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Perceptual Organization in Schizophrenia Spectrum Disorders: Empirical Research and Theoretical Implications

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The research into perceptual organization in schizophrenia spectrum disorders has found evidence for and against a perceptual organization deficit and has interpreted the data from within several different theoretical frameworks. A synthesis of this evidence, however, reveals that this body of work has produced reliable evidence for deficits in schizophrenia, as well as for the clinical, stimulus, and task parameters associated with normal and abnormal performance. Recent models of cognition have also advanced understanding of the underlying pathophysiological processes of perceptual organization dysfunction in schizophrenia spectrum disorders. These suggest that deficits in perceptual organization may be one manifestation of a wider disturbance in the integration of contextually related information across space and time.

Keywords: schizophrenia, perceptual organization, context, cognitive coordination

Starting with the studies of Cox and Leventhal (1978) and Place and Gilmore (1980), there have been numerous studies that have examined perceptual organization in schizophrenia spectrum disorders.[1] These studies have produced conflicting findings in terms of the presence, definition, extent, and clinical correlates of perceptual organization deficits in these populations. Thus, although some studies have found evidence for an impairment of perceptual organization, other studies could not confirm these findings, suggesting that perceptual organization is essentially intact. Moreover, studies that have reported dysfunctions in perceptual organization in schizophrenia spectrum disorders differ in their views as to whether these deficits are the result of an impairment in the early processing stages or reflect difficulties in the generation and/or utilization of top-down feedback to earlier processes. Finally, differential results have emerged on the relationship between psychotic syndromes and perceptual organization impairments.

In this review, we aim to clarify the wealth of empirical findings on perceptual organization in schizophrenia spectrum disorders and to examine the following hypotheses:

1. Perceptual organization deficits are characteristic of people with schizophrenia spectrum disorders.

2. Within schizophrenia spectrum disorders, heterogeneity of perceptual organization ability exists, with deficits being associated with features indicating greater symptom severity. This includes poorer premorbid functioning, poorer prognosis, and reduced cognitive organization in other, nonperceptual domains. We will account for these relationships by citing evidence for the hypothesis that the grouping of stimulus elements into coherent object representations is mediated by a common cortical-processing algorithm (Phillips & Singer, 1997), which operates across cognitive domains to coordinate activity in thought, language, and perception, and that this widespread algorithm is not operating normally in schizophrenia secondary to specific cortical circuitry malfunctions (Phillips & Silverstein, 2003).

3. The likelihood that perceptual organization dysfunction will be observed among schizophrenia spectrum patients with the above characteristics is directly proportional to the degree to which the experimental task requires top-down feedback to early visual processes or concurrent modulation of stimulus features by other stimuli. In contrast, tasks that use highly configural stimuli that can be processed solely via bottom-up prespecified feature hierarchies (Watt & Phillips, 2000) can be performed relatively normally by people with schizophrenia spectrum disorders.

In addition to testing the above three hypotheses, we will also review evidence that impaired perceptual organization can be accounted for by specific disordered biological mechanisms. Finally, we suggest future directions for research related to perceptual organization in schizophrenia spectrum disorders. We begin this review by examining briefly the role of perceptual organization in normal cognitive processing, which is then followed by a summary of studies in clinical populations.

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[1] In the following, the term *schizophrenia spectrum disorders* will be used to refer to schizophrenia, schizoaffective disorder, schizotypal personality disorder, individuals with a genetic risk factor for schizophrenia, and psychometrically defined schizotypy.

Perceptual Organization in Normal Cognition

Perceptual organization is typically defined as the ability of perceptual systems to organize sensory information into coherent representations that can serve as the basis of our phenomenal experience of the world (Palmer & Nelson, 2000). Principles involved in the formation of organized visual objects were first described by Wertheimer (1912, 1922, 1923, 1924/1938), who identified a number of laws or principles of perceptual grouping, including similarity, proximity, good continuation, and common fate. Perceptual organization is not confined to the processing of visual input, however. There exists a close relationship, for example, between the principles that govern the organization of visual input and the organization of the auditory world (for a review, see Bregman, 1990). Similarities in organization between different domains of cognition led the Gestalt theorists to conclude that organization is an inherent feature of consciousness, characterizing perception as well as memory, language, and affect (Koehler, 1929). More recent research supports this view by demonstrating that principles of perceptual grouping also apply to other domains of cognition, such as working memory and problem solving (Phillips & Singer, 1997).

The central tenet of Gestalt psychology—that perception is not a product of independent local stimulation but is characterized by emergent, holistic properties—has been confirmed in numerous experiments (e.g., Kanisza, 1976; Koffka, 1935; Kovács, 1996; Pomerantz, 1983; Prinzmetal, 1981; Wertheimer, 1922, 1923). New paradigms involving computational and traditional psychophysical approaches have also been developed, which allow a rigorous study of perceptual organization and its underlying processes, as well as a formal specification of parameters affecting stimulus organization (e.g., Compton & Logan, 1993; Field, Hayes, & Hess, 1993; see Watt & Phillips, 2000, for a review). Additional studies have established that a variety of other stimulus features, such as size (Bergen & Adelson, 1988), texture (Julesz, 1975), binocular disparity (Nakayama & Silverman, 1986), coincidence in time (Alais, Blake, & Lee, 1998), and connectedness (Palmer & Rock, 1994), also contribute to perceptual organization.

A number of findings, however, suggest that perceptual organization must be approached differently than originally proposed by Gestalt theorists. Current neuroscientific work suggests that the cognitive and neural mechanisms underlying perceptual organization depend on the combined operation of two different but mutually supportive processes: grouping through bottom-up convergence in prespecified feature hierarchies and grouping through dynamic Gestalt organization, which involves processes that create novel groupings that can be specified only after the input is known (Watt & Phillips, 2000). In the latter case, computational decisions regarding which features are bound together are typically a function of top-down factors, such as experience with prior groupings; contextual factors that make certain groupings more task relevant than others; and expectations about what is likely to be perceived. In short, perceptual organization is not a simple stimulus-driven process. It involves early and late influences (Palmer, Neff, & Beck, 1996; Palmer & Nelson, 2000), as well as stimulus-driven and top-down influences from other cognitive processes (Beck & Palmer, 2002; Coren & Enns, 1993; Gilbert, Ito, Kapadia, & Westheimer, 2000; Kovács, 1996).

