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Is disorganization a feature of schizophrenia or a modifying influence: evidence of covariation of perceptual and cognitive organization in a non-patient sample

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Abstract

A subgroup of people with schizophrenia is characterized by reduced organization in perception, thought, language, and motor functioning, and these impairments covary significantly. While this may reflect multiple expressions of an illness-related core processing impairment, it may also represent the extreme end of an organization-disorganization dimension that is found throughout the general population. In this view, disorganization is a modifying influence on illness expression. To obtain preliminary information on this hypothesis, we examined covariation of perceptual and cognitive organization in a non-patient sample. Subjects completed a battery of perceptual tasks with demonstrated sensitivity to schizophrenia and disorganization, and a battery of questionnaires examining cognitive organization. Our results indicated that level of perceptual organization ability, across multiple tasks, was associated with self-reported levels of cognitive organization on multiple measures. This is thus preliminary evidence for a common process affecting perceptual and cognitive organization in the general population, suggesting that disorganization may reflect a modifying influence mechanism, instead of an illness-related process, in schizophrenia.

Keywords

Perceptual organization; disorganization; schizophrenia; psychopathology; perception; cognition; behavior

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1. Introduction

Better characterization of the varied conditions within the syndrome of schizophrenia, and their relevant dimensions, has become a research priority (Insel et al., 2010). One strategy has been to focus on core biobehavioral processes thought to be dysfunctional (i.e., functioning at an extremely high or low level) in the disorder. Included among these are perceptual impairments, for which much evidence now exists regarding their nature, biological bases, and functional significance in schizophrenia (Silverstein and Keane, 2011; Chen, 2011; Green et al., 2011).

One perceptual process that has shown promise for characterizing heterogeneity in schizophrenia is perceptual organization (PO). PO refers to the ability to organize stimulus elements into meaningful edges, patterns, groupings, or object representations. PO dysfunction has been repeatedly demonstrated in schizophrenia patients (e.g. Snyder, 1961; Cox and Leventhal, 1978; Wells and Leventhal, 1984; Silverstein et al., 1996; Silverstein et al., 2000; for review, see Silverstein and Keane, 2011) and, among biobehavioral markers, has shown a high level of specificity for schizophrenia, having not been observed in psychiatric control groups (e.g., substance abuse, bipolar disorder, mixed affective psychoses) (Silverstein et al., 2000; Phillips and Silverstein, 2003; Silverstein and Keane, 2011). PO dysfunction has also been associated with multiple schizophrenia-related symptoms and features, including poor premorbid social functioning, long-term hospitalization, elevated nailfold plexus visibility, earlier illness onset, and reduced gamma- and beta-band synchrony (Phillips and Singer, 1997; Silverstein et al., 1998b; Knight and Silverstein, 1998; Rapoport et al., 2005; Uhlhaas et al., 2005; Schenkel et al., 2005; Uhlhaas et al., 2008; Silverstein et al., 2009; Butler et al., 2013). In particular, impaired PO is associated with more severe disorganization, a symptom dimension including inappropriate affect, odd movements, and formal thought disorder (Lindenmayer et al., 1994; Peralta and Cuesta, 2007). Disorganization is highly heritable and linked to many of the same features as is PO impairment, including impaired attention, poor premorbid social adjustment, and poor long-term functional outcome. Many of these features typically correlate and represent a 'poor outcome' or 'process' subtype of schizophrenia (Farmer et al., 1983; Sham et al., 1996; Wickham et al., 2001).

One interpretation of the above evidence is that impaired PO is an aspect of schizophrenia or subtype thereof. However, an alternative explanation is that: 1) PO is a manifestation of *cognitive coordination*: a canonical cortical function involving dynamic, context-based stimulus organization based on current spatial, temporal, or semantic relationships, which is thought to subserve PO, selective attention, and lexical disambiguation (Phillips and Singer, 1997; Phillips and Silverstein, 2003; Kay and Phillips, 2011; Phillips and Silverstein, 2013); 2) the integrity of this function varies considerably in the general population and is independent of schizophrenia; and 3) when individuals with schizophrenia (which is characterized by stimulus flooding, attentional impairment, and working memory failures) are low on PO and related aspects of cognitive coordination, they will demonstrate pronounced disorganized symptoms. Stated differently, poor cognitive coordination may be a *modifying influence* (Pogue-Geile and Harrow, 1985), but not a feature of schizophrenia per se.

