Published in final edited form as:

Psychiatry Res. 2015 September 30; 229(0): 426–433. doi:10.1016/j.psychres.2015.05.107.

Comparison of Visual Perceptual Organization in Schizophrenia and Body Dysmorphic Disorder

Steven M. Silverstein^{a,*}, Corinna M. Elliott^b, Jamie D. Feusner^c, Brian P. Keane^a, Deepthi Mikkilineni^a, Natasha Hansen^b, Andrea Hartmann^b, and Sabine Wilhelm^b

^aDepartment of Psychiatry and University Behavioral Health Care, Rutgers University, Piscataway, New Jersey, USA

^bDepartment of Psychiatry, Massachusetts General Hospital/Harvard Medical School, Boston, MA, USA

^cDepartment of Psychiatry and Biobehavioral Sciences, David Geffen School of Medicine at University of California-Los Angeles, Los Angeles, CA, USA

Abstract

People with schizophrenia are impaired at organizing potentially ambiguous visual information into well-formed shape and object representations. This perceptual organization (PO) impairment has not been found in other psychiatric disorders. However, recent data on body dysmorphic disorder (BDD), suggest that BDD may also be characterized by reduced PO. Similarities between these groups could have implications for understanding the RDoC dimension of visual perception in psychopathology, and for modeling symptom formation across these two conditions. We compared patients with SCZ (n=24) to those with BDD (n=20), as well as control groups of obsessive-compulsive disorder (OCD) patients (n=20) and healthy controls (n=20), on two measures of PO that have been reliably associated with schizophrenia-related performance impairment. On both the contour integration and Ebbinghaus illusion tests, only the SCZ group demonstrated abnormal performance relative to controls; the BDD group performed similarly to the OCD and CON groups. In addition, on both tasks, the SCZ group performed more abnormally than the BDD group. Overall, these data suggest that PO reductions observed in SCZ are not present in BDD. Visual processing impairments in BDD may arise instead from other perceptual disturbances or attentional biases related to emotional factors.

Keywords

Schizophrenia; Body Dysmorphic Disorder; Perception; Vision; Perceptual Organization; Obsessive-Compulsive Disorder; RDoC

*Corresponding author: Steven M. Silverstein, Ph.D. Rutgers University Behavioral Health Care, 151 Centennial Avenue, Piscataway, NJ 08854, USA. Tel.: +1-732-235-5149. steven.silverstein@rutgers.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Conflicts of Interest
None

1. Introduction

It is increasingly recognized that there is overlap between certain psychiatric syndromes in terms of their genetic, neurobiological, cognitive, behavioral, and phenomenological characteristics (Guilmatre et al., 2009; Bellivier et al., 2013; Doherty and Owen, 2014; Monzani et al., 2014). The mounting evidence for this conclusion has led the National Institute of Mental Health (NIMH) to introduce the Research Domain Criteria (RDoC) initiative (Cuthbert and Insel, 2010; Insel et al., 2010). The rationale behind RDoC is that diagnosis and treatment of mental disorders should not be driven primarily by a focus on signs and symptoms (given their problems with reliability and various forms of validity), but rather, by a focus on dimensions of functioning with known pathophysiological mechanisms. A related implication of RDoC is that the yield of psychopathology research may be more fruitful if studies examine these dimensions across current diagnostic categories. One RDoC dimension that has been studied repeatedly within diagnostic categories is cognition, a subcategory of which is perception.

A well-documented visual impairment in schizophrenia (SCZ) is in perceptual organization (PO) – the processes by which individual elements of sensory information are collectively structured into larger units of perceived objects and their interrelations (Palmer, 1999). Over 50 studies have demonstrated reduced PO in SCZ (for reviews, see Uhlhaas and Silverstein, 2005; Silverstein and Keane, 2011). Some of these studies suggest that, among psychiatric conditions, PO impairment is specific to SCZ, in that it has not been observed in mixed groups of psychotic patients without SCZ, in non-psychotic patients, or in patients who abuse drugs that are not psychotomimetic (Silverstein and Keane, 2011) [there is debate, however, over whether autism, another neurodevelopmental disorder, is characterized by reduced PO (Dakin and Frith, 2005; Sun et al., 2012)].

Recently, however, perceptual impairments that may be aspects of, or secondary to, reduced PO have been observed in body dysmorphic disorder (BDD), a condition characterized by preoccupation with perceived defects in visual appearance. For example, Feusner and colleagues demonstrated that BDD patients are impaired at processing low spatial frequency information in faces, and demonstrate hypoactivity in occipital regions during processing of low spatial frequency information from own face, other face, and object stimuli (Feusner et al., 2007; Feusner et al., 2010a; Feusner et al., 2010b; Feusner et al., 2010c; Feusner et al., 2011). Patients with BDD and individuals with a high degree of body image concern also show a reduced face inversion effect (i.e., a worsening of performance when making judgments about faces that are upended compared to upright faces) (Feusner et al., 2010b; Jefferies et al., 2012; Mundy and Sadusky, 2014). Because the face inversion effect has traditionally been thought to reflect the contrast between rapid configural processing of upright faces versus slower serial processing of inverted faces (Tanaka and Farah, 1993; Tanaka and Sengco, 1997; Freire et al., 2000; Taubert et al., 2011; Peters et al., 2013) [but see (Rakover, 2013; Civile et al., 2014; Xu and Biederman, 2014) for other accounts of the effect], and because low spatial frequency information carries the majority of information about global form (Tanaka and Farah, 1993; Costen et al., 1996; Deruelle and Fagot, 2005), these data suggest a reduction in PO in BDD. Of note, patients with SCZ have shown

performance impairments on tasks that are similar to the ones used to study face processing in BDD, including reduced face inversion effects (Schwartz et al., 2002; Chen et al., 2008; Soria Bauser et al., 2012; Tsunoda et al., 2012) [but see (Chambon et al., 2006; Butler et al., 2008)], reduced processing of low spatial frequency information in faces (Silverstein et al., 2010), and reduced encoding of the structural features of faces (Turetsky et al., 2007; Tsunoda et al., 2012). To date, however, no studies directly comparing BDD and SCZ on visual perception have been conducted.

The purpose of this pilot study was, therefore, to directly compare BDD and SCZ patients on two measures of PO that have repeatedly shown sensitivity to impairments in SCZ: an Ebbinghaus illusion task and a contour integration (CI) task. In addition, a group of obsessive-compulsive disorder (OCD) patients was included to control for obsessive-compulsive features, and to determine whether problems in organizational strategies that have been observed in OCD (e.g., on verbal and visual memory tasks (Deckersbach et al., 2000a; Deckersbach et al., 2000b; Deckersbach et al., 2000c; Savage et al., 2000) could account for task performance in BDD. Psychiatrically healthy controls were also included.

1.1 Ebbinghaus Illusion

In a typical Ebbinghaus illusion demonstration, the perceived size of a circle is altered when it is surrounded by other circles; it appears larger than its actual size when surrounded by smaller circles and smaller than its actual size when surrounded by larger circles (see Figure 1). The effect has been known for over 100 years (Titchener, 1902), and has been the subject of numerous experiments, especially since the 1970s (e.g., Massaro and Anderson, 1971; Gircus et al., 1972; Weintraub and Schneck, 1986; Coren and Enns, 1993; Rose and Bressan, 2002; Doherty, 2010; Schwarzkopf and Rees, 2013). Patients with schizophrenia have demonstrated reduced illusion effects, expressed as *more accurate size perception* compared to controls when judging target circle size in *misleading* context conditions (Uhlhaas et al., 2006; Silverstein et al., 2013; Tibber et al., 2013). This effect is most pronounced when patients have active psychotic symptoms (Silverstein et al., 2013).