Previous Research on Perceptual Organization in Schizophrenia Spectrum Disorders

We conducted a review of the literature to identify previous studies in both schizophrenia and schizophrenia spectrum disorders that had investigated perceptual organization. This literature review was conducted through (a) a search of the PubMed computer database (1975 through May 2004) by using the following subject terms: perceptual organization and schizophrenia, perceptual organization and schizophrenia spectrum disorders, perceptual organization and schizotypy, Gestalt and schizophrenia, Gestalt and schizophrenia spectrum disorders, Gestalt and schizotypy, perception and schizophrenia, perception and schizophrenia spectrum disorders, and perception and schizotypy; and (b) a search of the reference sections of any articles and book chapters on perceptual organization to find additional studies on perceptual organization in schizophrenia spectrum disorders.

A critical issue for the review was the question of whether an experimental paradigm constituted an example of perceptual organization alone, as opposed to relying heavily on another cognitive process (i.e., attention or working memory) in which abnormal performance could be explained by an impairment in these other processes. Many of the experimental tasks used in the studies reviewed did not utilize standard psychophysical procedures but used tasks in which performance relies on multiple cognitive processes. As we wanted to provide a comprehensive review of the literature, we included studies that did not use standard psychophysical procedures. Issues of construct validity of experimental tasks will be discussed later in this article.

Perceptual Organization in Schizophrenia

Is perceptual organization impaired in schizophrenia? An overview of studies of perceptual organization in schizophrenia discussed is shown in Table 1. Overall, we identified 33 studies that investigated perceptual organization in schizophrenia. Evidence from at least 28 studies suggests that patients with schizophrenia are characterized by impairments in perceptual organization. There is also evidence to suggest that perceptual organization is intact in schizophrenia, however. The studies by Carr, Dewis, and Lewin (1998), Chey and Holzman (1997), Knight, Manoach, Elliott, and Hershenson (2000), Rief (1991), and Silverstein, Osborn, West, and Knight (1998) did not confirm the hypothesis that schizophrenia patients are characterized by dysfunctional perceptual organization. As we discuss later, these studies provide important evidence regarding the task and stimulus conditions under which perceptual organization is normal or abnormal in schizophrenia.

Cox and Leventhal (1978) provided the first empirical demonstration of a perceptual organization deficit in schizophrenia. Compared with paranoid schizophrenia patients and a psychiatric control group, nonparanoid schizophrenia patients displayed a differential performance deficit on three standard, preattentive measures of visual processing, which was not present in the two other groups. The hypothesis of a dysfunction in perceptual organization in schizophrenia patients gained critical support from Place and Gilmore (1980). Their hypothesis was that controls would do better than schizophrenia patients at counting the number of lines in tachistoscopically presented arrays when the lines (2–6

Table 1
Studies of Perceptual Organization in Schizophrenia

Study	Patients	*N*	Task	Symptom rating	Effect size	Summary of findings
Bellgrove et al. (2003)	Early–onset ScZ	12	Global-local task	PANSS	0.87 (*d*)	In a divided-attention condition, early-onset patients exhibited a local-processing deficit.
Buchanan et al. (1994)	Deficit forms of ScZ Nondeficit forms of ScZ	18 21	Visual closure task	BPRS	0.32 (*f*)	Deficit forms of schizophrenia were associated with deficits in visual closure, which was not present in nondeficit schizophrenia.
Carr et al. (1998)	Outpatients with ScZ	30	Visual search task	SAPS, SANS	0.38 (*f*)	Intact perceptual grouping in patients with schizophrenia.
Carter et al. (1996)	Outpatients with ScZ	23	Global-local task	BPRS	0.38 (*f*)	Impaired performance for global elements for patients with schizophrenia in a divided-attention condition. Impaired performance was correlated with auditory hallucinations.
Chen et al. (2001)	Chronic ScZ	23	Motion perception task		0.24 (*f*)	Schizophrenia patients were impaired in the processing of coherent motion, which requires grouping. Local motion processing was intact.
Chey & Holzman (1997)	Chronic ScZ Chronic schizoaffective disorder	8 6	Embedded figures task, similarity task		0.18 (*d*), 0.18 (*d*)	Intact perceptual grouping in schizophrenia patients.
Cox & Leventhal (1978)	Paranoid ScZ Nonparanoid ScZ	15 15	Embedded figures test, visual suffix task, figure recognition task		0.54 (*f*), 0.46 (*f*), 0.38 (*f*)	Differential, preattentive, perceptual grouping deficit for nonparanoid schizophrenia patients.
Doniger et al. (2001)	Chronic ScZ	26	Visual closure task	PANSS	0.58 (*f*)	Patients with schizophrenia showed impaired perceptual closure. Impaired performance was correlated with negative symptoms.
Doniger et al. (2002)	Chronic ScZ	22	Visual closure task combined ERP recordings		0.58 (*f*)	Behavioral results replicated the earlier finding by the same authors. Deficits in perceptual closure were related to a primary deficit in magnocellular dorsal stream processing.
Ferman et al. (1999)	Acute ScZ Acute schizoaffective disorder	15	Global–local task	SAPS, SANS	0.42 (*f*)	Patients with schizophrenia responded faster to local targets. No significant correlations between performance and symptom ratings.
Frith et al. (1983)	Acute ScZ	21	Schematic face sorting task		0.31 (*f*)	Schizophrenia patients were significantly impaired in integrating Gestalt aspects of stimuli.
Granholm et al. (1999)	Outpatients with ScZ Chronic ScZ	10 12	Global-local task	BPRS	0.69 (*f*)	Impaired performance for global elements for patients with schizophrenia. No significant correlations between performance and BPRS ratings.
Izawa & Yamamoto (2002)	Chronic ScZ	24	Searchlight task	SANS, SAPS	0.82 (*d*)	Patients with schizophrenia were significantly impaired in the recall and recognition of fragmented complex figures. Impaired performance was significantly correlated with disorganized symptoms.
John & Hemsley (1992)	Chronic ScZ	15	Picture matching task	BPRS	0.71 (*f*)	Schizophrenia patients were significantly impaired in the use of top-down processing strategies in the interpretation of complex images.
Knight & Silverstein (1998)	Chronic ScZ Acute ScZ Non-ScZ psychotic disorders	21 22	Visual suffix task	TDI	0.57 (*r*)	Impaired perceptual grouping was associated with the scores on TDI categories *associative* and *disorganized* in schizophrenia. The magnitude of the performance reversal demonstrated by the poor premorbid schizophrenia group in Silverstein, Knight, et al.