The concept of an organization personality construct modifying the expression of schizophrenia-spectrum symptoms and task performance has received empirical support. For example: 1) cognitive disorganization is related to perceptual impairments in people without schizophrenia who have high levels of schizotypy (Cappe et al., 2012); 2) while both highly heritable, disorganization and psychosis have been shown to sort independently, suggesting different genetic origins (Rijsdijk et al., 2011); 3) disorganization traits are persistent across illness duration regardless of state (Paulus et al., 2001); and 4) trait-related allusive thinking, a mild form of thought disorder, occurs in the general population and is associated with reduced auditory mismatch negativity amplitude, suggesting that disorganized thinking is related to poorer pre-attentive processing, of which reduced PO is also a manifestation (Ward et al., 1992; McConaghy et al., 1993).

It is important, however, to distinguish between a personality dimension and a taxonic element. There is currently much debate about the latent structure of schizophrenia-spectrum symptoms. One approach conceptualizes schizotypic experiences as individual differences continuously distributed (i.e., dimensional) within the population (Eysenck, 1958; Claridge, 1972, 1987; Roberts and Claridge, 1991). Another group, following Meehl (1962, 1989, 1990), conceptualizes true schizotypy and its related symptoms as taxonic latent entities. Most investigations examining the latent structure of positive schizotypic symptoms support a taxonic view, while the evidence regarding the latent structure of negative symptoms is far more mixed (Fossati and Lenzenweger, 2009). To our knowledge, there have been no explicit investigations of the latent structure of disorganized symptoms. Our conceptualization of disorganization aligns more closely with the dimensional view, as we posit disorganized thinking and behavior arise from individual differences in neural functioning that impact the context-sensitivity of information processing (i.e., lead to reduced cognitive coordination). We do not believe deficits in cognitive coordination are an aspect of the latent liability for schizophrenia, rather that individual differences in cognitive coordination modify the expression of schizophrenia should it develop. As our conceptualization extends beyond classically observed disorganized symptoms characteristic of schizophrenia, so too do the behaviors and cognitive issues with which it may associate. We believe disorganization, broadly defined, can manifest in various aspects of cognition (e.g. reduced contextual constraint in language, decreased selective attention, greater interference with working memory, less stable mental representations, and poorer perceptual organization) and predictable compensatory strategies (e.g. increased subjective perception of a need for external structure).

To date, explorations of the nature of individual differences in PO in the general population have been limited. However, clinical studies have shown that PO ability can be as diverse in non-patient samples as among schizophrenia patients: some control subjects perform at chance levels on PO tasks and there can be significant overlap between patient and non-patient groups (Uhlhaas et al., 2006; Kurylo et al., 2007; Nikolaev et al., 2010; Baggott et al., 2010), suggesting a range of individual differences exists. Wholly unexamined in patient and non-patient samples is whether PO integrity is associated with cognitive organization. Here, we tested the hypothesis that decreased PO is associated with less organized cognition and behavior in a non-schizotypic community sample. To do this, we used a battery of self

report questionnaires that, *prima facie*, assess some aspect of cognitive organization, including: interference with selective attention and maintenance of representations in working memory, behavioral evidence of poor organization (e.g., frequent tardiness, forgetfulness), disruption in the perceived organization and maintenance of internal thoughts, alterations in somatic perception, intensification of (internal) visual imagery, and, at the most global levels, a perceived increased need for external structure in order to function effectively. We predicted that lower levels of cognitive organization reported on these measures would correlate with lower levels of PO. If confirmed, this would suggest that variation in integrity of a common cognitive-perceptual coordination process may contribute to observable behavioral differences in the general population and to the nature of symptomatology in schizophrenia patients.

2. Methods

2.1 Subjects

The study was conducted at Rutgers University. Eighty-one subjects (43 female) participated. All participants were recruited from the community, between the ages of 18–56, and, based on a set of standard questions, denied having a history of psychotic or neurologic illness, serious head injury, or drug use in the prior 6 months. Demographic details can be found in Table 1.

2.2 Apparatus

Stimuli were presented on a Samsung 2243BWX LCD monitor with viewable dimensions of 47.5 by 29.8 cm. The viewing distance was approximately 24 inches (60.9 cm). The screen resolution was 1680 × 1050, and therefore, the viewable screen subtended approximately 43° × 27° of visual angle. Spyder 3 Elite software was used to calibrate the monitors at the start of the study and then weekly afterwards. Monitors were set to a gamma value of 2.2 and a white point of 6500 K.