1.2 Contour Integration

CI is one of the most widely used measures of PO in the SCZ and basic vision literatures (Field et al., 1993; Kovacs and Julesz, 1993; Polat et al., 1997; Kovacs, 2000; Chandna et al., 2001). CI is typically measured as the ability to detect or make a judgment about a closed contour made up of non-contiguous elements, embedded within a display of randomly oriented elements (see Figure 2). Previous studies have shown that people with SCZ are less able to detect and make shape judgments about contours when compared to healthy, psychotic, non-psychotic and non-psychotomimetic substance abusing control groups (Uhlhaas and Silverstein, 2005; Silverstein and Keane, 2011). CI impairment has also been observed in aging (Roudaia et al., 2011), dyslexia (Simmers and Bex, 2001), and amblyopia (Polat et al., 1997), and can be affected by psychotomimetic drugs that affect occipital lobe functioning (Uhlhaas et al., 2007; White et al., 2013). To our knowledge, only one prior study has investigated CI in BDD (Rossell et al., 2014). This recent study found normal performance; however, they used an older, card-based version of the task with only 15 stimuli and a lengthy exposure duration (30 seconds). In the present study, we used a

recently developed computerized version of the CI task with a large number of trials and a relatively brief stimulus duration (Silverstein et al., 2012a).

2. Methods

2.1 Subjects

Four groups participated: 1) outpatients with BDD (n=20; 11 female); 2) outpatients with OCD (n=20, 7 female); 3) inpatients with SCZ (n=24; 11 female); and 4) controls (CON) without a psychiatric disorder (n=20; 10 female). BDD and OCD patients were recruited from specialized clinics at the Department of Psychiatry at Massachusetts General Hospital (MGH). All BDD participants were required to have a score of ≥ 20 on the BDD version of the Yale-Brown Obsessive-Compulsive Disorder Scale (BDD-YBOCS) (Phillips et al., 1997). All OCD participants were required to have a score of ≥ 16 on the Yale-Brown Obsessive-Compulsive Disorder Scale (YBOCS) (Goodman et al., 1989a; Goodman et al., 1989b). Thirteen BDD patients and 10 OCD patients were taking medication at the time of testing. Patients with schizophrenia were recruited from the adult psychiatric inpatient unit at Rutgers University Behavioral Health Care. All SCZ patients were hospitalized while tested, and were tested within 1 week of admission. All were taking second-generation antipsychotic medication at the time of testing. The CON group was recruited from the local community. Data from 58% of the SCZ and 50% of the CON groups only was included in a prior report (Silverstein et al., 2013). More details on exclusion criteria and patient medications can be found in Supplemental Information.

2.2 Clinical assessments

SCZ, BDD and OCD diagnoses were confirmed via the Structured Clinical Interview for DSM-IV diagnosis (SCID) (First et al., 2002b), in addition to collateral information obtained from clinical staff and the electronic medical record. BDD and OCD groups only also completed the Brown Assessment of Beliefs Scale (BABS) (Eisen et al., 1998) and the Peters' Delusional Inventory (PDI) (Peters et al., 1999) to assess insight and delusionality, in addition to the Y-BOCS and BDD-YBOCS as noted above. Symptoms were assessed for the SCZ group with the Positive and Negative Syndrome Scale (PANSS) (Kay et al., 1987) which was scored using a 5 factor model that included orthogonal factors for positive, negative, cognitive, depression, and excitement symptoms (Lindenmayer et al., 1994a, b; Lindenmayer et al., 1995a, b). We also derived a separate disorganization factor (Cuesta and Peralta, 1995), and focused specifically on item P2, conceptual disorganization, given prior observed relationships between reduced PO, including CI, and reduced thought organization in SCZ (Uhlhaas and Silverstein, 2005; Silverstein and Keane, 2011). Lack of psychiatric diagnosis for the CON group was confirmed with the SCID, non-patient version (First et al., 2002a).

2.3 Perceptual Organization Tasks

2.3.1 Apparatus—Stimuli at the Rutgers site (SCZ and CON groups) were presented on Samsung 2243BWX LCD monitors with viewable dimensions of 47.5 by 29.8 cm. The screen resolution was 1680 $\times$ 1050 pixels, viewing distance was 24 inches (61.0 cm), and therefore, the viewable screen subtended 43° $\times$ 27° of visual angle. Monitor parameters were

a gamma value of 2.2, color temperature (white point) of 6500K, and luminance of 120 cd/m². Stimuli at the Massachusetts General Hospital site (BDD and OCD groups) were presented on a Hewlett Packard Compaq nc8430 LCD laptop monitor with a viewable dimension of 33.1 by 20.7 cm. The screen resolution was 1680 × 1050 pixels, viewing distance was 18 inches (45.7 cm), and the viewable screen subtended 40° × 26° of visual angle. Therefore, the stimuli were very similar between sites, but not quite identical—at MGH, one pixel subtended .0247 deg² and at Rutgers, .0266² (i.e., MGH stimuli were 93% as large as those at Rutgers). At MGH, monitor parameters were a gamma value of 2.2, color temperature (white point) of 6500K, and luminance of 112.9 cd/m².

2.3.2 Ebbinghaus illusion task—On each trial, the task was to press a key to indicate whether the target on the left or the right half of the screen was larger (see Figure 1). All circles were black and presented on a white background. The stimulus appeared on the screen until the subject responded or after two seconds (whichever happened first). If a response was not recorded within 2 seconds of stimulus onset, the trial was counted as a guess (0.5 correct) so as not to penalize subjects who preferred to time-out rather than guess on a trial. Trials were separated by 200 milliseconds. The targets were centered on either side of the screen and appeared with surrounding circles (see below). The two target circles always differed in actual size, and this difference varied in magnitude across trials. As noted, the size of the objects at MGH were 93% the size of the objects at Rutgers. At the Rutgers site, the center circle on one side was always 2.67° of visual angle in diameter, while the center circle on the other side was always 0.05°, 0.16°, 0.27°, 0.37°, or 0.48° larger or smaller. The side on which the larger circle appeared was randomized across trials. This size comparison was presented in 2 conditions. (1) In the *misleading* condition, the target circles were always surrounded by 8 larger circles arranged in a square configuration (i.e., 3 above, one on each side, and 3 below, see Figure 1). Each of the five size differences was shown sixteen times, with the larger central circle always surrounded by larger circles (for Rutgers 3.33° in diameter) and the smaller central circle always surrounded by smaller circles (for Rutgers 1.33° in diameter). In this condition, size contrast impairs discrimination by biasing the observer to perceive the larger target as smaller and the smaller target as larger (Doherty et al., 2008). (2) In the *helpful* context condition, the two target circles (for Rutgers 2.61° and 2.72° of visual angle) were presented eight times each, again surrounded by 8 circles around the edges of an imaginary square, with the smaller center circle surrounded by larger circles (for Rutgers 3.33° in diameter) and the larger central circle surrounded by smaller circles (for Rutgers 1.33° in diameter). In this condition, size contrast increases accuracy. Note that in this condition, if subjects choose the array with larger *surrounds* then they will be wrong on every trial. As in prior studies, only 16 trials were presented in the helpful condition, and they were all at the hardest difficulty level (for Rutgers .05° size difference between center circles) (Phillips et al., 2004; Doherty et al., 2008; Doherty, 2010). The 96 trials in the context conditions (80 in the misleading and 16 in the helpful conditions) were presented in a different random order for each subject. The primary performance index for this study was that of context sensitivity, defined as the difference between scores in the 16-trial helpful condition and scores in the 16-trials from the misleading condition with the same target-surround size difference as in the helpful condition (Silverstein et al., 2013).

