

Visual Information Processing of Faces in Body Dysmorphic Disorder

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Context: Body dysmorphic disorder (BDD) is a severe psychiatric condition in which individuals are preoccupied with perceived appearance defects. Clinical observation suggests that patients with BDD focus on details of their appearance at the expense of configural elements. This study examines abnormalities in visual information processing in BDD that may underlie clinical symptoms.

Objective: To determine whether patients with BDD have abnormal patterns of brain activation when visually processing others' faces with high, low, or normal spatial frequency information.

Design: Case-control study.

Setting: University hospital.

Participants: Twelve right-handed, medication-free subjects with BDD and 13 control subjects matched by age, sex, and educational achievement.

Intervention: Functional magnetic resonance imaging while performing matching tasks of face stimuli. Stimuli were neutral-expression photographs of others' faces that were unaltered, altered to include only high spatial frequency visual information, or altered to include only low spatial frequency visual information.

Main Outcome Measure: Blood oxygen level-dependent functional magnetic resonance imaging signal changes in the BDD and control groups during tasks with each stimulus type.

Results: Subjects with BDD showed greater left hemisphere activity relative to controls, particularly in lateral prefrontal cortex and lateral temporal lobe regions for all face tasks (and dorsal anterior cingulate activity for the low spatial frequency task). Controls recruited left-sided prefrontal and dorsal anterior cingulate activity only for the high spatial frequency task.

Conclusions: Subjects with BDD demonstrate fundamental differences from controls in visually processing others' faces. The predominance of left-sided activity for low spatial frequency and normal faces suggests detail encoding and analysis rather than holistic processing, a pattern evident in controls only for high spatial frequency faces. These abnormalities may be associated with apparent perceptual distortions in patients with BDD. The fact that these findings occurred while subjects viewed others' faces suggests differences in visual processing beyond distortions of their own appearance.

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BODY DYSMORPHIC DISORDER (BDD) is a severe psychiatric condition in which patients are preoccupied with perceived physical defects. This causes them to believe that they appear disfigured and ugly. They subsequently experience significant distress, disability, and functional impairment, often accompanied by severe depression and suicidality.¹ Body dysmorphic disorder likely affects about 1.7% of the population² yet is understudied and underrecognized.

A better understanding of the neurobiology of BDD could assist in elucidating the pathophysiology underlying the clinical symptoms. This, in turn, can help improve strategies for clinical management. Little is known about the neurobi-

ology of BDD. To our knowledge, only 2 brain imaging studies of BDD have been published. A volumetric magnetic resonance imaging study³ found leftward shift in caudate asymmetry and greater total white matter volume in 8 women with BDD compared with 8 female control subjects, opposite to typical findings in obsessive-compulsive disorder (OCD).^{4,5} Using single-photon emission computed tomography, a small functional imaging study⁶ of 6 patients with BDD showed variable discrepant findings, including relative perfusion deficits in bilateral anteromedial temporal and occipital regions and asymmetric perfusion in parietal lobes. Although this study had no control or comparison group, the findings suggest the possibility of abnormalities in brain re-



Figure 1. Face stimuli. HSF indicates high spatial frequency; LSF, low spatial frequency; and NSF, normal spatial frequency. (On reproduction, the HSF image in this figure lost some of the detail that was visible in the experiment.)

