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Using theories of delusion formation to explain abnormal beliefs in Body Dysmorphic Disorder (BDD)

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ABSTRACT

Body Dysmorphic Disorder (BDD) is characterised by overvalued or delusional beliefs of 'imagined ugliness'. Delusional beliefs have been explained by a number of cognitive theories, including faulty perceptions, biases in attention, and corruption of semantic memory. Atypical aesthetics may also influence beliefs in BDD. In fourteen BDD patients, compared to controls ($n=14$), we examined these theories of beliefs in a cognitive test battery consisting of perceptual organisation and visual affect perception tasks, a Stroop task using body words, a sentence verification task, a fluency task, and an attractiveness task. BDD patients performed similar to controls on tasks measuring information (bias) processing and aesthetics. However, BDD showed abnormal abilities on semantic processing involving sentence verification and category fluency. There was only a trend finding of impaired performance on perceptual processing tasks in BDD. The findings suggest that the delusional beliefs in BDD may be explained by impaired semantic processing.

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1. Introduction

Body Dysmorphic Disorder (BDD) is characterised by severe dissatisfaction with one's appearance, with a preoccupation with 'imagined' or minor physical flaws. The beliefs held by BDD patients have been shown to vary in terms of the degree of conviction along a continuum from mild to severe (delusional) beliefs (Castle and Rossell, 2006; Labuschagne et al., 2010). These delusional beliefs in BDD are usually not bizarre, but are certainly exaggerated thoughts about their physical appearance, and the conviction about unattractiveness and/or abnormality in appearance causes extreme distress and preoccupation. There is also evidence to suggest that those BDD patients with delusional beliefs show greater morbidity, which was associated with more suicidal attempts, more drug abuse or dependence and less likelihood of receiving treatment (Phillips et al., 2006). Therefore, understanding the beliefs in BDD is essential for our understanding of the progression of the disease (Castle et al., 2006). We are aware of no published study that directly investigated the *cognitive* processes involved in the beliefs that BDD patients have, as most studies investigating the beliefs in BDD use measures that are assessing delusional or psychological qualities rather than cognitive aspects of the beliefs. We believe that the strong beliefs held by BDD can at least in part be explained by cognitive abnormalities. Therefore, it remains unclear whether there are cognitive abnormalities that may underpin the creation of appearance-related delusional beliefs in BDD.

There are a few published cognitive studies in BDD that have shown evidence of executive functioning impairments (with poor performances on tasks such as Tower of London and Stockings of Cambridge) as well as memory and learning deficits mediated by executive functioning deficits (Hanes, 1998; Deckersbach et al., 2000; Dunai et al., 2010; Labuschagne et al., 2011). There have also been a handful of studies implicating impaired visual and perceptual abilities and biased processing in the pathogenesis of BDD. For example, emotion recognition studies (Buhlmann et al., 2002a, 2004, 2006) have reported that BDD is associated with impaired facial emotion recognition abilities as well as a perceptual bias towards negative (i.e., angry) emotional face stimuli whereby they are more likely to misinterpret neutral expressions in a negative way. Similarly, a negative interpretive bias was also found in BDD patients when presented with body-related and general scenarios (Buhlmann et al., 2002b) suggesting that biased processing in BDD

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extends beyond that of face recognition. This evidence, together with the strong beliefs about physical appearance, suggests that perceptual and/or social processing abnormalities may be the key cognitive deficits of BDD. Interestingly, a more recent study showed that BDD patients were able to recognise emotions when presented with only the eye region of faces (Buhlmann et al., 2013). Together, we proposed that, based on the previous evidence, BDD may also be associated with perceptual integration abnormalities.

A number of cognitive impairments have been related to delusional thinking including anomalous 'faulty' perceptions (Maher, 1988), difficulties in social cognition and emotional attributions including attentional biases (Bentall et al., 1991; Kinderman et al., 1992; Langdon et al., 2002), aberrant semantic processing (Rossell et al., 1998), Theory of Mind (ToM) deficits (Frith, 1987, 1992) and reasoning abnormalities (Garety, 1991). However, the vast majority of this research has been performed in patients with schizophrenia, and might or might not be applicable to other disorders such as BDD. In a pilot study (Labuschagne et al., 2011) our research group did not identify either ToM or reasoning impairments in four BDD cases; which is supported by a more recent evidence (Reese et al., 2011). We are not ruling out that ToM and/or reasoning deficits could be a part of the neurocognitive profile of BDD, however, these processes are complex and time-consuming to assess, and thus were not a focus of the current work. The current work is based on four theories of cognitive (delusional) processing that may relate to BDD. These are reviewed below.