2.3 Stimuli and procedures

2.3.1 Jittered Orientation Visual Integration task (JOVI)—In this task, a continuous path of individual Gabor elements, embedded in background noise, forms an egg shaped contour (see Fig. 1A–D) and on each trial subjects are required to determine whether the shape is pointing right or left. Stimuli parameters were identical to those used in Silverstein et al. (2012), study 2. Difficulty was manipulated by applying varying degrees of orientational jitter to contour elements (see below). With two prior versions of this task, extent of performance impairment was related to level of disorganized symptoms in a population of schizophrenia patients (Silverstein et al., 2000; Uhlhaas et al., 2006).

Each trial consisted of a 2 second stimulus presentation with a 1 second interstimulus interval during which no responses were recorded. Blocks consisted of trials of stimuli at one level of orientation jitter (relative to their original positions) of the contour elements: +/−0°, 7°, 9°, 11°, 13°, and 15° (See Fig. 1A–D). Each block of 12 stimuli also contained two catch trials to determine extent of inattention and guessing. Catch trials were: 1)unjittered contours with curved lines drawn through the elements, enhancing contour salience and

eliminating the need for PO; and 2) contours presented without background elements to remove noise effects. Blocks were presented in increasing order of difficulty. Each 6 block sequence was repeated 4 times.

Analysis included total number of trials correct, with a 0.5 item correction for every skipped trial to equate subjects who timed out on trials to those who guessed. Subjects were excluded from the final analysis if they missed more than 4 catch trials in the actual experiment.

2.3.2 Ebbinghaus illusion task—The methods for this task were identical to those used in several prior studies (Phillips et al., 2004; Doherty et al., 2008; Doherty et al., 2010; Horton and Silverstein, 2011). Stimuli were either 2 circles alone (control condition), or 2 circles each surrounded by 8 other circles around the edges of an imaginary square [(3 on top, 3 on the bottom, and 1 on either side of the target circle (context conditions)] (Fig. 1 E–F). The center circle of one array was 100 pixels in diameter, while the center circle of the other array was 2, 6, 10, 14, or 18 pixels larger or smaller. The surrounding circles in each array were identical in size to each other (125 pixels in diameter when larger, 50 pixels when smaller) but not to the central circle.

We used a two-alternative forced choice paradigm, wherein, on each trial, subjects indicated whether the circular target on the right or left appeared larger by pressing the left or right arrow key. There were 16 trials in each pixel difference condition, consisting of all pixel differences in the *misleading* conditions and only the 2 pixel difference in the *helpful* context condition. In the *helpful* condition, the 98 and 102 pixel arrays were presented 8 times each with the smaller center circle surrounded by the larger surrounding circles and with the larger center circle surrounded by the smaller surrounding circles. This size contrast increases accuracy if participants are judging the apparent sizes of the center circles, but if they select the array with larger surrounds, they will always be wrong. In contrast, on *misleading* context trials, the larger target was always surrounded by larger circles, and the smaller target was always surrounded by smaller circles. In this condition, size contrast impairs discrimination by biasing the observer to perceive the target circle sizes in the opposite direction of their relative veridical sizes (Doherty et al., 2008). A block consisted of 96 total stimulus presentations, each on the screen until subjects responded or 2 seconds elapsed. There was a 200ms interval between trials. A control block of 96 trials was counterbalanced with the context conditions block, in which the same central circle comparisons were presented without surrounding distractors. Subjects were given a 25 stimulus practice session for each block.

To analyze context sensitivity, we calculated the difference in accuracy between the misleading and helpful context conditions, specifically in the 2 pixel condition (Doherty et al., 2008; Horton and Silverstein, 2011). Studies have shown that schizophrenia patients perceive stimuli more veridically (i.e., are less influenced by context and are more accurate than control subjects in the misleading condition) and that this is related to extent of disorganized symptoms (Uhlhaas et al., 2006; Horton and Silverstein, 2011; Silverstein et al., 2013). Higher accuracy on the misleading trials, therefore, indicates reduced PO and is represented by a smaller difference between helpful and misleading conditions.