Table 1 (*continued*)

Study	Patients	*N*	Task	Symptom rating	Effect size	Summary of findings
Knight et al. (2000)	Chronic poor premorbid ScZ Chronic good premorbid ScZ	10 10	Letter configuration task		1.31 (*f*)	(1996, Study 1) was significantly correlated with the PANSS Cognitive factor. Patients with schizophrenia revealed intact processing of stimuli with strong symmetrical properties.
Liddle (1987)[a]	Chronic ScZ	47	Figure-ground test	BPRS		Deficits in figure–ground perception correlated with elevated positive symptoms.
Lieb et al. (1994)	Chronic ScZ	24	Preattentive texton task	BPRS	1.33 (*d*)	Impairments in preattentive stimulus processing. No significant correlations between performance and BPRS ratings.
Malaspina et al. (2003)	ScZ	48	Figure–ground test	PANSS	0.42 (*r*)	Negative symptoms correlated with deficits in figure–ground perception.
Parnas et al. (2001)	Chronic ScZ Acute ScZ Prodromal ScZ	10 10 10	Global–local task Contour detection task Motion coherence task		0.82 (*f*) 0.42 (*f*) 0.71 (*f*)	Patients with prodromal symptoms showed enhanced perceptual grouping compared with chronic schizophrenics, who were characterized by significant impairments in Gestalt perception.
Peters et al. (2002)	Acute ScZ	11	Degraded version of the Stroop test	Manch. Scale	0.51 (*f*)	Impaired perceptual grouping resulted in less interference for psychotic subjects. Reduced interference correlated with positive symptoms.
Place & Gilmore (1980)	Chronic ScZ	10	Line numerosity task		1.80 (*f*)	Schizophrenia patients were significantly more accurate in the counting of line elements as a result of dysfunctional perceptual organization.
Reich & Cutting (1982)	Acute ScZ	25	Complex picture task		0.75 (*f*)	Patients with schizophrenia were characterized by a "piecemeal" approach in the description of complex images.
Rief (1991)	Chronic ScZ	24	Preattentive perceptual grouping task		0.48 (*f*)	Schizophrenia patients were characterized by intact perceptual grouping.
Silverstein, Bakshi, et al. (1998)	Chronic ScZ	18	Visual recognition task	PANSS	0.26 (*f*)	Schizophrenia patients were impaired in the ability to perceptually group unstructured patterns. Perceptual deficits were correlated with disorganized symptoms.
Silverstein, Knight, et al. (1996, Study 1)	Poor premorbid acute ScZ Good premorbid acute ScZ Non-ScZ psychotic disorders Good premorbid outpatients with ScZ	11 14 14 10	Preattentive perceptual grouping task		0.70 (*f*)	PPM schizophrenia patients were impaired in perceptual grouping, which led to a relative performance advantage over controls.
Silverstein, Knight, et al. (1996, Study 2)	Poor premorbid acute ScZ Good premorbid acute ScZ Non-ScZ psychotic disorders Good premorbid outpatients with ScZ	11 14 14 10	Modified preattentive perceptual grouping task		0.51 (*f*)	PPM schizophrenia patients demonstrated normal perceptual organization when a contextual manipulation facilitated top-down control over perceptual organization.
Silverstein, Kovacs et al. (2000)	Chronic ScZ Non-ScZ psychotic disorders	23 19	Contour integration task	PANSS	0.93 (*f*)	Patients with schizophrenia showed deficits in a low-level perceptual organization task. Deficits in perceptual organization correlated with elevated levels on the PANSS Disorganization and Cognitive factors.
Silverstein, Matteson, & Knight (1996)	Chronic ScZ Control subjects without psychiatric disorders	17 17	Auditory suffix task		0.31 (*f*)	Chronic schizophrenia patients grouped auditory information defined by physical cues as well as controls but, unlike controls, were unable to alter grouping performance based on a contextual manipulation.

(*table continues*)

Table 1 (*continued*)

Study	Patients	*N*	Task	Symptom rating	Effect size	Summary of findings
Silverstein, Osborn, et al. (1998)	Acute ScZ Chronic ScZ Psychosis	12 17 21	Visual suffix task		1.03 (*f*)	Patients with schizophrenia showed intact performance for pattern with strong figural properties.
Silverstein, Schenkel et al. (1998)	Chronic ScZ	18	Preattentive perceptual grouping task		0.70 (*f*)	The study examined deficits in perceptual grouping in relationship to rehabilitation outcome. Patients who were discharged within 3 years after testing were characterized by intact perceptual grouping at initial testing, whereas nondischargeable patients had displayed abnormal perceptual grouping.
Silverstein et al. (2000)	Chronic ScZ Non-ScZ psychotic disorders	23 20	Contour integration task	PANSS	0.51 (*f*)	Deficits in perceptual grouping for schizophrenia patients correlated with disorganized symptoms.
Spencer et al. (2003)	Chronic ScZ	12	Illusory square discrimination task	PANSS	0.47 (*f*)	Deficits in the perception of of Kanizsa-squares were associated with reduced evoked gamma-band activity and phase coherence in schizophrenia patients.
Uhlhaas et al. (2002)	Acute ScZ Non-ScZ psychotic disorders Nonpsychotic psychiatric disorders	37 30 26	Contour integration task, visual size perception task, visual closure task	PANSS	0.93 (*f*) 0.25 (*f*) 0.35 (*f*)	This study evaluated perceptual grouping in schizophrenia over the course of inpatient treatment, in relation to the remission of particular psychotic symptoms. Deficits in perceptual organization were observed in disorganized schizophrenia patients, which improved with reductions in disorganized symptoms during the course of treatment.
Vianin et al. (2002)	Chronic ScZ	10	Gestalt recognition task		0.81 (*f*)	Impaired detection of Gestalt stimuli was related to reduced P300 amplitudes in schizophrenia patients.
Wells & Leventhal (1984)	Paranoid ScZ Nonparanoid ScZ	10 10	Preattentive grouping task		0.41 (*f*)	The study replicated the findings by Place & Gilmore (1980). No differences between paranoid and nonparanoid schizophrenia patients were reported.

Note. ScZ = schizophrenia; PANSS = Positive and Negative Syndrome Scale; BPRS = Brief Psychiatric Rating Scale; SAPS = Scale for the Assessment of Positive Symptoms; SANS = Scale for the Assessment of Negative Symptoms; TDI = Thought Disorder Index; Manch. = Manchester; PPM = poor premorbid.

[a] Liddle (1987) reported that the correlation between figure and ground perception in positive symptoms was significant only after controlling for variations in education achievement. The author did not report the size of the correlation, however.

horizontal and/or vertical line segments arranged at the points of an imaginary hexagon) were arranged in a way that allowed for quick grouping (e.g., having lines of only one type or grouping all horizontal segments together and all vertical segments together). Moreover, Place and Gilmore predicted that in a condition where lines of differing orientations were randomly intermixed, the schizophrenia patients, who were hypothesized to be deficient in grouping processes, would be more accurate than controls. All of these predictions were confirmed, in addition to the overall performance of schizophrenia patients, collapsed across all three conditions, being superior to that of controls.