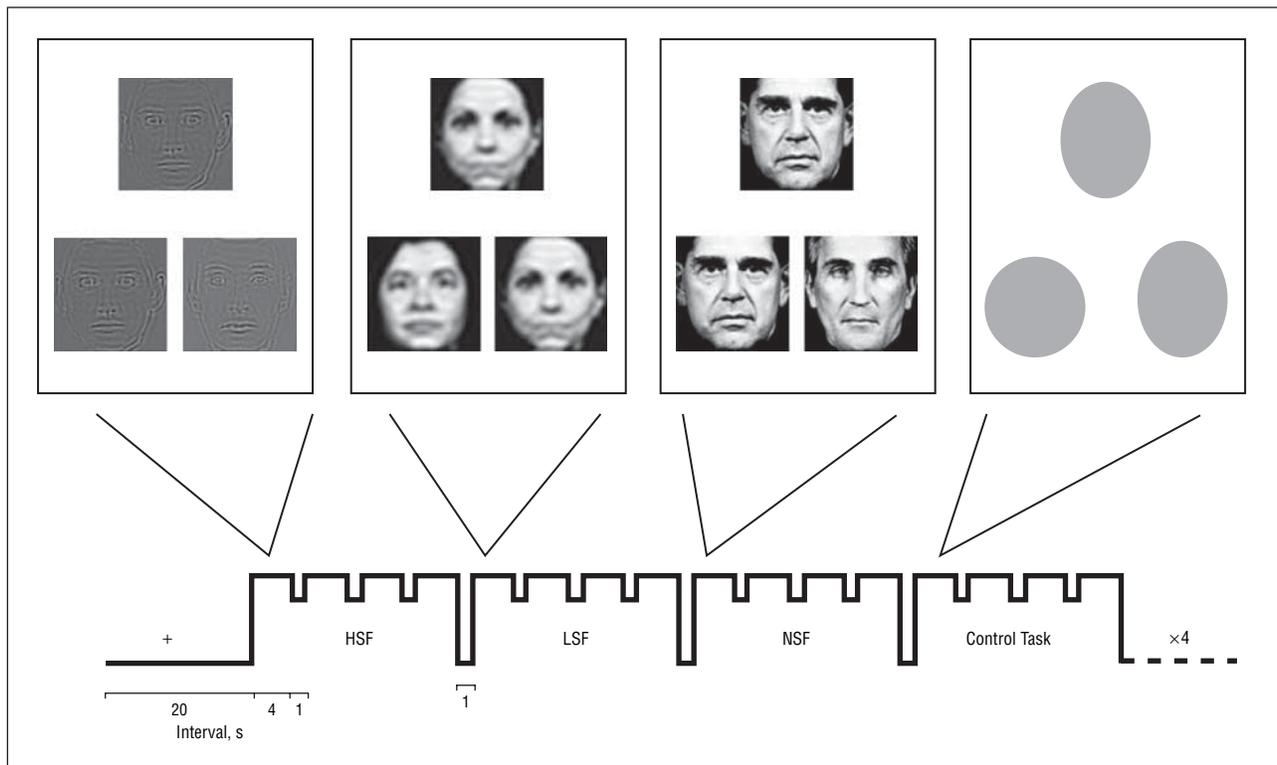


Figure 2. Blocked design for the presentation of face and control stimuli. HSF indicates high spatial frequency; LSF, low spatial frequency; and NSF, normal spatial frequency. Between subjects, differently ordered runs were counterbalanced using a Latin square design.

gions involved in visual processing and visuospatial functioning.

Clinically, patients with BDD most often perceive “defects” of their face and head areas.⁷ They tend to frequently check their appearance in mirrors and often scrutinize others’ faces. Clinical observation suggests that patients with BDD focus primarily on details, usually their face, at the expense of global or configural aspects. A neuropsychological study⁸ using the Rey-Osterrieth Complex Figure Copy and Delayed Recall Test demonstrated that patients with BDD performed poorly relative to controls because of differences in organizational strategies, including selective recall of details instead of larger organizational design features. The phenomenology of BDD and the

findings from this neuropsychological study suggest that patients with BDD may have aberrant visual information processing. If so, this may represent a core pathophysiological process contributing to the symptoms.

Evidence also suggests that individuals with BDD may have abnormalities in face processing. In a study⁹ that presented computerized images of their own faces to subjects with BDD, subjects with OCD, and healthy control subjects, half of the BDD and OCD groups but none of the controls perceived distortions that were not actually present. There is also evidence of abnormal processing of emotional faces in BDD. Buhlmann et al¹⁰ examined how patients with BDD interpret facial expressions compared with healthy controls and a group having OCD.

There were no differences in accuracy between groups in general facial feature recognition for neutral-expression faces. However, individuals with BDD had difficulty interpreting facial expressions, more often misidentifying faces as being angry. Although this may indicate abnormalities specifically in emotional recognition, it may also reflect abnormalities in an earlier component of the core system for visual analysis that is required for facial expression analysis.^{11,12}

Face perception in healthy control subjects seems to be mediated by multiple regions in the extrastriate visual cortex and other nonvisual cortex regions that form a distributed network.¹¹ The inferior occipital gyri, responsible for early perception of facial features, provides input to the superior temporal sulcus (changeable aspects of faces such as expressions) and the lateral fusiform gyrus (invariant aspects of faces).^{11,12} Functional neuroimaging of face-matching tasks has demonstrated activity in the ventral occipitotemporal and dorsolateral occipitoparietal cortices, as well as prefrontal and temporal regions.¹³⁻¹⁵

This study aimed to determine whether patients with BDD have a different pattern of brain activation from that of healthy control subjects for different spatial frequencies when viewing faces. Using others' faces rather than their own allows for testing of primary visual processing abnormalities while minimizing the influence of distorted self-representations and symptom provocation. To our knowledge, no functional imaging studies have tested the patterns of visual information processing in patients with BDD or compared patients with BDD with control subjects.

Detailed analysis of facial traits such as edges depicting contours of the nose, eyes, eyelashes, skin blemishes, and exact shape of the mouth relies on fine spatial resolution and texture analysis, which is conveyed by high spatial frequency (HSF) visual information.^{16,17} Configural aspects of faces (ie, spatial relationships between facial features such as the relative position of the eyes to the mouth and the general shape of the face¹⁸) are primarily conveyed by low spatial frequency (LSF) visual information.^{19,20} Previous functional magnetic resonance imaging (fMRI) studies^{21,22} in healthy control subjects demonstrated distinct neural pathways that process HSF vs LSF information. High spatial frequency visual information is projected via parvocellular channels primarily to the ventral cortical stream.^{23,24} Low spatial frequency visual information is projected via magnocellular channels to the dorsal cortical stream and provides rapid coarse visual signals.²⁵ Matching tasks in which faces are digitally filtered to produce HSF or LSF have been used to investigate mechanisms of visual processing in healthy control subjects^{26,27} and to identify abnormalities in configural processing in autism.²⁸ We designed 3 sets of facial-matching tasks using digitized photographs of faces that were altered to include only HSF, LSF, or normal spatial frequency (NSF). We used fMRI to identify the functional neuro-anatomical correlates of visual processing during the presentation of visual stimuli. We hypothesized that the BDD group would demonstrate abnormal functioning of the dorsal or ventral visual streams. Specifically, relative to control subjects, they may process faces using ventral visual pathways to a greater degree than dorsal

visual pathways, as reflected by their apparent visual bias for high levels of detail.