2.3.3 Target detection task—The methods for this task were adapted from Banks and Prinzmetal (1976) and have been described previously (Silverstein et al., 1996; Silverstein et al., 2006). Stimuli were presented to subjects as an array consisting of T-F hybrid characters and one ‘T’ or one ‘F’ (Fig. 1G). Stimuli were white, presented on a black background.

During task trials, subjects determined which target, either the ‘T’ or ‘F,’ was presented in the array. Subjects pressed the left arrow key if they observed a ‘T’ and the right arrow key for ‘F’. Practice trials consisted of single presentations of the target letters to ensure acclimation and attentiveness. Trials began with a 500ms fixation point, followed by the stimulus array (100ms) and then a black, blank screen. Responses were recorded for 1500ms, followed by a 500ms interstimulus interval.

This task manipulates set size, proximity of targets and distractors, and degree of grouping of target and distractors, across 5 conditions. Stimuli from each of the 5 conditions were randomly intermixed, and all trials were presented across two blocks. There were 16 presentations for each condition per block, two for each combination of target and location. Targets always appeared at one of the 4 corners. Condition 1 had 5 elements presented in a symmetrical pattern, such that the target was difficult to isolate from the distractors. Condition 2 had 7 elements arranged such that the distractors were grouped together and the target was isolated in its own perceptual group. Conditions 3–5 also had 7 elements, but the target was increasingly embedded within the noise, making it successively more difficult to detect using grouping strategies.

The primary dependent variable was the RT difference between Conditions 1 and 2. Ordinarily RT is faster (ranging from 5 to 0ms in prior studies) in Condition 2, despite the additional elements, due to rapid organization of the stimulus into two groups in Condition 2, facilitating target isolation and identification (Banks and Prinzmetal, 1976; Silverstein et al., 1996). This is a demonstration of set size effects in visual search being overridden by PO effects. Acutely psychotic schizophrenia patients, however, tend to have faster RT in Condition 1, indicating they are relying on serial processing to identify targets instead of PO. The extent of this abnormal RT difference is associated with disorganized symptoms and poorer treatment response (Silverstein et al., 1998a), and the RT pattern normalizes as symptoms remit (Silverstein et al., 1996).

2.3.4 Cognitive and personality measures—As noted above, questionnaires were chosen based on their sampling a range of aspects of behavior and cognition that we considered related to cognitive coordination and its manifestation in cognitive organization-disorganization. We used the Disorganization Factor from the Perfectionism Scale (Stober, 1998) as a self report measure of cognitive disorganization. Subjects rated how much they agreed with 35 phrases on a scale of 1 to 5, with 5 indicating increased disorganization (Example: “Strongly disagree: I am a neat person”). For the final 40 subjects, we administered the entire Perfectionism Scale, on which higher scores indicate increased internal pressure to maintain standards and performance.

With the hypothesis that a greater perceived need for external structure may arise to compensate for a poor ability to structure thoughts and organize plans, we used the Personal

Need for Structure Scale (PNS) (Thompson et al., 1989) to ascertain how subjects responded to external events. Subjects were asked to rate on a converted scale of 1 to 6 how much they agreed with 12 phrases, with 1 representing strong agreement. Higher scores indicate a preference for greater structure [Example: “I don’t like situations that are uncertain” (T)].

To assess cognitive organization, we used the Cognitive Slippage Scale (CSS) (Miers and Raulin, 1987), which comprises 47 True/False questions, where a ‘True’ response was counted as 1 (Example: “My thoughts are more random than orderly”). We also combined the Attention-Related Cognitive Errors Scale (Cheyne et al., 2006) with the Memory Failures Scale (Attention/Memory Scales), as has been done previously (Cheyne et al., 2006). The Attention/Memory Scales consists of 24 questions rated on how frequently specific events occurred in subjects’ lives, rated on a scale of 1 to 5, with 1 representing ‘never’ and 5 representing ‘very often.’ (Examples: “I forget passwords”; “I double book myself when scheduling appointments”). Higher scores on these measures indicate increased cognitive disorganization.

To assess individual differences in alterations in perceptual experiences we used the Perceptual Aberration Scale (PAS) (Chapman et al., 1978). This scale consists of 35 True/False questions (examples: “I have sometimes had the feeling that one of my arms or legs is disconnected from the rest of my body”), and is commonly used as a measure of schizotypy. However, we hypothesized that altered perceptual experiences in non-schizotypic people may reflect failures in the coordination of somatosensory signals, leading to a form of ‘disembodiment’ with subsequent periodic experiences of body parts as dead, decaying, or separate from the self (Connolly, 2013). As such, we conceptualized high PAS scores, in the absence of meaningful schizotypy, to indicate reduced cognitive coordination.