Firstly, Maher's (1974, 1988) cognitive account of delusions and delusional thinking emphasises '*faulty perceptions*' or an abnormality in perceptual processing which involves paradoxically 'normal' reasoning. That is, primary sensory inputs are disturbed and experienced at greater intensities than normal (e.g., the experience of increased vividness of colours) but the explanation, and thus the delusion, is derived via reasoning that is entirely normal (i.e., normal cognitive mechanisms). Therefore, in BDD this may relate to faulty perceptions of body-related concepts.

Secondly, delusional thinking has also been associated with *information processing bias*. Thus, Bentall et al. (1991, 1994, 2001) argued that delusions are a result of a bias in information processing, particularly that of negative events. These negative events have commonly been associated with the nature of the psychopathology such that the preferential encoding of stimuli relate to the main concern (i.e., thought-content specific bias). In the case of BDD, this supports the negative bias previously reported (Buhlmann et al., 2002b, 2006), and these negative events may be linked to negative thoughts and perceptions of their own bodies.

Thirdly, Rossell et al. (1998) articulated a theory of *semantic processing deficits* in which delusions are conceptualised as resulting from a corrupt storage mechanism for semantic information, including knowledge and facts about the world as well as the meanings of words. Rossell et al. (2010) argued that the disturbance of a person's store of information (i.e., aberrant semantic processing), co-jointly with the 'faulty perceptions' identified by Maher (1974, 1988), may result in a bias in the processing of general knowledge. Considering BDD, patients may be more likely to interpret someone laughing behind them as a negative response to their appearance, and this may relate to their belief in their specific 'abnormal' body part, but also their belief that other people pay particular attention to their part.

Finally, in addition to these theories regarding delusional beliefs, Veale et al. (2002, 2003) suggested that *atypical aesthetics* is involved in BDD, such that the appreciation of beauty is seen as playing a role in the development and maintenance of BDD. The theory suggests that patients with BDD are more aesthetically sensitive than the rest of the population and that BDD is associated with a failure to achieve an internal aesthetic standard. Buhlmann et al. (2008) reported that BDD patients perceived their own attractiveness as significantly lower when compared to an independent assessor, and they rated attractive photographs as significantly more attractive compare to the comparison groups. This heightened aesthetic sensitivity is reinforced by more recent evidence reporting that BDD patients have greater awareness of their aesthetic symmetry, possess a more critical eye and appreciation of aesthetics, and express a greater discrepancy between perceived actual self and their desired ideal self (Lambrou et al., 2011). This aesthetic sensitivity may explain why a small defect in appearance can severely disturb those with BDD. Such a sensitivity triggers their strong beliefs that they are distinct from others and therefore do not fit into the ideal world, and thereby resulting in their unusual (i.e., delusional) thinking.

In the current study, we aimed to characterise that cognitive impairments in BDD using four theories of delusional thinking. We hypothesised that BDD would be associated with; (a) impaired or 'faulty' perceptual processing, (b) bias in information processing, (c) a general knowledge (semantic) processing bias, and (d) atypical aesthetical sensitivity. As a priori hypotheses, we expected that BDD would show perceptual impairments such as impaired emotional face processing, particularly for angry faces (Buhlmann et al., 2002a, 2006); and deficits in tasks involving information processing and thus executive function (Dunai et al., 2010). Deficits in other domains were examined as exploratory hypotheses.

2. Methods

2.1. Subjects

Fourteen BDD patients were recruited from the BDD clinic at St Vincent's Hospital in Melbourne, Australia. BDD patients were diagnosed according to DSM-IV criteria by the study clinician (DJ Castle) using the self-rated Body Dysmorphic Disorder Questionnaire (BDDQ; Phillips et al., 1997) and the clinician-rated Body Dysmorphic Disorder Diagnostic Module (BDD-DM; Phillips et al., 1997). Current BDD severity was also assessed by the study clinician with the clinician-rated Yale-Brown Obsessive–Compulsive Scale modified for BDD (BDD-YBOCS; Goodman et al., 1989; Phillips et al., 1997). Scores on the BDD-YBOCS range from 0 to 48; higher scores indicate more severe symptoms. To assess and identify current Axis I diagnoses, we administered the Anxiety Disorders Interview Schedule for DSM-IV (ADIS-IV; Brown et al., 1994). Our sample of BDD patients experienced, on average, 1.9 ($\pm$1.6) comorbid disorders including major depressive disorder (n=7), social phobia (n=5), generalised social anxiety disorder (n=4), obsessive–compulsive disorder (n=3) and panic disorder (n=3), although BDD was their primary diagnosis as confirmed by their clinician and the ADIS interview. Twelve out of the 14 patients were on medications including antidepressants and antipsychotics (n=6), only antidepressants (n=3), only antipsychotics (n=1), and antidepressants, antipsychotics and anti-addictive medication (n=1). Our BDD sample reported concerns with a wide range of body parts, usually involving more than one concern, and which predominantly involved the face (n=5), skin (n=5), hair (n=4) and nose (n=4). Other concerns included breasts (n=3), weight (n=3), facial hair (n=2), teeth (n=2) and general body concerns (n=2), with single cases reporting concerns with ears (n=1), legs (n=1) and scrotum (n=1).