METHODS

SUBJECTS

The UCLA Institutional Review Board approved the protocol for the study. We obtained informed consent from 12 subjects with BDD and 13 healthy control subjects (age range, 18-64 years) recruited from the community. The BDD group and controls were matched by sex, age, and educational achievement. All participants were right-handed. All subjects with BDD met DSM-IV criteria for BDD using the Body Dysmorphic Disorder Module,²⁹ a reliable diagnostic module modeled after the Structured Clinical Interview for DSM. In addition, we performed a clinical psychiatric evaluation of all participants and screened them using the Mini-International Neuropsychiatric Interview.³⁰ All subjects with BDD were required to have a score of at least 15 on the BDD version of the Yale-Brown Obsessive Compulsive Scale (BDD-YBOCS).³¹ We allowed subjects with delusional beliefs.

Exclusion criteria for subjects and controls included pregnancy, active substance abuse, current neurological disorder, and any current medical disorder that may affect cerebral metabolism. We excluded subjects with any concurrent Axis I disorder other than dysthymia, major depressive disorder, or generalized anxiety disorder. Because depression and anxiety are so frequently comorbid in this population, we believed it would not be a representative sample if we excluded these. However, we excluded subjects with a score higher than 20 on the 17-item Hamilton Depression Rating Scale (HDRS)³² and subjects whom the investigator (J.D.F.) judged were suicidal. In addition to the BDD-YBOCS and the HDRS, we administered the Hamilton Anxiety Scale (HAMA)³³ to all subjects.

We determined handedness using the Edinburgh Handedness Inventory.³⁴ All participants were free from psychoactive medications for at least 3 weeks before entering the study and were free of fluoxetine hydrochloride for at least 5 weeks. Subjects were not receiving any cognitive behavior therapy. All participants had normal or corrected vision.

STIMULI

We used digitized gray-scale photographs of male and female faces. The faces, validated for neutral emotional expression, came from the Macbrain database,³⁵ the University of Pennsylvania Facial Emotional Stimuli,³⁶ and the Psychological Image Collection at Stirling (<http://pics.psych.stir.ac.uk/>). We Fourier transformed these 256 × 256-pixel photographs using Scion Imaging Software (<http://www.scioncorp.com>). Next, we deleted the central 30 × 30 pixels of the transformed images for the high-pass filtered images and deleted all but the central 30 × 30 pixels for the low-pass filtered images.²¹ We then inversely Fourier transformed these images to create each of the final high-pass or low-pass filtered images. A *high-pass filter* creates images that contain only HSF information. A *low-pass filter* creates images that contain only LSF information. In addition, we used unaltered photographs (NSF) of the same size (**Figure 1**). Three different categories of faces (NSF, HSF, and LSF) comprised the tasks (**Figure 2**). The control condition consisted of gray ovals and circles approximately the same size as the faces. We used commercially available software (MacStim 3.0; White Ant Occasional Publishing, West Melbourne, Australia) to program the stimuli presentation and to record accuracy and reaction time.

Table 1. Demographics and Psychometric Scores^a

Variable	BDD Group (n=12)	Control Group (n=13)	P Value
Age, y	28.7±10.0	31.3±11.3	.54
Female-male ratio	10:2	11:2	.75 ^b
Educational achievement, y	15.5±2.9	15.8±1.4	.78
BDD version of the Yale-Brown Obsessive Compulsive Scale score	28.7±7.0	0.46±0.97	<.001
Hamilton Depression Rating Scale score	8.58±5.74	0.77±1.01	<.001
Hamilton Anxiety Scale score	12.67±9.76	1.46±1.61	.002

Abbreviation: BDD, body dysmorphic disorder.

^aData are given as mean±SD unless otherwise indicated. All subjects were right-handed.

^b χ^2 Test; *t* test for all others.

TASK

The face-matching task is a forced-choice, 2-alternative test of face perception. Subjects matched digital photographs of unfamiliar emotionally neutral faces of others. The control task consisted of matching ovals and circles. In each task, the subject viewed 3 faces, including the target face on top and 2 comparison faces on the bottom. We instructed subjects to "Choose the face on the bottom that is the same face as the one on the top, by pressing the right or the left button. Make your selection as rapidly and as accurately as possible." Each set of faces appeared on the screen for 4 seconds, with a 1-second interstimulus interval. The task was designed to be easy enough that it would be unlikely to result in behavioral differences between groups.

Each block consisted of 4 sets of the same type of faces that were NSF, HSF, or LSF or the control task. Each set of 4 blocks (A-B-C-control) was repeated 4 times in each run (Figure 2). The total time for each run was 6 minutes and 20 seconds. There were 2 runs, with the second run presented in a different order. Between subjects, the differently ordered runs were counterbalanced using a Latin square design to avoid possible order effects. Subjects wore fMRI-compatible goggles to view the stimuli. If subjects wore eyeglasses, appropriate corrective lenses for the goggles were used. After each run, subjects rated their anxiety level during the tasks on a Likert-type scale of 0 (none) to 10 (high).

FUNCTIONAL MAGNETIC RESONANCE IMAGING

We used a 3-T MRI system (Allegra; Siemens AG, Munich, Germany) to evaluate blood oxygenation level-dependent contrast using T2-weighted echoplanar imaging gradient-echo pulse sequence (repetition time, 2.5 seconds; echo time, 35 milliseconds; flip angle, 90°; acquisition matrix, 64×64 pixels; field of view, 24×24 cm; inplane voxel size, 3.75×3.75 mm; section thickness, 3 mm; 1-mm intervening spaces; and 28 total sections). There were 151 whole-brain images per subject per run and 302 whole-brain images per experiment. We also obtained high-resolution T1-weighted images for each subject to provide detailed brain anatomy during structural image acquisition.