Most speculatively, based on the hypothesis that deficits in cognitive coordination lead to poorer PO, which in turn leads to degraded visual input and a corresponding increase in the salience of *internal* visual imagery (Baggott et al., 2010), we used the Vividness of Visual Imagery Questionnaire (Marks, 1973). Subjects rate each set of 16 standardized images on a scale from 1 to 5, with 1 representing perfect recollection. Lower scores indicate an ability to maintain and recall images more strongly (Example: “Think of a country scene which involves trees, mountains and a lake. Consider that picture that comes before your mind’s eye.”).

We inserted a 13 item-measure of infrequent responding to assess for random or careless response styles (Jackson, 1984). Subjects were excluded from analysis if they endorsed 3 or more of these questions in the positive direction. We screened for low intelligence with the Shipley-2 Institute of Living Scale vocabulary and abstraction components (Shipley, 2009).

2.4 Data analysis

Eleven subjects were excluded from analysis owing to scores greater than 3 on the infrequency scale or missing more than 4 catch trials on the JOVI task. Additionally, one subject was excluded for scoring 8 SDs above our sample mean on the PAS. The data from three subjects scoring at chance levels on the Target detection task, suggesting they responded randomly, were treated as missing. The Ebbinghaus task data from one subject

was treated as missing because he did not understand the directions. Missing data were replaced by the median scores for those measures.

We used Pearson correlation analyses to assess the relationships between scores on self-report questionnaires and experimental task performance. The Disorganization subscale from the Perfectionism Scale, along with the PNS, Imagery Scale, CSS, and PAS were transformed [by $\log(x + 1)$] to reduce significant skew in these measures' scores. To determine underlying factors within the personality and perceptual variables, we performed a canonical correlation. We did not control for multiple comparisons, as this was, to our knowledge, the first study of the issue, and because all statistical tests were hypothesis-driven. Nevertheless, we assessed whether the number of observed significant correlations exceeded chance expectations.

3. Results

3.1 Correlations between measures

Performance was generally in keeping with the previous studies mentioned in the Methods section (Means and SDs are reported in Table 2). No subject scored above 11 on the PAS, or 20 on the CSS, and so none of the scores exceeded the standard 2-SD-above-the-mean cutoffs for schizotypy (see Lenzenweger, 2010) reported in past studies for these scales (Miers and Raulin, 1987; Chmielewski et al., 1995). At $p = 0.05$, we would have expected 2 significant correlations by chance among the 36 total analyses performed. We observed a total of 11 significant relationships (Table 3). Context sensitivity, as indexed by the Ebbinghaus illusion task, was significantly and negatively correlated with scores on the PAS, PNS, and CSS, implying that reduced contextual coordination of visual information is associated with increased frequency of disruptions in cognitive functioning, greater perceived need for structure, and experiences of aberrant somatosensory perception. There were significant negative correlations between scores on the Target detection task and scores on the Imagery Scale and the CSS, suggesting reduced visual grouping is associated with increased cognitive disorganization and a decreased ability to recreate mental imagery. We found a significant negative correlation between the JOVI and the PNS, suggesting poorer PO is associated with increased perceived need for structure.

3.2 Interrelationship of personality factors

There were several significant and expected correlations between non-perceptual measures (Table 3). Scores on the PNS were positively correlated with those on the PAS and the Disorganization factor from the Perfectionism scale. CSS scores were strongly positively correlated with Attention/Memory Scales and PAS scores, and scores on the Attention/Memory Scales and the PAS were also strongly positively correlated. As these indices are hypothesized to assess aspects of cognitive organization, the relationships were all in the expected directions.