2.3.3 Contour integration test—Participants were shown static Gabor elements forming an oblong shaped contour embedded in a display of randomly oriented Gabor elements (see Figure 2). On each trial, participants responded whether the narrow end of the oblong contour was pointing left or right. Perceptual organization was manipulated by adding orientation jitter to the Gabor elements forming the contours, across 6 levels: $\pm 0^\circ$, $7-8^\circ$, $9-10^\circ$, $11-12^\circ$, $13-14^\circ$, and $15-16^\circ$. For all stimuli, there were 207 noise Gabor, and 15 contour-defining Gabor elements. The ratio of the density of adjacent background elements to the density of adjacent contour elements was 0.9. At this level, adjacent background elements are closer together than adjacent contour elements, and thus CI requires integration of activity at the spatial filters corresponding to the Gabor elements; perception of the contour by density cues is not possible at $D < 1.0$. All Gabor elements were identical except for their position and orientation. At Rutgers, the average distance between adjacent elements was 1.0° . The width and wavelength of each element was 0.2° . At MGH, the average distance between adjacent elements was $.93^\circ$ and the width and wavelength of each element was 0.186° .

Each stimulus was presented for 2 seconds followed by a 1 second inter stimulus interval during which responses were no longer recorded. Forty-eight stimulus trials per jitter condition were presented in blocks of 12 trials. Two types of catch stimuli (i.e., no errors expected) using 0° jitter were administered during each block to assess momentary attention lapses. One had curved lines drawn through the contours to highlight contour salience, and the other contained contour elements without background elements to eliminate distractor noise effects. Blocks were presented in increasing order of difficulty (starting with $\pm 0^\circ$ and ending at $15-16^\circ$), and each 6-block sequence was repeated 4 times for a total of 288 experimental and 48 catch trials. Total score across all jitter conditions (excluding catch trials) was used as the performance index as this score has higher test-retest reliability compared to psychometric function threshold values (Strauss et al., 2014). As in prior studies (Silverstein et al., 2012a; Feigenson, 2014), a timed-out response was scored as 0.5 correct, to not give any advantage to subjects who preferred to guess rather than time-out on a trial.

2.4 Ethics

All procedures contributing to this work comply with the ethical standards of Rutgers and MGH IRBs. All subjects provided written informed consent.

3. Results

3.1 Demographic data

Table 1 summarizes demographic and psychometric data. Data on comorbid conditions can be found in Supplemental Results.

The groups did not differ in sex composition: Pearson's $X^2(3)=1.75$, $p=.63$. There was a significant between-group difference in age: $F(3,83)=3.17$, $p<.05$. Post-hoc Tukey tests indicated that the SCZ group (mean=42.25, SD=11.16) was significantly older than the

BDD (31.55, 12.36) group, but not the CON (38.1, 11.86) or OCD (36.10, 11.29) groups. There were no other significant pairwise differences.

3.2 Ebbinghaus illusion

The 4 groups were compared across the helpful and misleading indices with a 4 (group) x 2 (condition) ANOVA with repeated measures on the condition factor. As predicted, there was a significant effect of condition, with accuracy being superior in the helpful context compared to the misleading context condition: $F(1,80)=41.16$, $p<.001$, partial eta squared=.34. The main effect of group was not significant: $F(3,80)=1.96$, $p=.13$, partial eta squared=.068. However, the group x condition interaction was significant [$F(3,80)=3.39$, $p<.05$, partial eta squared=.11; see Figure 3]. This interaction was explored by comparing groups on the context sensitivity index. The main effect of group on this index was significant [$F(3,80)=4.23$, $p<.001$, partial eta squared=.14]. Pairwise comparisons (Tukey) revealed that the expected group difference between SCZ and CON (SCZ < CON) was observed, $p=.01$, replicating past studies of reduced context sensitivity in SCZ. The SCZ group also demonstrated reduced context sensitivity compared to the BDD and OCD groups at close to the .05 level (p values were .049 and .051, respectively). Pairwise comparisons between the BDD, OCD, and CON groups were all associated with p values greater than .95.

3.3 Contour integration test

There were no effects of group for either type of catch trial [for line type, $F(3,79)=1.83$, $p=.15$; for no background type, $F(3,79)=2.24$, $p=.09$] indicating that all groups were paying adequate attention to the task. On the non-catch trials, the SCZ group had the lowest proportion correct (see Figure 4). Including all jitter conditions in a mixed model ANOVA (group x jitter) revealed the expected main effect of jitter [$F(5, 395)=194.61$, $p<.001$], a trend towards a main effect of group [$F(3, 79)=2.50$, $p=.066$], and a non-significant group x jitter interaction [$F(15, 395)=0.44$, $p=.97$], the latter replicating past studies comparing controls and schizophrenia patients. When total proportion correct was used as the dependent variable, however, a significant effect of group was observed: [$F(3, 79)=7.67$, $p<.001$]. Post-hoc tests (Tukey) indicated that the SCZ group achieved significantly lower scores than the BDD ($p=.017$), OCD ($p=.001$), and CON ($p=.001$) groups. The BDD and OCD groups did not differ from each other or from the CON group. Further exploratory post-hoc analyses indicated that the groups did not differ in performance at jitter levels 0°, 7°, or 9° (the 3 easiest conditions) or 15° (the most difficult condition). However, at 11° jitter, the SCZ group performed more poorly than the CON group ($p=.023$), and at 13° jitter, the SCZ group performed more poorly than the OCD ($p=.021$) and CON ($p=.033$) groups. Similar results to those reported above were observed when age (which can be inversely correlated with contour integration (Del Viva and Agostini, 2007; Roudaia et al., 2011)) was used as a covariate, and when catch trial scores were used as covariates.

3.4 Relationships between symptoms and task performance for the BDD, OCD, and SCZ groups

There were no relationships between task scores and symptoms for any group, with one exception (for the SCZ group) that would not survive correction for multiple comparisons. See Supplemental Information for details.

4. Discussion

The primary finding from this study was that BDD patients do not perform as schizophrenia patients do on two-well validated measures of PO. Rather, their performance was statistically indistinguishable from that of OCD and psychiatrically healthy control groups. Our results are consistent with earlier studies that found normal performance among BDD patients on tasks that have been previously associated with abnormalities in schizophrenia, (Reese et al., 2011a, b), including a recently published study demonstrating normal CI (Rossell et al., 2014), despite the prevalence of delusional thinking regarding personal appearance in many BDD patients seen in clinical settings (Phillips et al., 2006). One potential implication of these findings is that PO impairment may be somewhat specific to schizophrenia, and perhaps other clearly neurodevelopmental conditions such as autism (Sun et al., 2012) among psychiatric disorders. This has been the conclusion in several earlier studies that used mixed groups of psychotic disorders (Silverstein et al., 1996; Silverstein et al., 2000), patients with non-psychotic psychiatric disorders (Uhlhaas et al., 2006), or people with non-psychotomimetic substance abuse disorders (Place and Gilmore, 1980; Uhlhaas et al., 2006) as control groups, and found normal performance therein.