STATISTICAL ANALYSIS

For behavioral data, we used 2-way analysis of variance for reaction times and accuracy rates, with 1 group factor (BDD group

vs controls) and 1 repeated-measures factor (task condition) to determine differences between groups. For anxiety levels, 2-sample *t* test was used to compare mean subjective anxiety scores between groups.

For functional neuroimaging data, we used software (fMRI Expert Analysis Tool version 5.4) from the Oxford Centre for Functional Magnetic Resonance Imaging of the Brain Software Library (FSL) (<http://www.fmrib.ox.ac.uk/fsl>). Image processing included motion correction, skull stripping, spatial smoothing of 5-mm full width at half maximum gaussian kernel, mean-based intensity normalization of all volumes by the same factor, high-pass temporal filtering, and registration to standard space. We coregistered functional neuroimages of each subject to corresponding structural images in native space and registered structural images to structural Talairach and Tournoux standard images, approximated by the Montreal Neurological Institute standard brain supplied with FSL.

For within-group analyses, we performed a random-effects analysis in FSL with subjects as the random factor to identify typical patterns of brain activity in subjects with BDD and in control subjects. We modeled the hemodynamic response function by performing a simple convolution of the blocked experimental paradigms of each condition vs the control task using the canonical hemodynamic response function and its temporal derivative.³⁷ To determine the patterns of activation in the BDD group and in the control group, we analyzed the normalized data with multiple regression by using 3 regressors to model hemodynamic changes associated with the HSF, LSF, and NSF tasks, each contrasted to the control task (matching ovals and circles) as follows: contrast 1, NSF vs control task; contrast 2, HSF vs control task; and contrast 3, LSF vs control task.

Model fitting generated whole-brain images in native space of parameter estimates and corresponding variance, representing the mean signal change during each particular contrast. We used the FSL Improved Linear Model for time-series statistical analysis, with local autocorrelation correction.³⁸ We thresholded *z* score images using clusters determined by $z > 2.0$ and a (corrected) cluster significance threshold of $P = .05$.³⁹

For between-group analyses, we directly compared the BDD and control groups using a voxelwise mixed-effects analysis in FSL. After we performed the within-group analyses, we used only stage 1 of the FSL Local Analysis of Mixed Effects.^{40,41} We thresholded *z* score images using clusters determined by $z > 2.0$ and a (corrected) cluster significance threshold of $P = .05$.³⁹ A 2-sample paired *t* test identified group mean differences in activity at each voxel.

To investigate the relationship between symptom severity and regional brain activation, we entered results from the first-level (within group) analysis into a second-level analysis. In this analysis, demeaned BDD-YBOCS, HAMA, and HDRS scores were separate covariates of interest.

RESULTS

CHARACTERISTICS OF THE BDD GROUP

Table 1 summarizes the demographic and psychometric data for both groups. The mean±SD BDD-YBOCS score was 28.7±7.0. In addition to BDD, 1 subject had comorbid major depressive disorder, 1 had dysthymic disorder, 2 had generalized anxiety disorder, and 2 had both major depressive disorder and generalized anxiety disorder. The BDD symptoms were the primary concern in every subject. Typical of this population, all 12 subjects had preoccupations with perceived facial defects. Eight subjects had concerns solely about facial features, and 4 subjects had face and non-

Table 2. Accuracy Rates on the Face-Matching Tasks^a

Task	Accuracy, %	
	BDD Group	Control Group
NSF faces	99.5 ± 1.2	99.7 ± 0.9
LSF faces	99.2 ± 1.4	98.2 ± 3.1
HSF faces	97.9 ± 3.1	95.8 ± 9.0
Control task	99.7 ± 0.9	99.2 ± 1.9
Total experiment	99.1 ± 1.9	98.2 ± 4.9

Abbreviation: BDD, body dysmorphic disorder; HSF, high spatial frequency; LSF, low spatial frequency; NSF, normal spatial frequency.

^aData are given as mean ± SD, with 2-way analysis of variance with 1 repeated-measures factor: group effect: $F_{1,23}=1.09$, $P=.31$; task effect: $F_{3,72}=2.96$, $P=.04$; and group × task effect: $F_{3,72}=0.45$, $P=.72$.

face concerns. Four subjects had concerns solely about details (skin blemishes, wrinkles, and others), and 8 subjects had concerns about both details and configuration (comparative size of features, shape, symmetry, and others). The mean ± SD subjective anxiety levels during the task were not statistically significantly different between the BDD group and the control group (3.83 ± 2.25 and 3.92 ± 1.68 , respectively; $P=.92$).

BEHAVIORAL DATA

Accuracy rates were high (**Table 2**). There were no statistically significant group effects ($P=.31$) or group × task effects ($P=.72$), although there was a statistically significant effect of task ($P=.04$).

For reaction times, there was no main effect of group ($P=.86$) or group × task ($P=.40$). Again, there was a statistically significant effect of task ($P<.001$) (**Figure 3**).

fMRI DATA

Within-Group Analysis

For all tasks, the subjects with BDD and the control subjects activated bilateral extrastriate visual cortex (Brodmann area [BA] 18) and bilateral fusiform gyrus.