For comparison, a healthy control group (n=14) matched on age, gender and education was recruited through local newspaper advertisements and University noticeboards. We used the ADIS-IV and the control screen from the Structured Clinical Interview for DSM Disorders (SCID; First et al., 1996) to exclude any controls with a history of psychiatric illness and/or alcohol or substance abuse. All participants were between the ages of 18 and 55 years and had an estimated pre-morbid IQ as scored by the National Adult Reading Test (NART; Nelson, 1982) of $>$90. Exclusion criteria for all participants included any neurological disorder (self-report and clinician confirmed for the BDD cohort, and self-report for the controls), insufficient conversational English, and current abuse/dependence of alcohol or drugs. Table 1 presents the details of the demographic information.

2.2. Procedures

Participants were individually assessed during an approximately 3 h session on a single day. All participants completed a test battery of self-rated questionnaires to assess clinical status and cognitive abilities. The clinical assessment was always administered before the cognitive assessments, and all the questionnaires were administered in the same order to each participant. This study was approved by The University of Melbourne Human Research Ethics Committee and it conforms to the provisions of the Declaration of Helsinki (1995). All participants in the study provided written informed consent.

2.3. *Clinical assessment*

All participants were assessed for depression, using the Beck Depression Inventory (BDI-II; Beck et al., 1996), for anxiety, using the Beck Anxiety Inventory (BAI; Beck and Steer, 1990) and for delusional thinking, using the Peters' Delusional Inventory (PDI; Peters et al., 1999). The mean total scores on the BDI-II and BAI, and the mean percentage 'yes' answers on the PDI, were calculated for each participant for statistical analysis.

2.4. *Cognitive assessment*

2.4.1. *Perceptual processing*

Maher's theory of 'faulty perceptions' was assessed using three measures covering a range of simple and more complex perceptual abilities. First, the *Contour Integration task* (CIT; Pennefeather et al., 1998) is a perceptual organisation task examining contour integration by searching for closed circular contours, defined by Gabor elements, which are embedded in a Gabor background of randomly oriented distracters on a single page. For an illustration of the Gabor elements, see for example, Chandna et al., 2001. A total of 15 pages are presented with increase in difficulty and with 30 s response time per page. The percentage correct, based on a score out of 15, was calculated. Second, the *Visual Object and Space Perception test battery* (VOSP; Warrington and James, 1991) consists of the following four sub-tests: Incomplete Letters, Silhouettes, Object Decision and Progressive Silhouettes, which assess aspects of object and space perception while minimising the involvement of other cognitive skills. The percentage correct on each subtest was calculated. Third, socially-specific perceptual processing was assessed using a computerised *Facial Affect task* made up of single presentations of human faces (Ekman and Friesen, 1976) displaying different emotional expressions (i.e., happy, sad, neutral, angry or afraid). Stimuli were presented for 2000 ms on a white screen (SOA=1500 ms). Participants were required to identify the emotional expression by pressing the appropriate button on a computer keyboard. The percentage correct was calculated for the individual emotion types. In addition, bias in emotion processing was examined by calculating the percentage of each emotional type used during incorrect responses or 'error labels'.

2.4.2. *Information processing*

Bentall and colleagues' theory of bias in attention or information processing was examined using *a modified Stroop task* (Leafhead et al., 1996). Three stimulus-trials, made up of 10 X-sequences (e.g., 'XXXX' and 'XXXXX'), 10 animal words (e.g., 'frog' and 'mouse') and 10 body words (e.g., 'nose' and 'breast') were presented in four different colours (red, blue, green and yellow), resulting in three trials of 40 stimuli and a total of 120 stimuli. The X-sequences were matched on length, whereas the word stimuli (animal and body) were matched on length, frequency and colour. Stimuli were presented one at a time for 20 ms on a black background (SOA=2980 ms) and participants were required to respond as quickly as possible to the colour in which each stimulus was presented. The percentage correct and Reaction Time (RT) were calculated for each stimulus-trial (X-sequences, animal words and body words). For the RT data, an "inhibition effect" was investigated in which animal words were subtracted from the body words (body minus animal) to eliminate other cognitive processes involved in processing the body words.

Table 1
Demographics and clinical characteristics of two participant groups of healthy controls and BDD patients.