3.3 Canonical correlation

To determine whether underlying components in our independent variables (psychophysics measures) were related to components in our dependent variables (questionnaire scores), we

performed a canonical correlation analysis (Table 4). We removed the Disorganization subscale of the Perfectionism Scale from the analysis as it was uncorrelated with any of our main independent variables. The JOVI was only associated with the PNS and was also removed. The independent variables in this canonical correlation analysis therefore comprised performance on the Target detection and Ebbinghaus illusion tasks, while the dependent variables consisted of scores from the PNS, Imagery Scale, CSS, Attention/Memory Scales, and PAS (transformed as described in the methods). The first canonical correlation was significant ($r = 0.37$, F approximation to Wilk's lambda (10, 148) = 2.09, $p < 0.05$) and the second approached significance ($r = 0.33$, F approximation to Wilk's lambda (4, 75) = 2.31, $p = 0.07$). Both independent variables contributed significantly to both canonical variates. Among dependent variables, Imagery Scale and CSS scores were more related to the first canonical variate, PNS scores were more related to the second variate, and PAS scores were associated with both variates.

4. Discussion

The purpose of this study was to determine the extent of covariation between different phenomena that, *prima facie*, reflect manifestations of a dimension of organization-disorganization. In a non-clinical sample culled from the general population that possessed adequate individual differences in scores across measures, we observed covariation of behavioral, cognitive, and perceptual organization. As none of the participants met the standard psychometric high-risk criteria on the PAS for schizotypy (Chapman and Chapman, 1987) our results suggest that organization, broadly defined, may be a dimensional construct in the general population. Although far from definitive, this represents an important first step in understanding the nature of disorganization and whether individual differences in cognitive coordination can serve as a modifying influence on schizophrenia symptom expression.

The perceptual tasks in this study have previously demonstrated sensitivity to PO impairment in schizophrenia, and level of impairment on these tasks has been significantly related to level of disorganized symptoms in clinical studies. In contrast, there is scant research on relationships between perceptual and cognitive organization and behavior in psychiatrically healthy samples (see Corcoran et al., 2013, for a recent example). Our data demonstrate that the same relationships observed in schizophrenia can be observed in healthy, non-schizotypal individuals, suggesting a fundamental relationship between perceptual and cognitive organization, including variables that can be considered aspects of personality (e.g., perceived need for external structure).

Our interpretations complement those of recent studies demonstrating that clinical disorganization is highly heritable (Loftus et al., 1998; Rietkerk et al., 2008; McGrath et al., 2009), but independent of psychosis (Paulus et al., 2001; Rijdsdijk et al., 2011). Furthermore, work by Debanné and colleagues (2013) suggests that schizotypic disorganization, though largely independent of positive schizotypy, directly influences the expression of positive schizotypic symptoms. Considered within the framework of our findings, the network of relationships between schizophrenia, schizotypy, disorganization, and PO suggests that disorganization may be an individual differences factor, independent of the liability for

schizophrenia, that is continuously distributed in the population and modifies risk for and expression of schizophrenia-spectrum symptoms.

The nature of our sample precludes us from relating our findings to either a taxonic or dimensional view of schizotypy, as none of our participants scored high enough on the PAS to qualify as having significant indicators of schizotypy. Therefore, while we can be confident that our results do not reflect level of schizotypy, we cannot discern how our construct relates to schizotypic symptom dimensions (e.g., positive, negative, and disorganized) (Kwapil et al., 2008), clinically significant psychopathology (Chapman et al., 1994; Kwapil et al., 2000), or psychosocial adjustment and other personality dimensions in schizotypy (Barrantes-Vidal et al., 2010). To further explore this issue, future studies should include data from participants exhibiting a range of scores on various self-report measures of schizotypy.

As stated previously, within the context of schizophrenia spectrum symptom expression, we believe trait-like low levels of cognitive coordination are critical for the expression of disorganized symptoms. We do not, however, believe that this acts in isolation to produce these symptoms. Rather, to the extent that organization-disorganization is a dimension of functioning, it can be expected to interact with specific illness related features, including reduced sensory gating (leading to greater than normal amount of information to process), and problems in selective attention and working memory (further increasing information load) to produce clinically significant levels of disorganization (Carr and Wale, 1986). This could explain why, among schizophrenia patients, performance becomes more abnormal on tasks, such as those used in this study, when patients are acutely ill, later improving (but not reaching normal levels) during stabilization and stable phases (Silverstein et al., 2009; Silverstein et al., 2012). It could also account for why other psychiatric disorders, which are not characterized by stimulus flooding, have not demonstrated PO impairments.

Our hypothesis that reduced PO would relate to more vivid imagery (resulting from degraded visual input) was not supported. The opposite was observed, suggesting that rather than reduced PO serving to produce a form of sensory deprivation - which has been observed to increase imagery (Ziskind and Augsberg, 1962) - it may simply lead to higher amounts of information to process. This would increase difficulty performing tasks involving stimulus reconstruction, such as the visual imagery task.