For the HSF task, the BDD group also activated right inferior (BAs 44 and 45) and middle frontal (BA 45) gyri, as well as left inferior (BAs 44 and 47) and middle frontal (BA 9) gyri. There was also activation in bilateral hippocampi and parahippocampi, bilateral cingulate gyrus (BA 32), right inferior parietal lobule (BA 7), and right precuneus (BA 19). The control group also activated bilateral inferior (BAs 44 and 45) and middle frontal (BA 9) gyri. They activated bilateral hippocampi and parahippocampi, right cingulate (BA 32), right superior frontal gyri (BA 8), bilateral inferior parietal lobule (BA 7), and bilateral precuneus (BA 19).

For the LSF task, the BDD group activated the right inferior (BAs 44, 45, and 47) and middle (BA 9) frontal gyri. They also activated the left inferior (BAs 6 and 47) and middle (BAs 8 and 9) frontal gyri, as well as the left insula (BA 13). The control group activated the right inferior frontal gyrus (BAs 44, 45, and 46) and the right hippocampus.

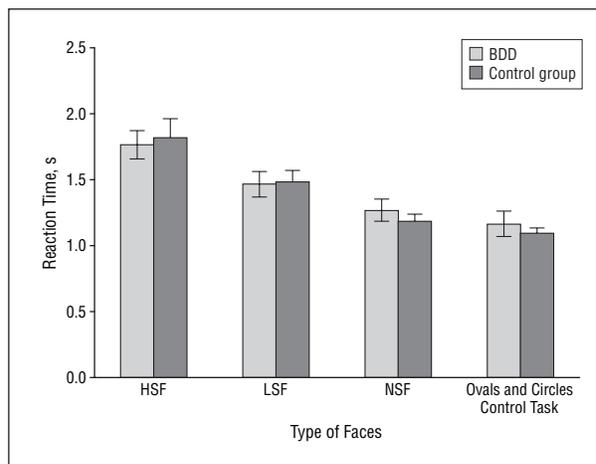


Figure 3. Mean reaction times for the body dysmorphic disorder (BDD) and control groups by task (2-way analysis of variance with 1 repeated-measures factor): group effect: $F_{1,23}=0.03$, $P=.86$; task effect: $F_{3,72}=70.67$, $P<.001$; and group × task effect: $F_{3,72}=1.00$, $P=.40$. HSF indicates high spatial frequency; LSF, low spatial frequency; and NSF, normal spatial frequency.

Table 3. Regions of Greater Brain Activation for the Body Dysmorphic Disorder (BDD) Group Compared With the Control Group, by Face Task and Contrast

Brain Region	z Score ^a	MNI
NSF vs Control Task		
Left superior temporal gyrus (BA 22)	3.44	-62, 8, 2
Left inferior frontal gyrus (BA 47)	3.42	-54, 18, -2
Left insula	2.81	-30, 18, -6
Left superior temporal gyrus (BA 38)	2.67	-44, 22, -20
LSF vs Control Task		
Left inferior parietal lobule (BA 40)	3.97	-36, -36, 54
Left inferior frontal gyrus (BA 44)	3.83	-42, 2, 32
Left superior temporal gyrus (BA 22)	3.79	-60, 8, 0
Right precentral gyrus (BA 6)	3.41	56, -2, 36
Right superior frontal gyrus (BA 8)	3.33	24, 14, 50
HSF vs Control Task		
Left middle temporal gyrus (BA 21)	3.66	-56, 10, -20
Left inferior temporal gyrus (BA 37)	3.21	-60, -48, -16

Abbreviations: BA, Brodmann area; HSF, high spatial frequency; LSF, low spatial frequency; MNI, Montreal Neurological Institute stereotactic space (an approximation of Talairach space⁴²); NSF, normal spatial frequency.

^aLocal maximum z scores.

For the NSF task, the BDD group activated bilateral inferior (BAs 44 and 45) and middle (BA 9) frontal gyri and the left precentral gyrus (BA 6). The control group activated the right inferior frontal gyrus (BAs 44 and 45).

Between-Group Analysis

For the HSF task, the BDD group showed statistically significant left middle (BA 21) and inferior (BA 37) temporal gyri activation relative to the control group (**Table 3**, and **Figure 4**). The control group did not demonstrate any regions of greater activation than the BDD group.

For the LSF task, the BDD group activated the left intraparietal sulcus (BA 40), the left inferior frontal gyrus (BA 44), and the left superior temporal gyrus (BA 22) to