	Controls (n=14)	BDD (n=14)	t	p
Male/Female	5/9	5/9	–	–
Age (years)	32.9 (13.4)	33.1 (13.4)	0.03	0.978
Education (no. of years)	16.1 (4.8)	15.0 (3.8)	0.75	0.458
NART IQ	119.0 (4.8)	112.6 (7.6)	2.65	0.014
BDD-YBOCS	–	23.8 (10.0)	–	–
BDI-II (scores)	2.1 (2.2)	17.6 (11.0)	5.2	0.0005
BAI (scores)	5.4 (5.4)	19.6 (8.7)	5.2	0.0005
PDI (%)	9.7 (6.8)	34.0 (14.0)	5.9	0.0005

Note: [mean (S.D.)]; BDD=Body Dysmorphic Disorder; NART=National Adult Reading Test; BDD-YBOCS=BDD version of the Yale-Brown Obsessive–Compulsive Scale; BDI-II=Beck's Depression Inventory (mean scores out of 63); BAI=Beck's Anxiety Inventory (mean scores out of 63); PDI= Peters Delusional Inventory (mean percentage yes-answers out of 21); t=t-test (d.f.=26); p=p-value (significance).

2.4.3. *Semantic memory*

Rossell and colleagues theory of semantic processing deficits was assessed using two measures of semantic memory. First, a *modified version of the Sentence Verification task* (Rossell et al., 1998). This task is designed to produce 'errors' in both patients and controls. A list of 96 sentences was presented of which 32 were true or a correct representation of the world (e.g., 'Blood is red'), 32 were plausible or possible representations of the world, but unlikely or unusual constructions (e.g., 'Noses can be taken off') and 32 were false/nonsense or not accurate representations of the world (e.g., 'Chin grows plants'). Two different content types were involved including somatic (48 sentences) and neutral (48 sentences). The somatic content type involved sentences which included anything body-related. Examples of true sentences include 'Blood is red' (somatic) and 'Fish swim in rivers' (neutral). Participants were required to respond to each sentence with either True (i.e., a true representation of the world and could happen) or False (i.e., an inadequate representation of the world and could not happen). The percentage correct was calculated for each content type (somatic and neutral) for each sentence type (true, unlikely, and false), which were then statistically analysed. Note, unlikely sentences were regarded as true, and thus errors (i.e., false answers to unlikely sentences) were incorrect rejections. Second, semantic functioning was also examined using the *Controlled Oral Word Association task* (COWAT; Benton and Hamsher, 1976). This task involves word generation and is used to assess Phonological Fluency (PF) using three letters (F, A and S) and Semantic Fluency (SF) using three categories (animals, food, and body parts). Participants were required to orally produce, within 60 s, as many words as possible from the letters or categories. The total number of words generated, minus the errors (category inappropriate words for SF, or proper nouns and perseverations for PF), were calculated for each letter and category.

2.4.4. *Aesthetics*

Veale and colleagues' judgement of aesthetics was assessed using an *Attractiveness task* (provided by Gillian Rhodes, University of Western Australia) which examines participants' beliefs about the 'beauty' of another person rather than themselves. Computerised presentations involving photographs of a previously validated series of 50 human bodies and 50 human faces were presented one at a time on a black screen. Participants were required to rate the level of attractiveness of each photograph on a 7-point Likert scale (1=least attractive, 7=most attractive). The mean attractiveness rating scores of the bodies and the faces were calculated.

2.5. *Statistical analysis*

Using an alpha level of 0.05, all data were analysed using simple independent t-tests and one-way analysis of variance (ANOVA). Bonferroni corrections were applied where appropriate. See Section 3 for more details.

3. Results

3.1. *Clinical data*

Simple independent samples t-tests showed that, compared to the Healthy Control group (HC), the BDD group scored significantly higher on levels of depression (BDI-II), anxiety (BAI), and overall delusional thinking (PDI), all p's <0.0005 (see Table 1). Due to the significant differences between groups on these clinical measures (BDII, BAI and PDI) as well as a significant difference on NART IQ, these were initially entered as covariates for analysis of all subsequent cognitive data. However, the assumptions for homogeneity of regression and linearity were not met for any of these measures, and thus they could not be included as covariates (Miller and Chapman, 2001). All significant cognitive results were subsequently correlated with BDD symptom severity (i.e., BDD-YBOCS) and are additionally presented.

3.2. *Cognitive assessment data*

Table 2 presents the means, standard deviations and the statistics of all the cognitive tasks administered in the current study.

Contour Integration task (*CIT*): A simple one-way ANOVA, revealed no significant difference for group [F(1,26)=0.578, p= 0.454, partial *eta* squared=0.02]. *Visual Object and Space Perception* (*VOSP*): Simple one-way ANOVAs revealed no significant group differences on three of the sub-tests, including Incomplete Letters [F(1,26)=0.200, p=0.658, partial *eta* squared=0.0], Silhouettes

[$F(1,26)=0.665$, $p=0.422$, partial *eta* squared$=0.03$], and Progressive Silhouettes [$F(1,26)=1.423$, $p=0.244$, partial *eta* squared$=0.05$]. The subtest Object Decision showed a trend, with a medium-to-large effect size, towards a significant group difference [$F(1,26)=3.253$, $p=0.083$, partial *eta* squared$=0.11$] with performance worse for BDD than HCs; see Table 2. Thus, to obtain significance at $p<0.05$ and power$=0.8$, participant groups of $n=27$ would have been required. Pearson's correlation analysis between Object Decision and BDD-YBOCS revealed no significant relationship, $r=0.09$, $n=14$, $p=0.748$.