Several limitations of the study must be noted. One is that only two tasks were included. Since scores on different tests involving PO are not always highly correlated (Joseph, Bae, and Silverstein, 2013), and since PO occurs at multiple stages of visual information processing (Palmer et al., 2003), it is possible that it involves multiple components. This raises the possibility that SCZ and BDD could both be impaired, but on different sub-processes, and that the tests we included are not sensitive to BDD-specific impairment. Related to this, it is possible that inclusion of tests on which BDD patients are known to perform poorly (e.g., face inversion (Feusner et al., 2010b)) would have revealed domains of greater similarity between the SCZ and BDD groups. This of course raises the issue of the nature of the perceptual impairment in BDD, which will be addressed below. Second, 13 of the 20 BDD participants, half of the OCD, and all of the SCZ participants were medicated. While antipsychotic medication does not appear to affect PO (Silverstein and Keane, 2011), little is known about the perceptual effects of serotonin reuptake inhibitors, and it is possible that they may have resulted in normalization of underlying perceptual disturbances. A third limitation is that the symptom assessment measures given to the patients differed across diagnostic groups. While the measures used were typical and appropriate for clinical and research assessment of each group, a more thorough evaluation of group similarities and differences in PO might have been possible if data on each of the scales were available for all patients regardless of diagnosis. A fourth limitation is that the display devices used to present the tasks differed across the two sites. We consider it unlikely that the pattern of results we observed is related to this, given the similarity in the tasks' basic effects across

multiple studies (cited above) using these identical tasks within the context of variation in display devices, and therefore in stimulus size and brightness. For the CI task, this includes similar results from studies where controls and patients were each tested at different, non-standardized sites (Kozma-Weibe, 2006), where controls and patients were both tested at multiple sites (Silverstein et al., 2012a), and where controls and patients were tested at the same single site (Silverstein et al., 2000; Silverstein et al., 2009). In addition, the luminance measurements of the monitors, and stimulus sizes, at Rutgers and MGH were very similar (e.g., MGH stimuli were 93% as large as Rutgers'). And, importantly, scale invariance (i.e., similarity in results across variations in stimulus size) has been previously demonstrated for the CI task (Hess and Dakin, 1997; Keane et al., 2014). A fifth limitation is that the BDD and SCZ groups differed in age, with the latter group being older. This is potentially problematic because perceptual organization, in the form of contour integration, has been shown to gradually decline with age in later adulthood (Del Viva and Agostini, 2007; Roudaia et al., 2008). However, the overall pattern of findings in the study, especially the expected differences between the SCZ and CON groups, cannot be explained by age since these two groups did not differ in age.

A final, and perhaps most important, limitation is that the SCZ group was an inpatient group while the BDD and OCD groups were outpatients. This was a deliberate aspect of the study design, because both tasks included in this study have demonstrated relationships with disorganized and psychotic symptoms in past studies, whereas performance is often much closer to normal after symptom remission (Uhlhaas et al., 2006; Silverstein et al., 2013). This is thought to reflect improvements in underlying mechanisms (computational and neurobiological) that are common to these symptoms and to aspects of abnormal perception, rather than simply the result of reduced interference from symptoms on task performance after symptoms remit (Phillips and Silverstein, 2003). So, rather than simply reflecting greater overall disability in the SCZ group, our findings can be taken as further evidence that schizophrenia-related processes are connected with abnormal PO. We consider it unlikely that the group differences simply reflect inpatient vs. outpatient status, since: 1) among SCZ patients in this study, we observed moderate effects (but at the trend level of evidence) for relationships between poorer context sensitivity (on the Ebbinghaus illusion task) and conceptual disorganization – a symptom that often leads to hospitalization (see Supplemental Information), and these effects have been observed at statistically significant levels in several prior studies (Uhlhaas and Silverstein, 2005; Silverstein and Keane, 2011); this symptom is not characteristic of either BDD or OCD, however; 2) CI performance has been shown to be stable from inpatient admission to discharge in SCZ patients, (Feigenson et al., 2014), and so similar results to those we observed can be expected in most outpatients with schizophrenia on the CI task; and 3) other groups of inpatients, including psychotic patients without schizophrenia, people with non-psychotomimetic substance abuse disorders, and brain injured patients with behavior disorders, all perform normally on either or both of the tests used in this study (Silverstein et al., 2000; Uhlhaas et al., 2005; Uhlhaas et al., 2006). However, it cannot be ruled out that BDD and/or OCD patients who require hospitalization for their OCD spectrum conditions might perform more abnormally on the two perception tasks compared to the patients included in this study, and so this requires further investigation.

A major question raised by the data involves the nature of the perceptual impairment in BDD. While earlier studies (reviewed in the Introduction) suggested an impairment in global form processing that might indicate reduced PO in BDD, the problem may lie elsewhere. For example, as noted above, recent work on the face inversion effect suggests that it is not due to an inability to process global features of inverted faces. Rather, it may be due to the more rapid (top-down) application of face-specific schemata during interpretation of sensory information in the upright faces condition (Rakover, 2013). This raises the possibility that high-level perceptual and/or emotional factors in BDD, distinct from PO, may interfere with this process. Alternatively, since in both studies that found reduced face inversion effects in BDD (Feusner et al., 2010b; Jefferies et al., 2012), the differences were due to better performance than controls with inverted faces, yet similar performance with upright faces, it is possible that individuals with BDD may have a tendency to preferentially allocate attention to processing details, particularly when allowed longer viewing durations, even when PO is normal.

It is also possible that reduced occipital activation in laboratory perception tasks among people with BDD reflects excessive modulation of feedforward perceptual activity, perhaps driven by emotional factors. This possibility has not yet been studied, although the ability of prefrontal areas to modulate occipital activity is now generally accepted (Cavada et al., 2000; Rainer and Miller, 2000; Petrides et al., 2002; van Turenout et al., 2003; Hasson et al., 2004; Bar et al., 2006; Deshpande et al., 2010; Chaumon et al., 2013; Volberg et al., 2013; Volberg and Greenlee, 2014). Moreover, the amygdala provides input to the frontal cortex that can affect perception (Sabatinelli et al., 2014), and emotion affects the likelihood that arousing information will be processed (Phelps et al., 2006), as well as how quickly it is processed (Ohman et al., 2001). The amygdala is also connected to both the ventral and dorsal visual streams; through these pathways, top-down signals may be carried to the visual cortex to enhance visual processing for emotionally salient stimuli (Furl et al., 2013), which may shift balances in global and local processing. In individuals with BDD, Bohon et al. (Bohon et al., 2012) found associations between brain activity in amygdala and in the ventral visual stream, as well as an association between anxiety and ventral visual stream activity, suggesting that arousal may increase processing of details in this population. In addition, expectations regarding what one will see can affect how much attention is allocated to processing a stimulus (Bressler et al., 2008). These data suggest that heightened emotional activity, especially regarding one's own appearance, excessively modulates the feedforward sweep of visual information, so that perception is excessively dominated by emotion-syntonic schemata. However, hypoactivity in visual association areas in BDD has been observed not only for emotionally-salient stimuli (own and others' faces) but also for stimuli that are not normally emotionally arousing (e.g., pictures of houses) (Feusner et al., 2011).

Finally, several studies of BDD have demonstrated reduced processing of low spatial frequency (LSF) information. While this typically carries information about global form, reduced LSF processing does not necessarily lead to reduced PO. Another function of LSF processing is to direct attention to relevant aspects in the visual field (Bar et al., 2006). It is therefore possible that reduced LSF processing in BDD serves as a setting condition for allocation of visual attention to be driven more by internal factors than by global form, even

if global form can be processed normally under many conditions. All of these potential scenarios suggest the possibility of a perception and emotion-mediated attentional bias in BDD that is different from what characterizes schizophrenia, but that can, in some cases, lead to similar clinical phenomena.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

We would like to thank Amanda Calkins, Lillian Reuman, Yushi Wang, and Danielle Paterno for their help with recruitment and testing. This research was supported in part by fellowship support awarded to Corinna Elliott from the Fonds de Recherche du Québec - Santé (FRQS), by NIMH grant R01MH093439 to the first author, by NIH IRACDA Postdoctoral Training Grant 1K12GM093854-05 to M. W. Roché, and by funding from The Neil and Anna Rasmussen Foundation to the last author.