Later studies by a number of investigators confirmed and extended these findings. Specifically, Wells and Leventhal (1984) replicated the results of Place and Gilmore (1980) with the same paradigm. Since 1980, numerous studies have confirmed both that schizophrenia patients are impaired in perceptual organization and that deficits in perceptual organization can lead to performance advantages in schizophrenia patients. For example, in 10 studies, schizophrenia patients were faster than control groups in detecting targets in cases where the configural arrangement of targets and distractors hindered performance of the control groups.

As discussed in previous work by Knight and Silverstein (1998, 2001), one of the most challenging problems for research in schizophrenia is the general difficulty of patients in cognitive tasks, which makes the interpretation of performance deficits far from straightforward. Demonstration of a relative or absolute task advantage as the result of a specific cognitive deficit is arguably one of the most convincing lines of evidence to refute predictions derived from the generalized deficit hypothesis (L. J. Chapman & Chapman, 1978), and this pattern has been observed in several studies of perceptual organization in schizophrenia. We therefore conclude that the pattern of performance observed in schizophrenia patients reflects a specific deficit in perceptual grouping as opposed to secondary factors, such as deficits in attention.

Dysfunctions in perceptual organization can also not be attributed to the effects of antipsychotic medication. The study by Frith, Stevens, Johnstone, and Owens (1983) included patients with schizophrenia who were not on neuroleptic medication and found

evidence for a perceptual organization deficit. Knight (1992) reported that there is also no relationship between level of depot medication and performance on perceptual organization tasks in schizophrenia patients.

Global–local task. The studies by Bellgrove, Vance, and Bradshaw (2003), Carter, Robertson, Nordahl, Chaderjian, and Oshora-Celaya (1996), and Granholm, Perry, Filoteo, and Braff (1999) reported results that differed in some respects from the findings discussed thus far. These studies used a version of the global–local task (Navon, 1977), which uses large letters made up of small letters. The task typically requires participants to identify the large letter that is made up of small letters (global level) or to identify small letters that make up the large letter (local level). The consistent finding for normal subjects is that targets at the global level are identified faster than targets at the local level. On the basis of initial results, Navon (1977) proposed that global attributes of a stimulus are analyzed first, with subsequent local analysis. In the context of the findings obtained by other studies of perceptual organization in schizophrenia that found reduced sensitivity to organizational qualities of stimuli (e.g., Doniger, Foxe, Murray, Higgins, & Javitt, 2002; Doniger, Silipo, Rabinowicz, Snodgrass, & Javitt, 2001; Place & Gilmore, 1980; Silverstein, Knight, et al., 1996, Study 1), a dysfunction in perceptual organization in schizophrenia would be expected to produce impairments in the detection of global targets but faster detection of the local targets. Precisely the opposite finding was reported by Bellgrove et al. (2003), Carter et al. (1996), and Granholm et al. (1999). In all three studies, patients with schizophrenia showed a reversed pattern. Schizophrenia patients showed faster response times for the global level and slower response times for the local level. On the other hand, a pattern consistent with the hypothesis of reduced responsiveness to Gestalt properties of stimuli in schizophrenia was reported by Ferman, Primeau, Delis, and Jampala (1999) with the same task. In this study, schizophrenia patients responded significantly faster to local relative to global targets.

Are abnormalities in perceptual organization linked to specific illness features? There is evidence to suggest that perceptual organization dysfunction is not present in all schizophrenia patients. In 8 of the 28 studies that reported deficits in perceptual organization in schizophrenia, these deficits were linked to specific subtypes of schizophrenia. Cox and Leventhal (1978) reported significantly more impairment in perceptual organization among nonparanoid schizophrenia patients. Uhlhaas, Phillips, and Silverstein (2005) differentiated between disorganized and nondisorganized forms of schizophrenia or schizoaffective disorder and found that disorganized patients showed dysfunctional perceptual organization on two tasks, whereas nondisorganized patients did not. Silverstein, Knight, et al. (1996, Study 1) differentiated between poor premorbid (in terms of social functioning) and good premorbid patients with schizophrenia. Poor premorbid patients exhibited pronounced impairments in perceptual organization, whereas good premorbid patients did not. Buchanan et al. (1994) reported that impairments in visual closure were associated with deficit forms of schizophrenia but were not present in nondeficit schizophrenia patients. Parnas, Vianin, Saebye, Volmer-Larsen, and Bovet (2001) suggested that potential differences may also exist between patient groups at various stages of the disorder. They compared three groups of patients (chronic schizophrenia, first-episode patients, and a high-risk group with prodromal symptoms) on three tasks of perceptual organization. Chronic patients exhibited reduced perceptual organization, but patients with prodromal symptoms were characterized by enhanced responsiveness to Gestalt qualities of stimuli on cognitive tasks. Although there is limited evidence for each of the subtype distinctions, it is noteworthy that (a) there is no published evidence disconfirming any of the above findings and (b) the characteristics that distinguish the groups in these studies (e.g., poor premorbid functioning, nonparanoid status, the presence of disorganization) have been found to themselves be strongly associated and to characterize a poor-premorbid, poor-prognosis subtype of schizophrenia patients (Farmer, McGuffin, & Spitznagel, 1983; Salokangas, 1997).

There is also evidence that schizophrenia patients with dysfunctions in perceptual organization are characterized by different course or outcome. Silverstein, Schenkel, Valone, and Nuernberger (1998) examined perceptual organization in a sample of chronic schizophrenia patients upon admission into a long-term psychiatric rehabilitation unit, with the task originally used in Silverstein, Knight, et al. (1996). The data revealed that, as a group, patients who were discharged within the next 3 years were characterized by intact perceptual organization at the initial testing, whereas the nondischargeable patients had displayed abnormal perceptual organization. A discriminant function analysis correctly classified 83.33% of patients as discharged or remaining after 3 years on the basis of their performance on a single perceptual measure.

The association between abnormal perceptual organization and poor outcome in schizophrenia is furthermore supported by data relating abnormal perceptual organization and nail-fold plexus visibility. Elevated visibility of the capillaries at the nail fold has been reliably demonstrated in students scoring high on schizotypy scales (Gooding & Miller, 1998) and in schizophrenia patients (Clementz, Iacono, Ficken, & Beiser, 1992; Maricq, 1966) and is associated with a more severe form of the disorder, including prognosis (Iacono, 1985; Maricq, 1966). In a sample of 20 chronic schizophrenia patients, abnormal perceptual organization correlated significantly with abnormal plexus visibility (Silverstein, Schenkel, et al., 1998).