One limitation of our study is that we did not control for multiple comparisons. While all statistical tests were hypothesis driven, our results should be considered preliminary and in need of replication. Furthermore, the JOVI was not included in the canonical correlation analysis because it showed a statistically significant relationship with only one dependent variable. The relatively weaker relationships observed between the JOVI and other personality measures, compared to the other two PO tasks, may occur because with the JOVI, as with most other cognitive tasks, integrity of the process of interest cannot be completely isolated from overall level of performance or behavioral confounds (e.g., poor motivation and attention, sedation, etc.), since poor performance is reflected in lower scores. In our other tasks, poorer PO is reflected in either superior performance in some conditions (e.g., misleading condition in the Ebbinghaus illusion), or a pattern of performance

qualitatively different than normal (e.g., Conditions 1–2 RT reversal in the Target detection task) and is independent of overall level of performance. In these cases, generalized performance deficits make minimal contributions to scores, thereby reducing error variance and increasing the sensitivity of correlational analyses.

Other limitations were not inquiring about familial psychiatric history, screening for current drug use beyond a verbal inquiry, or using clinical interviews to determine if our results were influenced by anxiety, depression, or other forms of psychopathology. Better characterization of the influence of these features on cognitive organization is needed. A recent study, however, indicated that positive symptoms and depression, as opposed to disorganization, were associated with *stronger* PO in a schizophrenia sample (Silverstein et al., 2013), and older work suggests substance abuse does not impair PO (Place and Gilmore, 1980). Moreover, studies have demonstrated that, among schizophrenia patients, only those with prominent disorganization display PO impairments (Uhlhaas et al., 2005; Uhlhaas et al., 2006), and presumably the non-disorganized schizophrenia, psychotic control, and other psychiatric control patients in these studies had significant levels of anxiety, depression, and substance abuse. Therefore, there is reason to believe that general psychopathology, and even non-disorganized aspects of psychosis (presumably including positive and negative schizotypy), are not related to impaired PO, but more research on this issue is needed.

To definitively conclude that disorganization modifies the presentation of schizophrenia symptoms, it would be useful to perform longitudinal studies with people who meet criteria for an ultra high-risk state (McGorry et al., 2003). We would hypothesize that only individuals high on disorganization scales and with reduced PO during the prodromal phase would exhibit significant levels of disorganized symptoms after full criteria for schizophrenia are met.

Finally, refining and uncovering the mechanisms of the organization-disorganization construct is an important task for future work. One promising lead comes from applications of complexity theory to cognition. For example, it has been demonstrated that spatial information processing in perception, attention, memory, and problem solving all involve a common algorithm based in grouping (Graham et al., 2000; Pizlo and Stefanov, 2013). All these functions operate by dividing a defined problem space into related clusters prior to local analysis (e.g., in PO - subsets of visual features likely to represent different objects; in selective attention - subsets of auditory or visual stimuli to group apart from others; in problem solving – dividing a larger task into coherent subtasks that can be completed efficiently, etc.). This strategy reduces computational complexity, whereas processing demands, and the likelihood of disorganized outputs, are increased when larger numbers of elements must be processed at one time, especially when these come from different subsets of a problem. The initial application of structure, followed by local analysis, has been demonstrated to be a computationally feasible strategy, and modeling results provide a good fit to data from cognitively healthy humans (Pizlo and Li, 2005). A next step will be to determine if modeling of individual differences in PO and other aspects of cognitive functioning (including problem solving) shows consistency across tasks and people, and can also be extended to characterizing behavior and subjective experience.

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Fig. 1. Perceptual Tasks

A–D) JOVI (Jittered Orientation of Visual Stimuli). The objective of the task is to determine the direction of an egg-shaped contour (right or left) presented within noise, using a 2 alternative forced choice. Difficulty is manipulated by jittering the orientation of contour elements across several conditions. Figures are cropped images from Silverstein, et al., 2009. **A)** 0° jitter. **B)** 7–8° jitter. **C)** 11–12° jitter. **D)** 15–16° jitter. **E)** Ebbinghaus Illusion, helpful condition. The center circle on the left is 2% larger than the central circle on the right. **F)** Ebbinghaus illusion, example of the misleading condition. The central circle on the left is still 2% larger than the central circle on the right, but the surrounding circles can misleadingly make it seem smaller. Objective is to determine which central circle is larger. Control condition (only center circles, no arrays) not shown. **G)** Target Detection Task, examples of the different conditions showing possible location of the target “T”. Task objective is to distinguish the target as “T” or “F” as quickly as possible. Condition 1 has 5 stimuli elements, with the target appearing in one of the corners, and all other elements serving as distracters. Condition 2 has seven total stimuli elements, but the target is oriented such that perceptual grouping separates it from the rest of the stimuli. Conditions 3–5 all contain 7 elements, but with the target element this time located within the group of distractor elements, making it more difficult to detect.