References

- Bar M, Kassam KS, Ghuman AS, Boshyan J, Schmid AM, Dale AM, Hamalainen MS, Marinkovic K, Schacter DL, Rosen BR, Halgren E. Top-down facilitation of visual recognition. *Proceedings of the National Academy of Sciences*. 2006; 103:449–454.
- Bellivier F, Geoffroy PA, Scott J, Schurhoff F, Leboyer M, Etain B. Biomarkers of bipolar disorder: specific or shared with schizophrenia? *Frontiers in Bioscience*. 2013; 5:845–863.
- Bohon C, Hembacher E, Moller H, Moody TD, Feusner JD. Nonlinear relationships between anxiety and visual processing of own and others' faces in body dysmorphic disorder. *Psychiatry Research*. 2012; 204:132–139. [PubMed: 23137801]
- Bressler SL, Tang W, Sylvester CM, Shulman GL, Corbetta M. Top-down control of human visual cortex by frontal and parietal cortex in anticipatory visual spatial attention. *Journal of Neuroscience*. 2008; 28:10056–10061. [PubMed: 18829963]
- Butler PD, Tambini A, Yovel G, Jalbrzikowski M, Ziwich R, Silipo G, Kanwisher N, Javitt DC. What's in a face? Effects of stimulus duration and inversion on face processing in schizophrenia. *Schizophrenia Research*. 2008; 103:283–292. [PubMed: 18450426]
- Cavada C, Company T, Tejedor J, Cruz-Rizzolo RJ, Reinoso-Suarez F. The anatomical connections of the macaque monkey orbitofrontal cortex. A review. *Cerebral Cortex*. 2000; 10:220–242. [PubMed: 10731218]
- Chambon V, Baudouin JY, Franck N. The role of configural information in facial emotion recognition in schizophrenia. *Neuropsychologia*. 2006; 44:2437–2444. [PubMed: 16806310]
- Chandna A, Pennefather PM, Kovacs I, Norcia AM. Contour integration deficits in anisometropic amblyopia. *Investigative Ophthalmology & Visual Science*. 2001; 42:875–878. [PubMed: 11222553]
- Chaumon M, Kveraga K, Barrett LF, Bar M. Visual Predictions in the Orbitofrontal Cortex Rely on Associative Content. *Cerebral Cortex*. 2014; 24:2899–2907. [PubMed: 23771980]
- Chen Y, Norton D, Ongur D, Heckers S. Inefficient face detection in schizophrenia. *Schizophrenia Bulletin*. 2008; 34:367–374. [PubMed: 17631619]
- Civile C, McLaren RP, McLaren IP. The face inversion effect—parts and wholes: individual features and their configuration. *Quarterly Journal of Experimental Psychology*. 2014; 67:728–746.
- Coren S, Enns JT. Size contrast as a function of conceptual similarity between test and inducers. *Perception & Psychophysics*. 1993; 54:579–588. [PubMed: 8290327]
- Costen NP, Parker DM, Craw I. Effects of high-pass and low-pass spatial filtering on face identification. *Perception & Psychophysics*. 1996; 58:602–612. [PubMed: 8934690]
- Cuesta MJ, Peralta V. Psychopathological dimensions in schizophrenia. *Schizophrenia Bulletin*. 1995; 21:473–482. [PubMed: 7481577]

- Cuthbert BN, Insel TR. Toward New Approaches to Psychotic Disorders: The NIMH Research Domain Criteria Project. *Schizophrenia Bulletin*. 2010; 36:1061–1062. [PubMed: 20929969]
- Dakin S, Frith U. Vagaries of visual perception in autism. *Neuron*. 2005; 48:497–507. [PubMed: 16269366]
- Deckersbach T, Otto MW, Savage CR, Baer L, Jenike MA. The relationship between semantic organization and memory in obsessive-compulsive disorder. *Psychotherapy & Psychosomatics*. 2000a; 69:101–107. [PubMed: 10671831]
- Deckersbach T, Savage CR, Henin A, Mataix-Cols D, Otto MW, Wilhelm S, Rauch SL, Baer L, Jenike MA. Reliability and validity of a scoring system for measuring organizational approach in the Complex Figure Test. *Journal of Clinical and Experimental Neuropsychology*. 2000b; 22:640–648. [PubMed: 11094399]
- Deckersbach T, Savage CR, Phillips KA, Wilhelm S, Buhlmann U, Rauch SL, Baer L, Jenike MA. Characteristics of memory dysfunction in body dysmorphic disorder. *Journal of the International Neuropsychological Society*. 2000c; 6:673–681. [PubMed: 11011514]
- Del Viva MM, Agostini R. Visual spatial integration in the elderly. *Investigative Ophthalmology & Visual Science*. 2007; 48:2940–2946. [PubMed: 17525231]
- Deruelle C, Fagot J. Categorizing facial identities, emotions, and genders: attention to high- and low-spatial frequencies by children and adults. *Journal of Experimental Child Psychology*. 2005; 90:172–184. [PubMed: 15683861]
- Deshpande G, Hu X, Lacey S, Stilla R, Sathian K. Object familiarity modulates effective connectivity during haptic shape perception. *NeuroImage*. 2010; 49:1991–2000. [PubMed: 19732841]
- Doherty JL, Owen MJ. Genomic insights into the overlap between psychiatric disorders: implications for research and clinical practice. *Genome Medicine*. 2014; 6:29. [PubMed: 24944580]
- Doherty MJ, Campbell NM, Tsuji H, Phillips WA. The Ebbinghaus illusion deceives adults but not children. *Developmental Science*. 2010; 13:714–721. [PubMed: 20712737]
- Doherty MJ, Tsuji H, Phillips WA. The context sensitivity of visual size perception varies across cultures. *Perception*. 2008; 37:1426–1433. [PubMed: 18986068]
- Eisen JL, Phillips KA, Baer L, Beer DA, Atala KD, Rasmussen SA. The Brown Assessment of Beliefs Scale: reliability and validity. *American Journal of Psychiatry*. 1998; 155:102–108. [PubMed: 9433346]
- Feigenson KA, Keane BP, Roche MW, Silverstein SM. Contour integration impairment in schizophrenia and first episode psychosis: state or trait? *Schizophrenia Research*. 2014; 159:515–520. [PubMed: 25306205]
- Feusner JD, Bystritsky A, Helleman G, Bookheimer S. Impaired identity recognition of faces with emotional expressions in body dysmorphic disorder. *Psychiatry Research*. 2010a; 179:318–323. [PubMed: 20493560]
- Feusner JD, Hembacher E, Moller H, Moody TD. Abnormalities of object visual processing in body dysmorphic disorder. *Psychological Medicine*. 2011; 41:2385–2397. [PubMed: 21557897]
- Feusner JD, Moller H, Altstein L, Sugar C, Bookheimer S, Yoon J, Hembacher E. Inverted face processing in body dysmorphic disorder. *Journal of Psychiatric Research*. 2010b; 44:1088–1094. [PubMed: 20434170]
- Feusner JD, Moody T, Hembacher E, Townsend J, McKinley M, Moller H, Bookheimer S. Abnormalities of visual processing and frontostriatal systems in body dysmorphic disorder. *Archives of General Psychiatry*. 2010c; 67:197–205. [PubMed: 20124119]
- Feusner JD, Townsend J, Bystritsky A, Bookheimer S. Visual information processing of faces in body dysmorphic disorder. *Archives of General Psychiatry*. 2007; 64:1417–1425. [PubMed: 18056550]
- Field DJ, Hayes A, Hess RF. Contour integration by the human visual system: evidence for a local “association field”. *Vision Research*. 1993; 33:173–193. [PubMed: 8447091]
- First, M.; Spitzer, R.; Gibbon, M.; Williams, JBW. Biometrics Research. New York, NY: New York State Psychiatric Institute; 2002a. Structured clinical interview for DSM-IV-TR Axis I Disorders, Research Version, Non-Patient Edition. (SCID-I/NP).
- First, M.; Spitzer, R.; Gibbon, M.; Williams, JBW. Biometrics Research. New York, NY: New York State Psychiatric Institute; 2002b. Structured clinical interview for DSM-IV-TR Axis I Disorders, Research Version, Patient Edition. (SCID-I/P).