The findings of the research presented above, examining differences in perceptual organization among categorically defined illness subtypes, are supported by data on symptom correlates. The most robust finding that has emerged so far is that higher Disorganization factor scores, on such measures as the Positive and Negative Syndrome Scale (PANSS; Kay, Opler, & Fiszbein, 1986), correlate with deficits in perceptual organization in schizophrenia. This finding has been supported by all six of the studies that have included Disorganization as a separate symptom factor (Izawa & Yamamoto, 2002; Knight & Silverstein, 1998; Silverstein, Bakshi, Chapman, & Nowlis, 1998; Silverstein, Kovács, Corry, & Valone, 2000; Uhlhaas et al., 2005). Research on relationships between specific disorganized symptoms and perceptual organization has also been conducted. Using the Thought Disorder Index (TDI; Johnston & Holzman, 1979), Knight and Silverstein (1998) reported a link between dysfunctional perceptual organization and the TDI Disorganized and Associative factors, suggesting a link between reduced organization in thinking and reduced organization in perception. Carter et al. (1996) reported that dysfunctional perceptual organization as assessed by the global–local task was correlated with an increase in auditory hallucinations. This association was not replicated by Granholm et al. (1999), who

used the same experimental task. Doniger et al. (2001) and Malaspina, Simon, Mujica-Parodi, Goetz, and Gorman (2003) found that elevated negative symptoms were related to a perceptual closure deficit in schizophrenia. Positive symptoms emerged as the main clinical correlate of dysfunctional perceptual organization in studies by Liddle (1987) and Peters, Nunn, Pickering, and Hemsley (2002). No significant correlations between psychotic syndromes and dysfunctional perceptual organization were reported by Carr et al. (1998), Ferman et al. (1999), Granholm et al. (1999), or Lieb, Merklin, Rieth, Schüttler, and Hess (1994).

Differences in symptom correlates of dysfunctional perceptual organization across studies can be accounted for by the different symptom models used. Studies by Silverstein, Bakshi, et al. (1998) and Silverstein et al. (2000) used both four- and five-factor solutions for the PANSS that included a Disorganization factor, whereas Peters et al. (2002) grouped symptoms into Positive and Negative factors only. Doniger et al. (2001) used a three-factor model proposed by White, Harvey, Opler, and Lindenmayer (1997), which differs significantly from the most common symptom models. Furthermore, particular syndromes of schizophrenia, such as disorganization, may be more prevalent in chronic schizophrenia than in acute patients (Salokangas, 1997). Cognitive impairments and symptoms may therefore correlate differently in chronic and acute samples of schizophrenia patients. Moreover, the absence of significant correlations between symptom ratings and deficits in perceptual organization in the studies by Carr et al. (1998) and Lieb et al. (1994) may be explained by the relatively low levels of psychotic symptoms in patients in both studies. Nonetheless, the most robust finding that has emerged so far is that the PANSS disorganization and cognitive factors correlate with deficits in perceptual organization in schizophrenia.

Are deficits in perceptual organization related to stimulus characteristics and task demands? An important issue is whether schizophrenia patients show selective impairments in perceptual organization or whether a comprehensive deficit occurs in all experimental tasks regardless of the influence of task manipulations or stimulus structure. The processing of stimuli with prepotent structures in schizophrenia was specifically examined by Knight et al. (2000) and Silverstein, Bakshi, et al. (1998). These studies specifically tested the hypothesis that perceptual organization in schizophrenia is intact for stimuli with strong configural properties. Knight et al. (2000) used both physical and name-match paradigms by using two-letter combinations that were arranged in either symmetrical or asymmetrical configurations. The results indicated that schizophrenia patients exhibited intact perceptual grouping performance for stimuli with strong symmetrical properties but were impaired in the utilization of top-down cues for stimulus grouping. Likewise, Silverstein, Bakshi, et al. (1998) demonstrated that schizophrenia patients displayed intact perception for stimuli with "good" (symmetrical) form but were significantly impaired in detection of stimuli with "poor" (nonsymmetrical) form in a pattern recognition task. This was furthermore supported by Rabinowicz, Opler, Owen, and Knight (1996), who examined the stage of processing at which perceptual organization deficits in schizophrenia occur. In a study notable for the conceptual sophistication of the experimental design, the authors evaluated whether impairments in perceptual organization in schizophrenia are due to deficits in a primary sensory store versus an impairment in short-term visual memory (STVM). The results indicated that schizophrenic patients were capable of basic structural information processing in the sensory store but deficient in the allocation of cognitive and conceptual processing resources to incoming data in STVM.

Silverstein, Knight, et al. (1996, Study 2) included a task manipulation to examine specifically the contributions of top-down processing strategies to impairments in perceptual organization. Strengthening of contextual top-down feedback normalized performance of poor premorbid schizophrenia patients, suggesting that impairments in top-down processing might be a critical deficit in perceptual organization in schizophrenia. Similarly, Cox and Leventhal (1978) observed that nonparanoid schizophrenia improved these patients' perceptual organization performance after the preattentive discriminability of stimuli was increased. In addition, Place and Gilmore (1980) observed that in contrast to controls, schizophrenia patients did not benefit from previous exposure to configural stimuli, suggesting a weakening of the influence of stored memories or regularities of previous input (top-down input) on current perception (Hemsley, 1994).

The finding of a global advantage for schizophrenia patients in the studies by Bellgrove et al. (2003), Carter et al. (1996), and Granholm et al. (1999) may be explained by the specific task manipulations used in these studies. A global advantage was found only for the condition in which attention was divided between the local and global levels and there was an equal probability of the target appearing at both levels. Bellgrove et al. (2003) specifically examined the source of this deficit in schizophrenia through an analysis of the individual trials in patients. The results indicated that schizophrenia patients were significantly slower to detect targets at the local level in comparison with the global level if they had attended in the immediately preceding trials to the global spatial scale. The same pattern of performance was not found for the control group. Thus, the global advantage for schizophrenia patients may be explained as an "inability to shift the spatial scale of attention from the global local level" (Bellgrove et al., 2003, p. 62) rather than as a deficit in processing in global targets.

Summary. The large majority (28 of 33) of studies reviewed suggest that (a) schizophrenia is characterized by dysfunctional perceptual organization; (b) the dysfunction in perceptual organization is most pronounced in a subtype of schizophrenia that is characterized by poor premorbidity, increased levels of disorganization, and poor outcome; and (c) deficits in perceptual organization are observed mainly when task stimuli have fewer configural properties and when task-relevant processing requires top-down influences. Studies that did not find evidence of perceptual organization dysfunction typically used stimuli that were highly configural and therefore could be processed through bottom-up prespecified feature hierarchies, such tasks as the global–local task that predominantly assess functions other than perceptual organization (e.g., attentional resource allocation strategies and set shifting), or relatively asymptomatic patients.