Facial Affect task: The percentage correct data was analysed using a 2 group (HC, BDD) × 5 emotions (happy, sad, angry, fear, neutral) repeated-measures ANOVA. There was no significant main effect for group [$F(1,26)=0.216$, $p=0.646$, partial *eta* squared$=0.01$] and no interaction [$F(4,104)=1.032$, $p=0.373$, partial *eta* squared$=0.04$]. The main effect for emotion was significant [$F(4,104)=21.489$, $p<0.0005$, partial *eta* squared$=0.453$], with the least-to-most correct responses (and mean percentage) for sad (64.27%) < angry (83.57%) < fearful (88.57%) < neutral (91.43%) < happy (99.29%). Due to our *a priori* hypothesis, a simple one-way ANOVA was conducted with each emotion, and a trend, with a medium-to-large effect size, for a significant group difference was obtained for only angry faces [$F(1,26)=3.682$, $p=0.066$, partial *eta* squared$=0.12$], with BDD performing worse than HC (Table 2). To obtain significance at $p<0.05$ and power$=0.8$, participant groups of $n=24$ would have been required. Given the importance of this group difference, a Pearson's correlation analysis between angry faces and BDD-YBOCS scores in the BDD sample was performed, revealing a significant negative correlation between the variables, $r=-0.553$, $n=14$, $p=0.040$. The emotion 'error' labels given to the incorrect answers were analysed using a similar 2 × 5 repeated-measures ANOVA. No significant main effect for group [$F(1,26)=2.00$, $p=0.169$, partial *eta* squared$=0.07$] or interaction [$F(4,104)=0.470$, $p=0.659$, partial *eta* squared$=0.02$] was observed for the 'error' labelling responses. However, a significant main effect was evident for emotion [$F(4,104)=12.001$, $p<0.0005$, partial *eta* squared$=0.32$], with the most-to-least errors labelled as: angry (36.28%) > fearful (31.23%) > neutral (19.44%) > sad (10.23%) > happy (2.82%).

Stroop task: The percentage correct data was analysed using a 2 group (HC, BDD) × 3 trial (X-sequence, animal, body words) repeated-measures ANOVA. No significant main effect for group was obtained [$F(1,26)=0.367$, $p=0.550$, partial *eta* squared$=0.01$] as well as no interaction [$F(2,52)=0.837$, $p=0.439$, partial *eta* squared$=0.03$]. A significant main effect for trial was present [$F(2,52)=16.254$, $p<0.0005$, partial *eta* squared$=0.39$], such that accuracy was equal for X-sequences and body-related words (means: 98.57 and 98.60, respectively), which were significantly better than animal words (mean$=95.97$; p's <0.0005). The RT data was analysed using a similar 2 × 3 repeated-measures ANOVA, with no main effect for group [$F(1,26)=0.932$, $p=0.343$, partial *eta* squared$=0.04$] or interaction [$F(2,52)=0.588$, $p=0.508$, partial *eta* squared$=0.02$]. There was a near significant main effect for trial RT [$F(2,52)=3.483$, $p=0.055$, partial *eta* squared$=0.12$], with fastest-to-slowest mean RTs: X-sequences (7987.96 ms) < animal words (8186.16 ms) < body-related words (8257.88 ms). An "inhibition effect" (body minus animal) was analysed using a simple one-way ANOVA, however no significant group difference was obtained [$F(1,26)=1.814$, $p=0.190$, partial *eta* squared$=0.07$].

Sentence Verification task: The percentage incorrect 'error' data was analysed using a 2 × 2 × 3 (mixed model) ANOVA, with group (controls and BDD) as the between-subjects factor, and emotion (somatic and neutral) and sentence (true, unlikely and false) as the within-subjects factors. All three main effects were significant: group [$F(1,26)=4.412$, $p<0.046$, partial *eta* squared$=0.15$], with greater mean percentage errors for HCs (24.9%) than BDD (20.6%); sentence [$F(2,52)=399.810$, $p<0.0005$, partial *eta* squared$=0.94$], with the greatest-to-least mean percentage of errors were: unlikely (62.2%) > true (4.6%) > false (1.3%) sentences; and emotion [$F(1,26)=14.283$, $p=0.001$, partial *eta* squared$=0.36$], with greater mean percentage errors on neutral sentences (25.23%) compared to somatic sentences (20.24%). A significant interaction was obtained for sentence × emotion [$F(2,52)=4.321$, $p=0.039$, partial *eta* squared$=0.14$], with

Table 2
Means and standard deviations (S.D.) of the cognitive task.