- Freire A, Lee K, Symons LA. The face-inversion effect as a deficit in the encoding of configural information: direct evidence. *Perception*. 2000; 29:159–170. [PubMed: 10820599]
- Furl N, Henson RN, Friston KJ, Calder AJ. Top-down control of visual responses to fear by the amygdala. *Journal of Neuroscience*. 2013; 33:17435–17443. [PubMed: 24174677]
- Girgus JS, Coren S, Agdern M. The interrelationship between the Ebbinghaus and Delboeuf illusions. *Journal of Experimental Psychology*. 1972; 95:453–455. [PubMed: 5071920]
- Goodman WK, Price LH, Rasmussen SA, Mazure C, Delgado P, Heninger GR, Charney DS. The Yale-Brown Obsessive Compulsive Scale. II. Validity. *Archives of General Psychiatry*. 1989a; 46:1012–1016. [PubMed: 2510699]
- Goodman WK, Price LH, Rasmussen SA, Mazure C, Fleischmann RL, Hill CL, Heninger GR, Charney DS. The Yale-Brown Obsessive Compulsive Scale. I. Development, use, and reliability. *Archives of General Psychiatry*. 1989b; 46:1006–1011. [PubMed: 2684084]
- Guilmatre A, Dubourg C, Mosca AL, Legallie S, Goldenberg A, Drouin-Garraud V, Layet V, Rosier A, Briault S, Bonnet-Brilhault F, Laumonnier F, Odent S, Le Vacon G, Joly-Helas G, David V, Bendavid C, Pinoit JM, Henry C, Impallomeni C, Germano E, Tortorella G, Di Rosa G, Barthelemy C, Andres C, Faivre L, Frebourg T, Saugier Veber P, Champion D. Recurrent rearrangements in synaptic and neurodevelopmental genes and shared biologic pathways in schizophrenia, autism, and mental retardation. *Archives of General Psychiatry*. 2009; 66:947–956. [PubMed: 19736351]
- Hasson U, Nir Y, Levy I, Fuhrmann G, Malach R. Intersubject synchronization of cortical activity during natural vision. *Science*. 2004; 303:1634–1640. [PubMed: 15016991]
- Hess RF, Dakin SC. Absence of contour linking in peripheral vision. *Nature*. 1997; 390:602–604. [PubMed: 9403687]
- Insel T, Cuthbert B, Garvey M, Heinssen R, Pine DS, Quinn K, Sanislow C, Wang P. Research domain criteria (RDoC): toward a new classification framework for research on mental disorders. *American Journal of Psychiatry*. 2010; 167:748–751. [PubMed: 20595427]
- Jefferies K, Laws KR, Fineberg NA. Superior face recognition in Body Dysmorphic Disorder. *Journal of Obsessive-Compulsive and Related Disorders*. 2012; 1:175–179.
- Joseph J, Bae G, Silverstein SM. Sex, symptom, and premorbid social functioning associated with perceptual organization and dysfunction in schizophrenia. *Frontiers in Psychology*. 2013; 4:547. [PubMed: 23986732]
- Kay SR, Fiszbein A, Opler LA. The positive and negative syndrome scale (PANSS) for schizophrenia. *Schizophrenia Bulletin*. 1987; 13:261–276. [PubMed: 3616518]
- Keane BP, Erlikhman G, Kastner S, Paterno D, Silverstein SM. Multiple forms of contour grouping deficits in schizophrenia: what is the role of spatial frequency? *Neuropsychologia*. 2014; 65:221–233. [PubMed: 25446968]
- Knight RA, Silverstein SM. A process-oriented approach for averting confounds resulting from general performance deficiencies in schizophrenia. *Journal of Abnormal Psychology*. 2001; 110:15–30. [PubMed: 11261389]
- Kovacs I. Human development of perceptual organization. *Vision Research*. 2000; 40:1301–1310. [PubMed: 10788641]
- Kovacs I, Julesz B. A closed curve is much more than an incomplete one: effect of closure in figure-ground segmentation. *Proceedings of the National Academy of Sciences*. 1993; 90:7495–7497.
- Kozma-Weibe P, Silverstein SM, Feher A, Kovacs I, Uhlhaas P, Wilkniess S. Development of a World-Wide-Web based contour integration test: Reliability and validity. *Computers in Human Behavior*. 2006; 22:971–980.
- Lindenmayer JP, Bernstein-Hyman R, Grochowski S. Five-factor model of schizophrenia. Initial validation. *Journal of Nervous and Mental Disease*. 1994a; 182:631–638. [PubMed: 7964671]
- Lindenmayer JP, Bernstein-Hyman R, Grochowski S. A new five factor model of schizophrenia. *Psychiatric Quarterly*. 1994b; 65:299–322. [PubMed: 7831416]
- Lindenmayer JP, Bernstein-Hyman R, Grochowski S, Bark N. Psychopathology of Schizophrenia: initial validation of a 5-factor model. *Psychopathology*. 1995a; 28:22–31. [PubMed: 7871117]
- Lindenmayer JP, Grochowski S, Hyman RB. Five factor model of schizophrenia: replication across samples. *Schizophrenia Research*. 1995b; 14:229–234. [PubMed: 7766534]