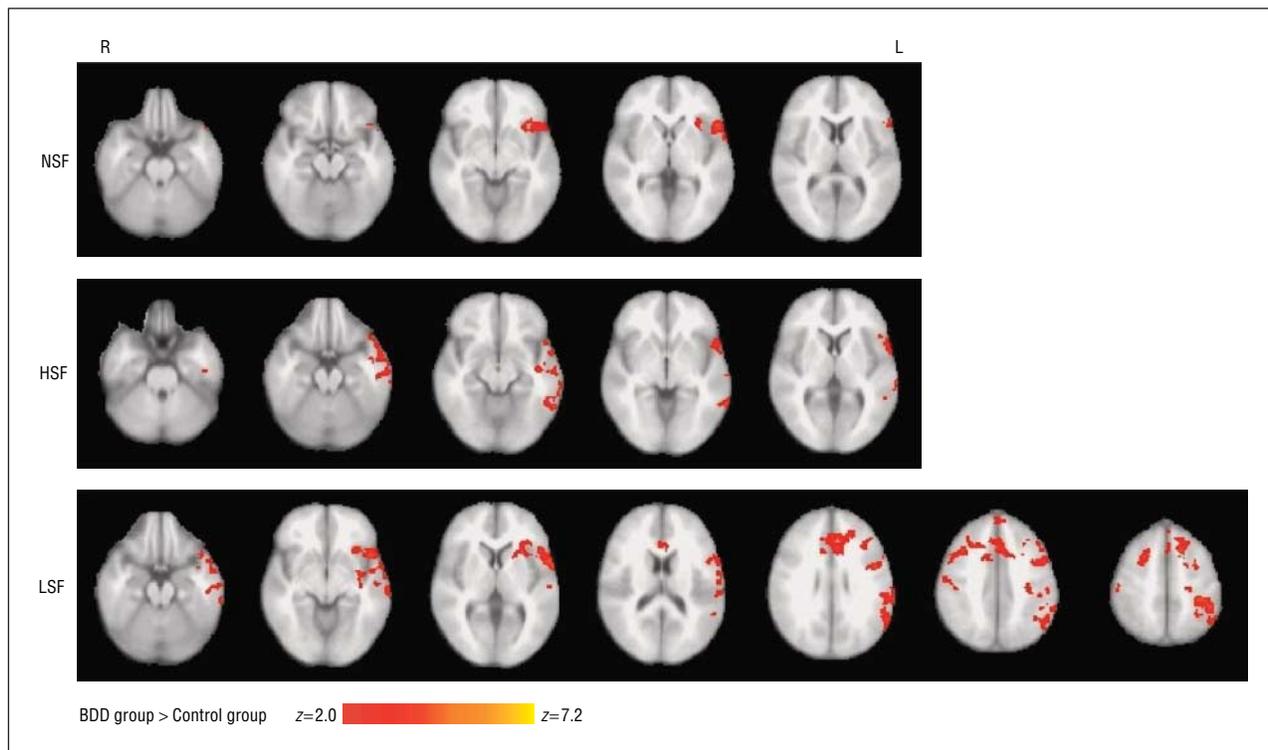


Figure 4. Parametric maps of statistically significant activation between groups for high spatial frequency (HSF), low spatial frequency (LSF), and normal spatial frequency (NSF) face tasks, all contrasted to the control task of matching ovals and circles. For simplicity, only representative axial sections are shown. The red spectrum indicates regions for which the body dysmorphic disorder (BDD) group showed greater activation than the control group. Presented in radiologic convention (the right hemisphere on the left and the left hemisphere on the right). L indicates left; R, right.

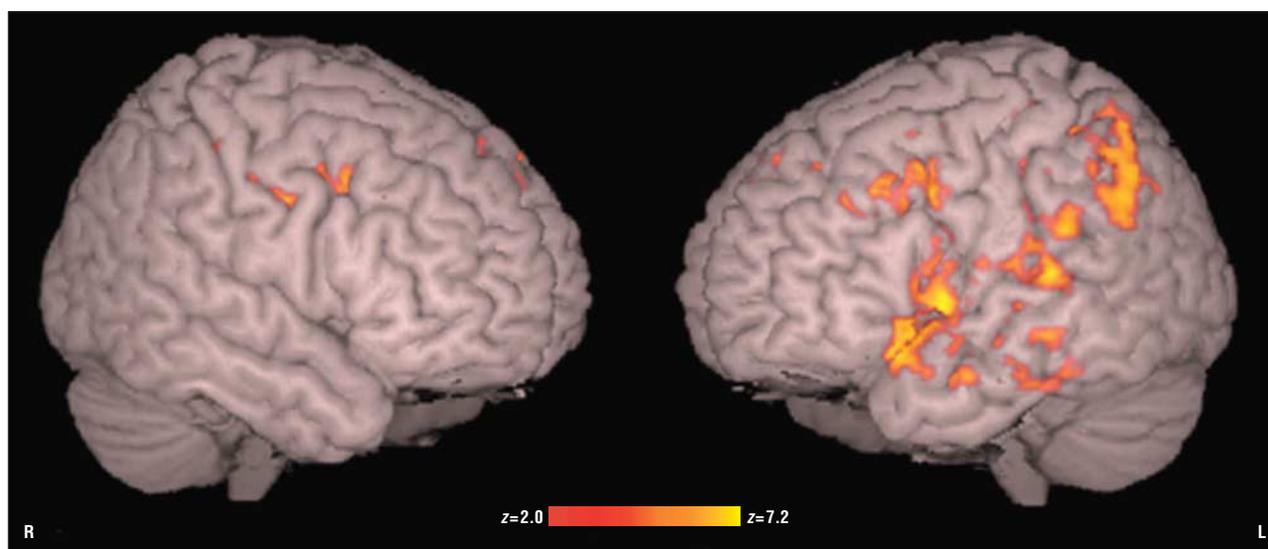


Figure 5. Three-dimensional representation of statistically significant regions of greater brain activation for the subjects with body dysmorphic disorder compared with control subjects for low spatial frequency faces projected on an individual high-resolution volume scan (mri3dX software [<http://www.aston.ac.uk/lhs/staff/singhkd/mri3dX/mri3dX.jsp>]). L indicates left; R, right.

a greater degree than controls. They also activated right precentral (BA 6) and postcentral (BA 1) gyri, as well as the right superior (BA 8) and middle (BA 6) frontal gyri and bilateral dorsal anterior cingulate (BA 32) to a greater degree than controls (Table 3, Figure 4, and **Figure 5**). The control group again did not demonstrate any regions of greater activation compared with the BDD group.

For the NSF task, the BDD group activated the left superior temporal gyrus (BAs 22 and 38), the left inferior frontal gyrus (BA 47), and the left insula to a greater degree than the control group (Table 3 and Figure 4). The control group showed greater activation of bilateral cuneus (BAs 18 and 19) and the left middle occipital gyrus (BA 19) (**Table 4**).