Cognitive tasks	Controls ($n=14$)		BDD ($n=14$)		Effect size
	M	S.D.	*M*	S.D.	*d*[b]
Perceptual processing:					
Contour integration					
% Correct	66.2	13.7	61.9	16.0	0.29
VOSP					
% Correct					
Incompl. letters	99.3	2.7	99.6	1.3	−0.14
Silhouettes	71.2	12.4	67.4	12.3	0.31
Object decision	93.3	8.9	88.2	5.8	0.68[c]
Progr. silhouettes	57.9	13.5	51.8	13.4	0.45
Facial affect					
% Correct					
Neutral	90.7	10.7	92.1	11.2	−0.13
Happy	100.0	0	98.6	3.6	0.55[c]
Sad	61.4	29.8	67.1	15.4	−0.24
Angry	88.6	11.0	78.6	16.1	0.73[c]
Fear	89.3	17.3	87.9	12.5	0.09
% Error					
Neutral	22.3	17.0	16.6	13.4	0.37
Happy	3.0	6.5	2.6	5.4	0.07
Sad	5.7	8.5	14.8	21.0	−0.57[c]
Angry	37.6	23.9	34.9	26.6	0.11
Fear	31.4	24.8	31.1	26.4	0.01
Information processing and bias:					
Stroop					
% Correct					
X-sequence	98.4	3.2	98.7	1.6	−0.12
Animal	96.2	1.6	95.7	3.0	0.21
Body	99.1	1.6	98.1	2.6	0.46[c]
RT in ms					
X-sequence	7781.5	1224.1	8194.4	1406.0	−0.31
Animal	7892.5	969.8	8479.8	1516.8	−0.46[c]
Body	8072.6	1014.2	8443.2	1513.3	−0.29
Inhibition-effect					
Body-Animal	180.1	487.0	−36.6	354.0	0.34
Semantic processing:					
Sentence verification					
% Error					
True-body	4.5	8.7	0.9	2.2	0.57[c]
True-neutral	7.7	6.7	5.4	4.8	0.39
Unlikely-body	63.4	14.0	50.4	28.0	0.59[c]
Unlikely-neutral	70.5	10.2	64.7	15.4	0.44
False-body	1.8	2.9	0.4	1.7	0.59[c]
False-neutral	1.3	3.6	1.8	3.8	−0.14
Phonological fluency					
Letters[a]					
F	14.9	5.0	13.7	4.5	0.25
A	12.9	3.9	12.0	5.0	0.20
S	16.1	3.6	15.9	3.8	0.05
Semantic fluency					
Categories[a]					
Animal	25.5	5.4	19.4	7.8	0.91[c]
Food	29.9	7.9	20.1	6.3	1.14[c]
Body	29.4	5.4	22.3	7.5	1.09[c]
Aesthetics:					
Attractiveness					
Mean scores					
Bodies	3.7	1.0	3.4	1.1	0.29
Faces	3.2	0.7	2.9	1.2	0.31

Note: [mean (S.D.)]; VOSP=; RT=Reaction Time.
[a] Scores minus errors.
[b] Cohen's *d*.
[c] Medium to large effect size ($d \geq 0.45$).

greatest-to-least percentage error on unlikely-neutral (67.62%) > unlikely-somatic (56.90%) > true-neutral (6.51%) > true-somatic (2.69%) > negative-neutral (1.56%) > negative-somatic (1.12%) sentences. However, no significant interactions were obtained for group × sentence [$F(2,52)=1.815$, $p=0.173$, partial *eta* squared = 0.07], group × emotion [$F(1,26)=1.684$, $p=0.206$, partial *eta* squared = 0.06] or group × sentence × emotion [$F(2,52)=0.427$, $p=0.655$, partial *eta* squared = 0.02].