- Massaro DW, Anderson NH. Judgmental model of the Ebbinghaus illusion. *Journal of Experimental Psychology*. 1971; 89:147–151. [PubMed: 5569620]
- Monzani B, Rijdsdijk F, Harris J, Mataix-Cols D. The structure of genetic and environmental risk factors for dimensional representations of DSM-5 obsessive-compulsive spectrum disorders. *JAMA Psychiatry*. 2014; 71:182–189. [PubMed: 24369376]
- Mundy EM, Sadusky A. Abnormalities in visual processing amongst students with body image concerns. *Advances in Cognitive Psychology*. 2014; 10:39–48. [PubMed: 25157299]
- Ohman A, Flykt A, Esteves F. Emotion drives attention: detecting the snake in the grass. *Journal of Experimental Psychology: General*. 2001; 130:466–478. [PubMed: 11561921]
- Palmer, SE. *Vision science: photons to phenomenology*. Cambridge, MA: MIT Press; 1999.
- Palmer SE, Brooks JL, Nelson R. When does grouping happen? *Acta Psychologica*. 2003; 114:311–330. [PubMed: 14670702]
- Peters ER, Joseph SA, Garety PA. Measurement of delusional ideation in the normal population: introducing the PDI (Peters et al. Delusions Inventory). *Schizophrenia Bulletin*. 1999; 25:553–576. [PubMed: 10478789]
- Peters JC, Vlamings P, Kemner C. Neural processing of high and low spatial frequency information in faces changes across development: qualitative changes in face processing during adolescence. *European Journal of Neuroscience*. 2013; 37:1448–1457. [PubMed: 23480636]
- Petrides M, Alivisatos B, Frey S. Differential activation of the human orbital, mid-ventrolateral, and mid-dorsolateral prefrontal cortex during the processing of visual stimuli. *Proceedings of the National Academy of Science*. 2002; 99:5649–5654.
- Phelps EA, Ling S, Carrasco M. Emotion facilitates perception and potentiates the perceptual benefits of attention. *Psychological Science*. 2006; 17:292–299. [PubMed: 16623685]
- Phillips KA, Hollander E, Rasmussen SA, Aronowitz BR, DeCaria C, Goodman WK. A severity rating scale for body dysmorphic disorder: development, reliability, and validity of a modified version of the Yale-Brown Obsessive Compulsive Scale. *Psychopharmacology Bulletin*. 1997; 33:17–22. [PubMed: 9133747]
- Phillips KA, Menard W, Pagano ME, Fay C, Stout RL. Delusional versus nondelusional body dysmorphic disorder: clinical features and course of illness. *Journal of Psychiatric Research*. 2006; 40:95–104. [PubMed: 16229856]
- Phillips WA, Chapman KL, Berry PD. Size perception is less context-sensitive in males. *Perception*. 2004; 33:79–86. [PubMed: 15035330]
- Phillips WA, Silverstein SM. Convergence of biological and psychological perspectives on cognitive coordination in schizophrenia. *Behavioral and Brain Sciences*. 2003; 26:65–82. discussion 82–137. [PubMed: 14598440]
- Place EJ, Gilmore GC. Perceptual organization in schizophrenia. *Journal of Abnormal Psychology*. 1980; 89:409–418. [PubMed: 7410708]
- Polat U, Sagi D, Norcia AM. Abnormal long-range spatial interactions in amblyopia. *Vision Research*. 1997; 37:737–744. [PubMed: 9156218]
- Rainer G, Miller EK. Effects of visual experience on the representation of objects in the prefrontal cortex. *Neuron*. 2000; 27:179–189. [PubMed: 10939341]
- Rakover SS. Explaining the face-inversion effect: the face-scheme incompatibility (FSI) model. *Psychonomic Bulletin & Review*. 2013; 20:665–692. [PubMed: 23381811]
- Reese HE, McNally RJ, Wilhelm S. Probabilistic reasoning in patients with body dysmorphic disorder. *Journal of Behavior Therapy and Experimental Psychiatry*. 2011a; 42:270–276. [PubMed: 21349243]
- Reese HE, McNally RJ, Wilhelm S. Reality monitoring in patients with body dysmorphic disorder. *Behavior Therapy*. 2011b; 42:387–398. [PubMed: 21658522]
- Rose D, Bressan P. Going round in circles: shape effects in the Ebbinghaus illusion. *Spatial Vision*. 2002; 15:191–203. [PubMed: 11991574]
- Rossell SL, Labuschagne I, Dunai J, Kyrios M, Castle DJ. Using theories of delusion formation to explain abnormal beliefs in Body Dysmorphic Disorder (BDD). *Psychiatry Research*. 2014; 215:599–605. [PubMed: 24412353]

- Roudaia E, Bennett PJ, Sekuler AB. The effect of aging on contour integration. *Vision Research*. 2008; 48:2767–2774. [PubMed: 18831983]
- Roudaia E, Farber LE, Bennett PJ, Sekuler AB. The effects of aging on contour discrimination in clutter. *Vision Research*. 2011; 51:1022–1032. [PubMed: 21345346]
- Sabatinielli D, Frank DW, Wanger TJ, Dhamala M, Adhikari BM, Li X. The timing and directional connectivity of human frontoparietal and ventral visual attention networks in emotional scene perception. *Neuroscience*. 2014; 277:229–238. [PubMed: 25018086]
- Savage CR, Deckersbach T, Wilhelm S, Rauch SL, Baer L, Reid T, Jenike MA. Strategic processing and episodic memory impairment in obsessive compulsive disorder. *Neuropsychology*. 2000; 14:141–151. [PubMed: 10674806]
- Schwartz BL, Marvel CL, Drapalski A, Rosse RB, Deutsch SI. Configural processing in face recognition in schizophrenia. *Cognitive Neuropsychiatry*. 2002; 7:15–39. [PubMed: 16528403]
- Schwarzkopf DS, Rees G. Subjective Size Perception Depends on Central Visual Cortical Magnification in Human V1. *PLoS One*. 2013; 8:e60550. [PubMed: 23536915]
- Silverstein SM. Measuring specific, rather than generalized, cognitive deficits and maximizing between-group effect size in studies of cognition and cognitive change. *Schizophrenia Bulletin*. 2008; 34:645–655. [PubMed: 18468987]
- Silverstein SM, All SD, Kasi R, Berten S, Essex B, Lathrop KL, Little DM. Increased fusiform area activation in schizophrenia during processing of spatial frequency-degraded faces, as revealed by fMRI. *Psychological Medicine*. 2010; 40:1159–1169. [PubMed: 19895721]
- Silverstein SM, Berten S, Essex B, Kovacs I, Susmaras T, Little DM. An fMRI examination of visual integration in schizophrenia. *Journal of Integrative Neuroscience*. 2009; 8:175–202. [PubMed: 19618486]
- Silverstein SM, Keane BP. Perceptual organization impairment in schizophrenia and associated brain mechanisms: review of research from 2005 to 2010. *Schizophrenia Bulletin*. 2011; 37:690–699. [PubMed: 21700589]
- Silverstein SM, Keane BP, Barch DM, Carter CS, Gold JM, Kovacs I, MacDonald A 3rd, Ragland JD, Strauss ME. Optimization and validation of a visual integration test for schizophrenia research. *Schizophrenia Bulletin*. 2012a; 38:125–134. [PubMed: 22021658]
- Silverstein SM, Keane BP, Barch DM, Carter CS, Gold JM, Kovács I, MacDonald A, Ragland JD, Strauss ME. Optimization and validation of a visual integration test for schizophrenia research. *Schizophrenia Bulletin*. 2012b; 38:125–134. [PubMed: 22021658]
- Silverstein SM, Keane BP, Wang Y, Mikkilineni D, Paterno D, Papatomas TV, Feigenson K. Effects of short-term inpatient treatment on sensitivity to a size contrast illusion in first-episode psychosis and multiple-episode schizophrenia. *Frontiers in Psychology*. 2013; 4:466. [PubMed: 23898311]
- Silverstein SM, Knight RA, Schwarzkopf SB, West LL, Osborn LM, Kamin D. Stimulus configuration and context effects in perceptual organization in schizophrenia. *Journal of Abnormal Psychology*. 1996; 105:410–420. [PubMed: 8772011]
- Silverstein SM, Kovacs I, Corry R, Valone C. Perceptual organization, the disorganization syndrome, and context processing in chronic schizophrenia. *Schizophrenia Research*. 2000; 43:11–20. [PubMed: 10828411]
- Simmers AJ, Bex PJ. Deficit of visual contour integration in dyslexia. *Investigative Ophthalmology & Visual Science*. 2001; 42:2737–2742. [PubMed: 11581223]
- Soria Bauser D, Thoma P, Aizenberg V, Brune M, Juckel G, Daum I. Face and body perception in schizophrenia: a configural processing deficit? *Psychiatry Research*. 2012; 195:9–17. [PubMed: 21803427]
- Strauss ME, McLouth CJ, Barch DM, Carter CS, Gold JM, Luck SJ, MacDonald AW 3rd, Ragland JD, Ranganath C, Keane BP, Silverstein SM. Temporal Stability and Moderating Effects of Age and Sex on CNTRaCS Task Performance. *Schizophrenia Bulletin*. 2014; 40:835–844. [PubMed: 23817024]
- Sun L, Grutzner C, Bolte S, Wibral M, Tozman T, Schlitt S, Poustka F, Singer W, Freitag CM, Uhlhaas PJ. Impaired gamma-band activity during perceptual organization in adults with autism spectrum disorders: evidence for dysfunctional network activity in frontal-posterior cortices. *Journal of Neuroscience*. 2012; 32:9563–9573. [PubMed: 22787042]