Table 4. Regions of Greater Brain Activation for the Control Group Compared With the Body Dysmorphic Disorder (BDD) Group, by Face Task and Contrast

Brain Region	z Score ^a	MNI
NSF vs Control Task		
Left cuneus (BA 18)	3.43	-6, -74, 16
Right cuneus (BA 19)	2.83	22, -88, 22
Left middle occipital gyrus (BA 19)	2.99	-24, -86, 6

Abbreviations: BA, Brodmann area; MNI, Montreal Neurological Institute stereotaxic space (an approximation of Talairach space⁴²); NSF, normal spatial frequency.

^aLocal maximum z scores.

CORRELATION WITH SYMPTOM SEVERITY AND POST HOC ANALYSIS

There were no statistically significant correlations between BDD-YBOCS, HAMA, or HDRS scores and activations in any regions.

The within-group activation maps indicated statistically significant bilateral amygdala activation for the NSF task for both groups. Because of its relevance for face processing and its small size, we performed a post hoc anatomical region-of-interest analysis of the amygdala to better characterize its activation pattern. Statistically significant activations included a mean \pm SEM 0.61% \pm 0.14% signal change in the BDD group vs a mean \pm SEM -0.06% \pm 0.15% signal change in the control group for the right amygdala for the LSF task ($t=3.26$, $P=.003$; 2-sample t test, 2-tailed), as well as a mean \pm SEM 0.53% \pm 0.12% signal change in the BDD group vs a mean \pm SEM -0.12% \pm 0.23% signal change in the control group for the HSF task ($t=2.4$, $P=.03$) (Figure 6). For the left amygdala, there were similar but statistically nonsignificant trends for the HSF ($P=.08$) and LSF ($P=.14$) tasks. Differences between groups for the NSF task were statistically nonsignificant for the right ($P=.57$) and left ($P=.31$) amygdala.

Correlation analyses revealed no statistically significant correlations between amygdala activity and subjective anxiety, BDD-YBOCS, HAMA, or HDRS scores.

COMMENT

These results suggest that subjects with BDD differ fundamentally from control subjects in their patterns of visual processing of faces. The BDD group demonstrated more left-sided activations in lateral aspects of the prefrontal and temporal cortices for all tasks, as well as dorsal anterior cingulate activity for the LSF task. The control group demonstrated this pattern only for the HSF task, suggesting that subjects with BDD use a similar network for processing NSF and LSF faces that control subjects use only for HSF faces. These laterality patterns suggest a bias for local, or detail, processing over global processing of faces for subjects with BDD. In addition, the BDD group showed abnormal activation of the amygdalae for HSF and LSF face tasks. We did not find differences in early ventral or dorsal visual stream regions

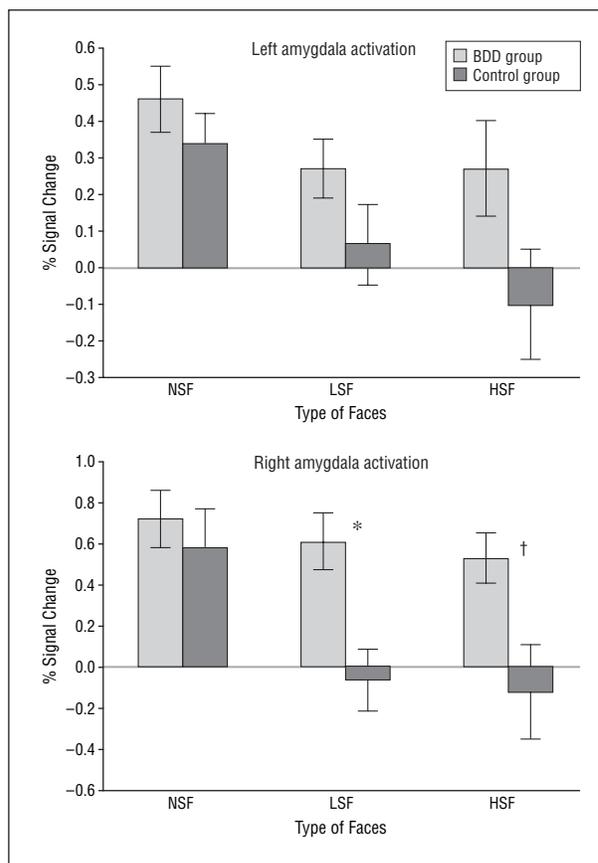


Figure 6. Mean \pm SEM percentage signal change in the right and left amygdala for the body dysmorphic disorder (BDD) and control groups by task contrast: NSF (normal spatial frequency) vs control task, LSF (low spatial frequency) vs control task, and HSF (high spatial frequency) vs control task. There were statistically significant different mean activations in the right amygdala for the *LSF task ($t=3.26$, $P=.003$) and for the †HSF task ($t=2.4$, $P=.03$).

as hypothesized; rather, the differences found are in regions that may represent later stages of visual processing or top-down effects.

LATERALITY

A major difference in the BDD group relative to the control group was the predominance of left-sided activations in frontal, temporal, and parietal regions for all face tasks. This was evident for the within-group and between-group comparisons. Previous studies^{14,15} showed that a network of lateral prefrontal, temporal, and occipital regions is involved in face-matching tasks. Haxby et al,¹⁵ using a similar forced-choice face-matching task, found primarily right-sided inferior frontal gyrus activation, bilateral occipital activation, and bilateral ventral temporal activation (with more extensive right-sided activations).

