI paradigm that consisted of six different blocks across two task conditions (self body-image task condition and other body-image task condition): self fat-image, self real-image, self thin-image, other fat-image, other real-image, and other thin-image (Fig. 1b). Presentation order of the self and other tasks was counterbalanced. Each block began with a 3-s cue that indicated "TASK1", "CONTROL", or "TASK2". Five image sets were presented in each block. Each image set was shown for 5 s, with a 1-s interstimulus interval (ISI). Six different blocks were presented in one cycle. Our paradigm consisted of three cycles (Fig. 1c). The blood oxygen level-dependent (BOLD) response was recorded during the six task blocks. During each ISI, a fixation-cross placed centrally on the screen replaced the image set. Baseline fMRI was obtained during a 9-s interval before the first block of trials, during which the participant viewed a centrally placed fixation-cross. During each trial, the image set was projected to the center of the participant's field of view by a Super Video Graphics adapter computer-controlled projection system. Presentation timing of the image sets was controlled by Presentation Software Version 0.76 (Neurobehavioral Systems, Inc., San Francisco, CA). The image sets were presented in a random order, with presentation order counterbalanced.

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