- Tanaka JW, Farah MJ. Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology A*. 1993; 46:225–245.
- Tanaka JW, Sengco JA. Features and their configuration in face recognition. *Memory & Cognition*. 1997; 25:583–592. [PubMed: 9337578]
- Taubert J, Aporthorp D, Aagten-Murphy D, Alais D. The role of holistic processing in face perception: evidence from the face inversion effect. *Vision Research*. 2011; 51:1273–1278. [PubMed: 21496463]
- Titchener, EB. *Experimental Psychology*. New York, NY: The MacMillan Company; 1902.
- Tsunoda T, Kanba S, Ueno T, Hirano Y, Hirano S, Maekawa T, Onitsuka T. Altered face inversion effect and association between face N170 reduction and social dysfunction in patients with schizophrenia. *Clinical Neurophysiology*. 2012; 123:1762–1768. [PubMed: 22456098]
- Turetsky BI, Kohler CG, Indersmitten T, Bhati MT, Charbonnier D, Gur RC. Facial emotion recognition in schizophrenia: when and why does it go awry? *Schizophrenia Research*. 2007; 94:253–263. [PubMed: 17583481]
- Uhlhaas PJ, Millard I, Muetzelfeldt L, Curran HV, Morgan CJ. Perceptual organization in ketamine users: preliminary evidence of deficits on night of drug use but not 3 days later. *Journal of Psychopharmacology*. 2007; 21:347–352. [PubMed: 17591661]
- Uhlhaas PJ, Phillips WA, Mitchell G, Silverstein SM. Perceptual grouping in disorganized schizophrenia. *Psychiatry Research*. 2006; 145:105–117. [PubMed: 17081620]
- Uhlhaas PJ, Phillips WA, Silverstein SM. The course and clinical correlates of dysfunctions in visual perceptual organization in schizophrenia during the remission of psychotic symptoms. *Schizophrenia Research*. 2005; 75:183–192. [PubMed: 15885509]
- Uhlhaas PJ, Silverstein SM. Perceptual organization in schizophrenia spectrum disorders: empirical research and theoretical implications. *Psychological Bulletin*. 2005; 131:618–632. [PubMed: 16060805]
- van Turennout M, Bielamowicz L, Martin A. Modulation of neural activity during object naming: effects of time and practice. *Cerebral Cortex*. 2003; 13:381–391. [PubMed: 12631567]
- Volberg G, Greenlee MW. Brain networks supporting perceptual grouping and contour selection. *Frontiers in Psychology*. 2014; 5:264. [PubMed: 24772096]
- Volberg G, Wutz A, Greenlee MW. Top-down control in contour grouping. *PLoS One*. 2013; 8:e54085. [PubMed: 23326575]
- Weintraub DJ, Schneek MK. Fragments of Delboeuf and Ebbinghaus illusions: contour/context explorations of misjudged circle size. *Attention, Perception, & Psychophysics*. 1986; 40:147–158.
- White C, Brown J, Edwards M. Altered visual perception in long-term ecstasy (MDMA) users. *Psychopharmacology*. 2013; 229:155–165. [PubMed: 23609769]
- Xu X, Biederman I. Neural correlates of face detection. *Cerebral Cortex*. 2014; 24:1555–1564. [PubMed: 23365211]

Highlights

1. Among psychiatric populations, only schizophrenia and body dysmorphic disorder appear to be characterized by visual perceptual organization impairments.
2. This study represents the first direct comparison of schizophrenia and body dysmorphic disorder on perceptual organization.
3. Only schizophrenia patients were characterized by a disturbance in perceptual organization.
4. The excessive focus on visual detail in body dysmorphic disorder likely arises from disturbances in processes other than visual perceptual organization.

Figure 1. Sample stimuli from each of the 2 conditions (bottom 2 panels) of the Ebbinghaus illusion task. In each case, the target circle on the right is larger than the one on the left. The top panel shows the actual circle sizes, for comparison.

Figure 2.

Sample stimuli from the contour integration test. Top left: 7–8° jitter, leaving a still visible contour. Top right: 15–16° jitter, leaving a contour that most people cannot detect. Bottom left: Catch trial with line drawn through contour, to eliminate the need for grouping. Bottom right: Catch trial with no background, eliminating effects of noise

Figure 3.

Ebbinghaus illusion: Context sensitivity values, by group. Error bars represent 1 SD. Dotted line represents post-hoc pairwise group difference at the 0.1 level of statistical significance. Dashed line represents a pairwise difference at $p < .05$.

Figure 4.

Contour integration test: Proportion accuracy, by group. Error bars represent 1 SD. Solid lines represent group differences at the .001 level of statistical significance in post-hoc pairwise comparisons. Dashed line represents a pairwise difference at $p < .05$.

Table 1

Means (SDs) for study variables, by group.

	BDD (n=20)	OCD (n=20)	SCZ (n=24)	CON (n=20)
Age [^]	31.55(12.36)	36.10(11.29)	42.25(11.16)	38.10(11.86)
Ebbinghaus – Misleading context [^]	37.39(26.38)	47.21(23.83)	60.77(26.90)	47.13(19.67)
Ebbinghaus – Helpful context [^]	86.14(27.15)	87.17(29.30)	67.40(39.06)	91.48(19.62)
Ebbinghaus – Context sensitivity ^{^^}	11.15(8.45)	11.10(8.50)	3.88(11.83)	12.60(6.14)
Contour Integration – Main trials [*]	65.38(13.89)	65.89(10.97)	62.80(9.83)	71.35(11.00)
Contour Integration – Catch trial: Line	92.71(22.78)	98.33(3.42)	89.93(17.15)	97.50(4.36)
Contour Integration – Catch trial: No Noise	93.54(22.72)	97.71(3.44)	89.93(15.68)	98.33(2.49)
Y-BOCS ^{^^^}	3.25(6.92)	22.75(4.85)	*****	*****
BDD Y-BOCS ^{^^^}	26.65(4.88)	3.90(7.73)	*****	*****
BABS ^{^^}	11.15(5.21)	2.70(5.88)	*****	*****
PDI	6.50(4.88)	9.2(11.43)	*****	*****
PANSS – Positive	*****	*****	12.13(3.53)	*****
PANSS – Negative	*****	*****	16.79(3.75)	*****
PANSS – Cognitive	*****	*****	11.38(3.05)	*****
PANSS – Excitement	*****	*****	9.54(3.19)	*****
PANSS – Depression	*****	*****	14.04(4.87)	*****
PANSS – Disorganization	*****	*****	5.96(2.01)	*****
PANS – Conceptual Disorganization	*****	*****	2.13(1.15)	*****

*
 $p=.01$ [^]
 $p<.05$ ^{^^}
 $p<.01$ ^{^^^}
 $p < .001$