COWAT: Phonological (letter) fluency (PF) and semantic (category) fluency (SF) data (scores minus errors) were analysed separately using a 2 × 3 repeated-measures ANOVA, with a between-subject factor of group (HC, BDD), and letter (F, A, S) or category (animals, food, body parts) as the within-subject factors. For PF, no significant main effect was obtained for group [$F(1,26)=0.284$, $p=0.599$, partial *eta* squared = 0.01], as well as no significant interaction [$F(2,52)=0.321$, $p=0.727$, partial *eta* squared = 0.02]. A significant main effect was obtained for letter [$F(1,26)=13.043$, $p<0.0005$, partial *eta* squared = 0.33], with the greatest-to-least mean number (and standard error) of words (minus errors) generated: $S=16.0$ (0.7) > $F=14.3$ (0.9) > $A=12.5$ (0.8). For SF, a significant main effect was obtained for group [$F(1,26)=11.211$, $p=0.002$, partial *eta* squared = 0.30], with the overall mean categories score (and standard error) being greater for the HCs = 28.3 (1.6) compare to BDD = 20.57 (1.6); and category [$F(1,26)=165.177$, $p=0.001$, partial *eta* squared = 0.369], with the greatest-to-least number of words (and standard error) generated: body = 25.86 (1.2) > food = 24.96 (1.3) > animal = 22.43 (1.3). No significant interaction was found for group × category [$F(2,52)=1.778$, $p=0.179$, partial *eta* squared = 0.06]. However, after visual inspection of data in Table 2 and based on *a priori* hypothesis relating to deficits on executive function, post-hoc one-way ANOVAs were run on the raw score category data to further explore for group differences, Bonferroni corrected for multiple comparisons ($\alpha=0.0167$). Significant group differences were obtained for food [$F(1,26)=13.177$, $p=0.001$] and body word [$F(1,26)=8.333$, $p=0.008$], with the BDD group scoring lower than the HC group on both categories, but no significant group difference for animals [$F(1,26)=5.876$, $p=0.023$]. Pearson's correlation analyses for the different category variables (food and body words) and BDD-YBOCS did not reveal any significant relationships, all p's > 0.1. Analyses were run on the errors produced on both PF and SF, however no significant main effects or interactions were obtained (all p's > 0.05) and hence data for this is not reported.

Attractiveness task: Mean attractiveness rating scores were analysed using a 2 group (HC, BDD) × 2 stimuli (bodies, faces) repeated-measures ANOVA. No significant group difference was evident [$F(1,26)=0.505$, $p=0.484$, partial *eta* squared = 0.02] and no significant interaction [$F(1,26)=0.004$, $p=0.949$, partial *eta* squared = 0.0]. A significant main effect was obtained for overall stimuli [$F(1,26)=8.465$, $p=0.007$, partial *eta* squared = 0.25], with higher attractiveness scores (and standard errors) for bodies = 3.5 (0.2) compared to faces = 3.0 (1.9).

4. Discussion

Our BDD patients experienced higher levels of depression, anxiety and delusional thinking compared to healthy controls. However, BDD was associated with only mild depression and moderate levels of anxiety. More importantly, our cognitive outcomes demonstrated that patients with BDD show abnormal abilities on semantic processing tasks (involving sentence verification and category fluency). Interestingly, the BDD patients outperformed (i.e., were better than) the healthy controls on processing sentences of somatic and neutral content, but were poor at generating words in the category fluency task. In contrast, patients with BDD showed intact abilities for information (bias) processing and aesthetics. That is, no group differences were found on tasks assessing contour integration, bias (i.e., Stroop) processing or attractiveness. Finally, there were subtle trends ($p=0.06$ and $p=0.08$) of impaired perceptual processing on tasks involving simple visual processing skills, such as that of object detection, and perception of emotions, particularly angry facial expressions. These results suggest that cognitive deficits in BDD are in accordance with an unusual storage of semantic information (Rossell et al., 1998) with some evidence of 'faulty perceptions' (Maher, 1988). Our findings did not show evidence of support for the theories of information or biased processing (Kinderman et al., 1992; Bentall et al., 2001; Langdon et al., 2002) or biased aesthetics (Veale et al., 2002, 2003).

We only found a trend in perceptual impairments in BDD in our study, which lends only partial support to the delusional theory of '*faulty perceptions*' proposed by Maher (1988). During objection decision assessment, the BDD patients showed a poor ability to differentiate 'real' but abstract (silhouette) objects from 'nonsense' (silhouette) objects, suggesting a problem in differentiating between real and unreal/imaginary figures. Although we presented cues of general rather than disorder-specific (body-related) visual content, the findings suggest that people with BDD may have difficulties interpreting reality from idealistic or imaginary concepts. This may be an attribute and an explanation for their inability to differentiate between what they actually look like (i.e., reality) and what they think they should look like (i.e., the ideal self). The findings require confirmation because of the statistically non-significant finding. However, there was a large effect size for this test ($d=0.68$) when compared to the other similar subtests, that showed marginally smaller effect sizes (0.1–0.4). This provides early evidence that these individuals are associated with poor perceptual skills when required to differentiate between real and non-sense visual objects.