In the present study, the control group demonstrated right predominance, while the BDD group demonstrated left-predominant activation patterns in lateral aspects of the middle and inferior prefrontal cortex for the LSF and NSF tasks. In general, the left hemisphere subserves analytic (or local) processing, while the right hemisphere dominates for holistic (or global) process-

ing.⁴³⁻⁴⁵ These left prefrontal activations, recruited by control subjects only for the HSF faces, suggest that subjects with BDD were using a more detailed and piecemeal analysis for matching these face types. Conversely, the predominantly right-sided prefrontal activations for the control group suggest that they were processing more holistically or configurally for the LSF and NSF faces.⁴⁶ These results are consonant with results from the neuropsychological study⁸ in BDD that found selective recall of details at the expense of configural elements for a non-face visuospatial task. Similar findings for the same task were demonstrated in OCD⁴⁷ and in anorexia nervosa,⁴² suggesting a relationship between these disorders.

Other face-matching studies^{46,48-50} that have manipulated difficulty levels or introduced a working memory component have shown shifts in laterality from right to left in extended networks involved in face matching, interpreted as a change from a perceptually based processing strategy to one based more on elaboration and analytic encoding. However, because the present study was not specifically a working memory task, it remains speculative whether the BDD group was using similar cognitive strategies.

The greater activity in the dorsal anterior cingulate gyrus for the LSF task among the BDD group may be an indication of selective attention and modulation of activity in the extrastriate cortices.⁵¹ This suggests attempts to focus attention on details even for LSF faces.

AMYGDALA ACTIVATION PATTERNS

Another finding of note is the BDD group's abnormal activation of bilateral amygdala for the LSF and HSF face tasks. In contrast, the control group showed bilateral activation of the amygdala for the NSF task but showed reduced activity or deactivation for the LSF and HSF tasks (Figure 6). Previous studies^{52,53} demonstrated that the amygdala responds to neutral facial expressions in addition to emotional faces. In the present study, subjects with BDD and control subjects rated their task-related anxiety as equally low, and anxiety did not correlate with amygdala activation. In addition, amygdala activation did not correlate with any symptom severity scores. We did not record emotional arousal or aversiveness ratings among participants for each face, as this was not specifically part of our a priori hypothesis. Because of this lack of behavioral data, the significance of the abnormal amygdalae activation is unclear, although it seems to be specific to HSF and LSF faces.

VISUAL CORTEX ACTIVATION PATTERNS

The only contrast in which the control subjects activated regions to a greater extent than the subjects with BDD was for the NSF faces. The control group demonstrated greater activation in the left middle occipital gyrus and bilateral cuneus, part of the primary and secondary visual cortex.

BEHAVIORAL DATA

There were no statistically significant differences between the groups in reaction times or accuracy rates

(Table 2 and Figure 3). The similarity in behavioral performance suggests that different brain activation patterns reflect different cognitive strategies between groups, producing the same end result.

There was a statistically significant effect of task, with the following order of reaction times: HSF, LSF, NSF, and control task. This is consonant with the observation that HSF information is processed more slowly than LSF information,⁵⁴ and both are processed more slowly than NSF information.²²

CLINICAL IMPLICATIONS

These findings likely have clinical correlates in patients with BDD. The finding of greater left hemisphere activations suggests that subjects with BDD may rely more on extraction and processing of details. Subjects with BDD may process faces in a piecemeal manner, while perception of faces by healthy control subjects may be more configural and holistic.

Clinically, patients with BDD often report honing in on details of their appearance features that they perceive are defective. They also frequently check appearance features of others to compare with their own.⁷ If they are less able to visualize faces holistically and configurally, their perception of appearance will remain different from that of others. Individuals with BDD may implicitly assume that everyone else is as detail biased as they are in their perception of appearance. This could contribute to the extreme self-consciousness and ideas of reference⁵⁵ that they often experience. Future studies are important to test if the abnormalities that may underlie a detail bias found in this study also exist for processing subjects' own faces.

Another question that arises is whether abnormalities in visual processing among patients with BDD occur exclusively for faces or whether they may also be operating when processing nonhuman stimuli. Future studies would be important to test visual processing for objects (eg, to establish if these abnormalities are specific to faces or are generalized to other stimuli as well). This could help establish whether these visual processing abnormalities are occurring earlier in the visual processing stream or are associated with later top-down processing that may relate to allocation of attentional resources to pertinent appearance-related stimuli.

LIMITATIONS

One of the limitations of this study was the small sample size. This may have resulted in insufficient power to detect smaller-magnitude differences in activations (eg, in occipital and fusiform regions). Another limitation in these subjects is the narrow range of severity of BDD, which likely did not provide enough variance to allow for a meaningful correlation analysis of symptom severity with brain activation. In addition, the absence of subjects' ratings of emotional valence for the faces hindered interpretation of the amygdala activation results. Future larger studies are needed that record emotional valence ratings for each task and that include subjects who have a range in severity from milder subsyndromal symptoms to severe BDD.

CONCLUSIONS

These results suggest that subjects with BDD may have fundamental abnormalities in an extended visual processing network. Because this experiment used others' faces and not subjects' own, these differences are not just limited to how patients with BDD process and perceive their own appearance. Abnormal visual processing represents an underlying pathophysiological process that may contribute to the symptoms in BDD. Additional research is important to further this line of inquiry for this little-studied disorder.

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