Perceptual Organization in Schizophrenia Spectrum Disorders and Schizotypy

Seven studies were identified in the literature that examined perceptual organization in schizophrenia spectrum disorders and schizotypy. Table 2 presents an overview of these studies. The large majority of the studies support the hypothesis that deficits in

Table 2
Studies of Perceptual Organization in Schizophrenia Spectrum Disorders

Study	Participants	*N*	Task	Scale	Effect size	Summary of findings
Goodarzi et al. (2000)	Student population	32	Global–local task	O-Life	0.32 (*f*)	Subjects with elevated levels of schizotypy showed superior local processing. Local bias was associated with right-hemisphere activation and increased positive symptoms.
Granholm et al. (2002)	SPD	21	Global–local task	SPQ	0.34 (*f*)	Impaired performance for global elements in patients with SPD. Impaired performance was correlated with greater interpersonal deficits.
Lieb et al. (1996)	Adolescents with genetic risk for ScZ	17	Preattentive texton detection task		1.33 (*d*)	Offspring of parents with schizophrenia were significantly impaired in the detection of texton elements, which was associated with dysfunctional processing in the right hemisphere.
Rawlings & Claridge (1984)	Student population	32	Navon global–local task	EPQ, STQ	0.32 (*f*)	Schizotypic subjects showed superior local processing for stimuli in the left visual field.
Silverstein et al. (1992)	Student population	57	Preattentive grouping task, visual suffix task, configural superiority task	PercAb, PhyAnhed	0.27 (*f*) 0.25 (*f*) 0.54 (*f*)	Students with elevated levels on the Physical Anhedonia, Perceptual Abberation, and Magical Ideation Scales displayed intact perceptual organization in three tasks.
Tsakanikos & Reed (2003)	Student population	100	Figure–ground test	O-Life	0.56 (*f*)	Higher levels of introverted anhedonia were associated with impaired figure–ground segregation.
Uhlhaas et al. (2004)	Student population	67	Contour integration task, visual size perception task	SPQ, TDI	0.30 (*f*), 0.28 (*f*)	Schizotypic subjects with thought disorder were significantly impaired in contour integration and were more accurate in size perception were than non–thought-disordered schizotypes and nonschizotypic controls.

Note. O-Life = Oxford–Liverpool Inventory of Feelings and Experiences; SPD = schizotypal personality disorder; SPQ = Schizotypal Personality Questionnaire; ScZ = schizophrenia; EPQ = Eysenck Personality Questionnaire; STQ = Schizotypy Questionnaire; PercAb = Perceptual Abberation Scale; PhyAnhed = Physical Anhedonia Scale; TDI = Thought Disorder Index.

perceptual organization can be found in people with disorders related to schizophrenia. The first study to examine perceptual organization in relationship to schizotypal traits was conducted by Rawlings and Claridge (1984). In this study, a student population ($N = 32$) was administered the global–local task (Navon, 1977). Students with elevated levels of schizotypal symptoms showed a local processing advantage in the left visual field compared with low schizotypal subjects. Later studies extended this finding by demonstrating that dysfunctional perceptual organization can be found in schizotypal personality disorder (Granholm, Cadenhead, Shafer, & Filoteo, 2002) as well as in individuals with a genetic risk factor for schizophrenia (Lieb et al., 1996). The most consistent evidence for a deficit in perceptual organization among spectrum populations comes from studies that have used the global–local task (Navon, 1977). Yet these studies differ significantly in the pattern of deficits observed; these differences will be discussed in detail below. Additional studies (Tsakanikos & Reed, 2003; Uhlhaas, Silverstein, Phillips, & Lovell, 2004) have provided evidence for a dysfunction in perceptual organization in schizophrenia spectrum disorders by using a number of paradigms. Only the study by Silverstein, Raulin, Pristach, and Pomerantz (1992) did not confirm this finding.

Similar to research in schizophrenia patients, studies that used the global–local task (Navon, 1977) found conflicting evidence for a perceptual organization deficit in spectrum populations. Granholm et al. (2002) reported that patients with schizotypal personality disorder were more responsive to stimuli at the global level in a divided attention paradigm. Goodarzi, Wykes, and Hemsley (2000) and Rawlings and Claridge (1984) found that students with elevated levels of schizotypal symptoms showed a local processing advantage that resulted in significantly faster reaction times. In these two studies, however, global–local processing was examined within a directed attention paradigm. As explained above, the global advantage in the divided attention paradigm reported by Granholm et al. (2002) in schizotypal personality disorder may not reflect a genuine impairment in perceptual organization but rather a deficit in attentional resource allocation.

Four studies examined symptom correlates of impairments in perceptual organization. Goodarzi et al. (2000) found that impaired perceptual organization was significantly correlated with positive symptomatology in schizotypal participants. Granholm et al. (2002) obtained a significant correlation between interpersonal deficits and enhanced processing of stimulus organization, whereas impaired figure–ground perception was correlated with higher levels of introverted anhedonia in a study by Tsakanikos and Reed (2003). Uhlhaas et al. (2004) reported no significant correlations between deficits on two tasks of perceptual organization and schizotypal symptomatology. In that study, however,

dysfunctional perceptual organization was present only in schizotypal subjects with thought disorder as assessed by the TDI (Johnston & Holzman, 1979), suggesting a relationship between disorganization and cognitive deficits in schizotypy.

The evidence suggests that deficits in perceptual organization can be observed in clinical and nonclinical subject populations of the schizophrenia spectrum who supposedly share a common (genetic or behavioral) predisposition (i.e., schizotaxia) (Meehl, 1962), including participants with schizotypal personality disorder (Granholm et al., 2002), offspring of parents with a diagnosis of schizophrenia (Lieb et al., 1996), and student populations with elevated levels of schizotypy (Goodarzi et al., 2000; Rawlings & Claridge, 1984; Tsakanikos & Reed, 2003; Uhlhaas et al., 2004). Similar to the evidence from studies of perceptual organization in schizophrenia patients, the type of dysfunction, pattern of performance on experimental tasks, and clinical correlates of cognitive deficits have varied significantly across studies in subjects with schizophrenia spectrum disorders. The studies with the global–local task (Goodarzi et al., 2000; Granholm et al., 2002; Rawlings & Claridge, 1984), for example, have identified differential patterns of performance that closely parallel the conflicting evidence from schizophrenia patients. Moreover, all three main symptom factors (Positive, Negative, and Disorganized) have been associated with dysfunctional perceptual organization. As argued above, such conflicting findings may be attributed to the variety of experimental tasks used and to differences in symptom models and scales for the assessment of symptoms that were used across studies. Finally, differential patterns of performance across studies were observed. In three of seven studies, dysfunctional perceptual organization in schizophrenia spectrum disorders was accompanied by enhanced performance on experimental tasks in which intact stimulus grouping abilities would impair performance.