Table 1

Demographic information of study participants

Total Participants	81
Age (Years)	34.16 $\pm$ 11.23
Sex (# Female)	43
Race (#)	
White	32
Black	30
Hispanic	7
Asian	9
Other	3
Education (Years)	14.3 $\pm$ 3.1
Shipley-2 Score	99.76 $\pm$ 14.6

Table 2

Scores on Measures

Task	Mean
<i>Perceptual</i>	
Ebb	0.89 ± 0.14
TF	0.006 ± 0.035
JOVI	206.6 ± 23.35
<i>Personality</i>	
Disorganization	24.1 ± 4.4
PNS	45.1 ± 7.8
CSS	5.7 ± 5.2
M/A	55.3 ± 12.9
PAS	1.9 ± 2
VVIQ	36.9 ± 15.2

Ebb = Ebbinghaus Illusion, % correct, Helpful Condition (2 pixel difference) – Misleading condition (2 pixel difference); TF = Target Detection, reaction time in ms Condition 1 – Condition 2, JOVI = Jittered Orientation, total correct; Visual Integration task; PNS = Personal Need For Structure Scale; CSS = Cognitive Slippage Scale; M/A = Mental Failure Scale/Attention-Related Cognitive Errors Scale; PAS = Perceptual Aberration Scale; VVIQ = Vividness of Visual Imagery Questionnaire

Table 3

Pearson Correlation Matrix

	Dis	PNS	VVIQ	CSS	M/A	PAS	Ebb	TF	JOVI
Dis	1								
PNS	0.28*	1							
VVIQ	-0.17	0.07	1						
CSS	-0.02	0.05	0.11	1					
M/A	-0.10	-0.08	0.01	0.54***	1				
PAS	0.15	0.24*	0.09	0.61***	0.41***	1			
Ebb (n = 80)	-0.11	-0.22*	-0.17	-0.22*	-0.16	-0.28*	1		
TF (n = 78)	-0.04	0.08	-0.23*	-0.22*	-0.04	-0.03	0.20	1	
JOVI (n = 81)	0.07	-0.22*	-0.14	-0.02	0.06	-0.09	0.12	-0.01	1

Dis = Disorganization Scale; PNS = Personal Need For Structure Scale; VVIQ = Vividness of Visual Imagery Questionnaire; CSS = Cognitive Slippage Scale; M/A = Mental Failure Scale/Attention-Related Cognitive Errors Scale; PAS = Perceptual Aberration Scale; Ebb = Ebberinghaus Illusion, % correct, Helpful Condition (2 pixel difference) – Misleading condition (2 pixel difference), TF = Target Detection, reaction time, Condition 1 – Condition 2, JOVI = Jittered Orientation Visual Integration task

*
p < 0.05,

p < 0.001

Table 4

Standardized correlations and coefficients for individual variables and canonical variables

Canonical Variable 1		Canonical Variable 2	
Proportional Variance	0.59		0.41
Redundancy	0.08		0.04
Correlation		Coefficient	Coefficient
Perception			
Ebb	-0.88	-0.78	-0.48
TF	-0.65	-0.49	0.76
Personality			
PNS	0.35	0.24	0.66
VVIQ	0.65	0.56	-0.28
CSS	0.76	0.58	-0.15
M/A	0.37	0.01	0.21
PAS	0.63	0.18	0.47

Ebb = Ebbinghaus Illusion, TF = Target Detection Task, JOVI = Jittered Orientation Visual Integration task, PNS = Personal Need for Structure Scale; VVIQ = Vividness of Visual Imagery Questionnaire; CSS = Cognitive Slippage Scale; M/A = Mental Failure Scale and the Attention-Related Cognitive Errors Scale; PAS = Perceptual Aberration Scale