The BDD patients also showed a trend towards impairments on a visual domain task involving emotion recognition from facial expressions, particularly that of anger which also significantly correlated with their illness severity. In previous studies, including work from our research group, a recognition bias for angry facial expression has been reported such that people with BDD misinterpret other emotions (e.g., disgust and neutral) as being 'angry' (Buhlmann et al., 2002a, 2004, 2006; Labuschagne et al., 2011). However, the current study did not show a group difference on the percentage of error labels (misclassifications) on the facial affect task, suggesting that both BDD and control individuals were equally biased when an error was made. More evidence is needed to further elucidate whether BDD patients are particularly impaired on perceptual processes such as recognition of objects and emotions. In particular, the recent notion that BDD patients are able to recognise emotions when presented with only the eye regions of emotional faces (Buhlmann et al., 2013), suggest that future research needs to also include a measure of perceptual integration to further characterised these impairments in BDD.

We showed for the first time that BDD is associated with heightened ability (i.e., significantly better than controls) in the processing of *semantic information*, but that patients showed poor category fluency skills whilst phonological fluency was intact. Both these abnormal abilities on sentence verification and category fluency involve semantic information consisting of body-related information, and thus, these abnormalities support the delusional theory of a corrupt storage mechanism for semantic information as proposed previously by our research group (Rossell et al., 1998). It is unknown why our BDD patients outperformed controls (i.e., made less errors) on sentence verification. However, since half of the content presented in these sentences was of somatic (body-related) type, the group difference may be due the BDD individuals' heightened preoccupation with body-related information which may have been of benefit to them in this particular assessment.

Deficits on category (i.e., semantic) fluency such as that found in our study has been related to the experience of delusions, with such impairments likely resulting in idiosyncratic and implausible beliefs (Rossell et al., 1999). In the case of BDD, such beliefs are likely to contribute to their unrealistic perception of themselves. Similar to previous findings from our research group (Labuschagne et al., 2011), no significant group differences were found on the fluency error data, thereby suggesting a genuine impairment on fluency which cannot be accounted for by the errors made during the task. This is unlike other clinical populations, such as schizophrenia, in which impairments on fluency are accounted for by perseverations made during the assessment (Crider, 1997; Rossell, 2006). In addition, the current fluency outcome is in contrast to previous BDD case studies where our research group reported impairments relating to phonological fluency but not category fluency (Labuschagne et al., 2011). The discrepancy is likely due to the variations in sample sizes, with our earlier study only reporting on three cases.

The delusional theories of *information processing bias* (Kinderman et al., 1992; Bentall et al., 2001; Langdon et al., 2002) and aesthetics (Veale et al., 2003) were not supported by the current study, as we did not find group differences on a modified Stroop task or the task of rating attractiveness of presented bodies and faces, both of which contained disorder-specific (i.e., body-related) cues. Although we did not find evidence of an information bias on the Stroop task, the BDD group did showed a bias related to general knowledge involving semantic processing during the sentences verification task as part of the semantic processing assessment.

No group difference was evident on the attractiveness tasks, suggesting that BDD individuals are not *aesthetically biased* (Veale et al., 2002, 2003) and that they judge attractiveness in others similar to that of the controls. This is surprising seeing that patients with BDD hold attractiveness as a primary value (Neziroglu et al., 2004) and they are also associated with a superior awareness and appreciation of aesthetics (Veale et al., 2002, 2003; Buhlmann et al., 2008; Lambrou et al., 2011). However, we would not fully rule out the possibility of maladaptive aesthetics, as such impairments in BDD may be more associated with how these individuals perceive attractiveness in themselves as found by Buhlmann et al. (2008), rather than attractiveness in others. This is consistent with the theory of Veale et al. (2003) that self-discrepancy in BDD is related more to how concerned BDD patients are with how they should look, rather than what others may think of them.

Overall, our findings provide support for a recent proposal, proposed by our research group (Rossell et al., 2010), that abnormal processing of semantic information is likely to help explain the biased processing of general knowledge and therefore cognitive impairments in BDD. However, we should not overlook theories of perceptual deficits (Maher 1988), biased information processing (Kinderman et al., 1992; Bentall et al., 2001; Langdon et al., 2002) and biased aesthetics (Veale et al., 2003) since we only employed single, including modified, assessments for each of these theories. For example, we employed a modified version of the Stroop task which we cannot compare with other studies. Furthermore, it is possible that the body areas of concern within the BDD sample, such as that involving the face, may have influenced performance on the tasks, especially the facial affect task. Our sample size was too small to examine an association between body parts of concern and cognitive task performance, and we therefore encourage future studies to consider this in future study designs. Other limitations of the current study include the small sample sizes, with diverse symptom profiles which were not controlled for in statistical analyses. Future studies should aim to replicate and extend the current findings using large sample sizes, including investigating "belief flexibility" which relates to one's own beliefs and changing them by generating and considering alternative ideas (Garety et al., 2005). Moreover, future studies will benefit from including a clinical control group to further elucidate whether the findings are specific to BDD. Finally, it is important that future studies aim to distinguish between belief formation and the reasoning that maintains or alters a belief in BDD. This will help further the understanding of the nature of the strength of conviction in the beliefs held by BDD individuals about their appearance.

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