Table 3
Patient Reports of Changes in Visual Perception in Schizophrenia

Source	Patient report
Arieti (1962, p. 85)	"She remembered that she could not look at the whole door. She could only see the knob or some corner of the door. The wall was fragmented into parts."
Matussek (1952, 1987, p. 92)	"I may look at the garden, but I don't see it as I normally do. I can only concentrate on detail. For instance, I can lose myself in looking at a bird on a branch, but then I don't see anything else."
J. Chapman (1966, p. 229)	"Everything I see is split up. It's like a photograph that's torn in bits and put together again. If somebody moves or speaks, everything I see disappears quickly and I have to put it together."
McGhie & Chapman (1961, p. 106)	"It's the same with listening. You can hear snatches of conversation and you can't fit them together."
McGhie & Chapman (1961, p. 105)	"I notice it most with background noises—you know what I mean, noises, that are always around but you don't notice them."

Future Perspectives for Research on Perceptual Organization in Schizophrenia Spectrum Disorders

The discussion below consists of two parts. First, we will briefly summarize where the weight of the evidence lies for each of the hypotheses stated at the outset. Second, we will discuss future directions for this research area.

Hypothesis 1 was that deficits in perceptual organization are a general feature of schizophrenia spectrum disorders. The majority of studies indicate that this is the case. The evidence reviewed suggests that schizophrenia spectrum disorders are characterized by deficits in perceptual organization. This is supported by findings from various clinical and nonclinical participant groups that used a multitude of experimental paradigms and by experimental results that are incompatible with predictions derived from a generalized deficit model (L. J. Chapman & Chapman, 1978). Thus, for example, deficits in perceptual organization produced performance advantages in schizophrenia and schizotypal subjects, which were the result of a specific deficit in perceptual grouping as opposed to secondary factors, such as deficit in attention. Moreover, patients' descriptions of their experience of the visual world (see Table 3) provide further evidence for a dysfunction in perceptual organization in schizophrenia. These reports closely parallel the experimental evidence of deficit in the integration of sensory information (for a review, see Silverstein & Uhlhaas, 2004; Uhlhaas & Silverstein, 2003). Studies in which no deficit was found can be understood as being the result of specific task features and/or the particular characteristics of the patient sample studied, as noted below.

An important issue is whether dysfunctions in perceptual organization are specific to schizophrenia spectrum disorders or whether they can also be found in other forms of psychopathology. Many of the studies reported above that compared schizophrenia patients with other affective disorders or nonschizophrenia psychotic disorders have consistently found that deficits in perceptual organization are specific to schizophrenia spectrum disorders and, as noted, often to more severely ill schizophrenia patients. However, perceptual organization deficits can be found among neurodevelopmentally and neurologically disordered populations, such as autism and Williams syndrome (Phillips & Silverstein, 2003); right-hemisphere learning disabilities (Silverstein & Palumbo, 1995); and amblyopia, a condition known to affect coordinated activity between feature detectors in the visual cortex (Chandna, Pennefather, Kovacs, & Norcia, 2001; Simmers & Bex, 2001), which is a mechanism hypothesized to be operative in schizophrenia (Phillips & Silverstein, 2003). Moreover, people with known brain lesions (often secondary to surgery to remove an epilepsy focus) of the right temporal lobe or temporal–parietal junction (Doyon & Milner, 1991; Lansdell, 1970; Robertson, Lamb, & Knight, 1988) have demonstrated perceptual organization deficits. In contrast, people with lesions of the prefrontal cortex appear to have normal perceptual organization (Robertson, Lamb, & Knight, 1991). Researchers have also identified a subgroup of Alzheimer's disease patients with right-hemisphere impairment that exhibits deficits in perceptual organization (Massman et al., 1993). Overall, these data support the hypothesis that perceptual organization dysfunction in schizophrenia is a biologically based deficit involving impairment in basic feature integration mechanisms and, possibly, in higher level, right-hemisphere-based processing of perceptual wholes at large spatial scales as well.

Hypothesis 2 was that perceptual organization deficits are linked to specific schizophrenia subtypes and/or symptom dimensions. The most consistent evidence to support such a hypothesis has been evidence linking a subtype of schizophrenia spectrum disorders characterized by poor premorbid social history and increased disorganization to deficits in perceptual organization. Thus, the three studies (Knight et al., 2000; Knight & Silverstein, 1998; Silverstein, Knight, et al., 1996) that examined perceptual organization and premorbid social history all confirmed such a link. This association is also supported by prior work specifically focusing on impaired perceptual organization as a mechanism underlying visual processing deficits in schizophrenia. In a series of studies, Knight and colleagues (Knight, Elliott, & Freedman, 1985; Knight, Sherer, Putchat, & Carter, 1978; Knight, Sims-Knight, & Petchers-Cassell, 1977) examined STVM, a processing stage during which consolidation of stimulus elements into a conceptual-level representation takes place. These studies demonstrated that poor premorbid patients were characterized by a specific deficit in STVM, which was not present in good premorbid patients. Subsequent research by other groups (Luck & Vogel, 1997; Raffone & Wolters, 2001) indicated that consolidation in STVM involves the grouping processes that are hypothesized to operate in more traditional demonstrations of perceptual organization.

At the level of signs and symptoms, elevated levels of disorganization are the most consistent correlate of dysfunctions in perceptual organization in schizophrenia spectrum disorders. Thus, six of the eight studies reviewed that used symptom models that included a disorganization factor found that elevated levels of disorganized symptoms were the strongest clinical correlates of deficits in perceptual organization in schizophrenia patients. As noted above, negative findings on the association between disorganized symptoms and dysfunctional perceptual organization can be explained by the different symptom models used and the clinical characteristics of the particular patient sample. For example, the relatively low rate of disorganized symptoms in schizotypal and first-episode patients may limit the ability to detect any relationships in these populations. The cooccurrence of disorganization, poor premorbid social history, and impairments in perceptual organization reflects, in our view, a developmental trajectory that indicates a neurodevelopmental subtype of schizophrenia spectrum disorders. This is also supported by the association between abnormal plexus visibility and impaired perceptual organization in schizophrenia spectrum disorders (Silverstein, Schenkel, et al., 1998) and poor response to behavioral and pharmacological treatment (Silverstein, Schenkel, et al., 1998).

Third, we hypothesized that perceptual organization deficits in schizophrenia are observed to the extent that top-down input is required to form novel stimulus groupings, whereas performance is relatively normal on tasks using highly configural stimuli. Five studies (Chey & Holzman, 1997; Knight et al., 2000; Rabinowicz et al., 1996; Silverstein, Bakshi, et al., 1998; Silverstein, Osborn, et al., 1998) that investigated perceptual organization on tasks using stimuli with high levels of prepotent structure found that perceptual organization was intact in schizophrenia patients. In contrast, studies that required top-down input found significant impairments in both auditory and visual perceptual organization (e.g., Izawa & Yamamoto, 2002; Silverstein, Bakshi, et al., 1998; Silverstein, Matteson, & Knight, 1996). Evidence also suggests that strengthening top-down feedback to perceptual processes can improve the performance of schizophrenia patients in perceptual organization tasks (Silverstein, Knight, et al., 1996, Study 2).

Although the accumulated evidence is impressive, we propose that the research carried out so far can be improved in a number of ways that will further our understanding of the cognitive and neural basis of perceptual organization deficits in schizophrenia spectrum disorders.

Heterogeneity in Schizophrenia Spectrum Disorders and Perceptual Organization

Schizophrenia spectrum disorders may represent a group of disorders that share a common outcome (psychosis) but differ in the etiological mechanisms that bring about this end state (Tsuang & Faraone, 1995). The study of patients who are identified on the basis of nonspecific symptoms with possibly different underlying cognitive and neurobiological abnormalities may, therefore, constitute a major stumbling block in the search for the causes of the disorder. The heterogeneity of schizophrenia spectrum disorders is most evident on the level of symptoms and outcome but includes cognitive dysfunctions (Heinrichs, 1993) and neuropathology as well (Selemon, 2001).

The research on perceptual organization in schizophrenia spectrum disorders suggests that dysfunctional perceptual organization may characterize one subtype of the disorder. Specifically, our review suggests that poor premorbid social history, increased disorganization, poor response to behavioral and pharmacological treatment, and reduced nail-fold plexus visibility may be related to dysfunctions in perceptual organization in schizophrenia spectrum disorders, and that these features may constitute a taxon (i.e., category or type). Such a taxon most closely corresponds to the proposed neurodevelopmental subtype of schizophrenia (Farmer et al., 1983; Jones, Guth, Lewis, & Murray, 1994). This is supported by the cooccurence of impairments in perceptual organization in neurodevelopmental disorders, such as autism (Happe, 1999), Williams syndrome (Pani, Mervis, & Robinson, 1999), and nonverbal learning disabilities (Silverstein & Palumbo, 1995).

To strengthen this hypothesis, future research would benefit from the simultaneous inclusion of multiple measures that allow the examination of specific clinical parameters that have been associated with deficits in perceptual organization. These would include the Premorbid Adjustment Scale (Cannon-Spoor, Potkin, & Wyatt, 1982), symptom rating scales that include a disorganization dimension (Liddle, 1987), and more fine-grained approaches toward the study of the disorganization in schizophrenia spectrum disorders, that is, detailed analysis of thought disorder (Johnston & Holzman, 1979). Evidence for a link between perceptual organization deficits in schizophrenia spectrum disorders and neurodevelopmental disorders could be strengthened by specifically examining the prevalence of markers of abnormal neurodevelopment, such as neurologic soft signs, in relationship to perceptual organization in schizophrenia patients as well as the direct comparisons between impairments in perceptual organization in autism, for example, and schizophrenia spectrum disorders.

Construct Validity of Experimental Tasks

Few studies of perceptual organization in schizophrenia spectrum disorders have used experimental tasks whose conceptual

relationship to the construct of perceptual organization is clear and that have a substantial history of replicability and reliability in the normal psychological literature. Second, no data that have examined the relationships between measures of perceptual organization are available in the literature; this makes comparisons between studies difficult and raises the question of the construct validity of the various measures used. These issues are critical because the only useful tasks will be those whose underlying cognitive processes are clearly defined and that can guide both biological exploration and relationships to macrobehavioral symptomatology (Knight & Silverstein, 1998). Accordingly, research into perceptual organization in schizophrenia spectrum disorders will benefit from a grounding in current developments in cognitive neuroscience so that tasks are selected that have been thoroughly investigated in the normal psychological literature and that may also allow inferences regarding the underlying neurophysiological substrates of perceptual organization.

Issues of construct validity also apply to tasks that have been seen as paradigmatic examples of perceptual organization. Kimchi (1992), for example, argued that the global–local task might measure not the precedence of holistic processing (and therefore the intactness of perceptual grouping) but, more appropriately, the precedence of higher level units before lower level units in stimulus processing.

Perceptual Organization and Cognitive Deficits in Schizophrenia Spectrum Disorders

Research into perceptual organization in schizophrenia spectrum disorders may also hold clues for a wider understanding of cognitive deficits in these conditions. Grouping of stimulus elements into coherent object representations according to Gestalt principles is a paradigmatic example of context processing (Phillips & Silverstein, 2003). The classic demonstrations of Gestalt principles show that stimulus characteristics are dependent on the global aspects of the stimulus configuration where the neighboring stimulus elements constitute the "context" that influences perceptual processes. Deficits in the processing of contextual information are seen by several investigators (Braver, Barch, & Cohen, 1999; Cohen & Servan-Schreiber, 1992; Gray, Feldon, Rawlins, Hemsley, & Smith, 1991; Hemsley, 1994; Phillips & Silverstein, 2003) as a core deficit that can explain various cognitive impairments of the disorder. Although our view (Phillips & Silverstein, 2003) is consistent with the models proposed by Gray et al. (1991) and Cohen and Servan-Schreiber (1992), we believe that deficits in perceptual organization in schizophrenia spectrum disorders reflect not only deficits in postattentive working-memory-based linkages of features across time but also preattentive concurrent modulation from surrounding stimulus features across space, as demonstrated in a series of studies of our group (Silverstein, Knight, et al., 1996; Silverstein et al., 2000; Uhlhaas et al., 2004, 2005). Thus, impairments in perceptual organization in schizophrenia spectrum disorders may be indicative of a widespread deficit in the generation of contextually coordinated neural activity across both space and time and operating across cognitive domains (Phillips & Silverstein, 2003).

Evidence for such a hypothesis comes from research that has demonstrated that deficits in perceptual organization occur not only in visual perception but also in the auditory domain (Silverstein, Matteson, & Knight, 1996) and that deficits in language perception and production may also be considered as evidence of an impairment in contextual processing (Kuperberg, McGuire, & David, 1998; Spitzer, Breuckers, Beyer, Maier, & Hermle, 1994). On a clinical level, the most consistent correlates of impaired perceptual organization in schizophrenia are the disorganized symptoms, such as thought disorder, and inappropriate affect and behavior. It can be argued that these symptoms represent the behavioral manifestation of an underlying deficit in the context-related coordination of neural and cognitive activity, and a core aspect of phenomenology in schizophrenia, namely the fragmentation of mind (Bleuler, 1911/1950).

Yet, further support is needed for the hypothesis that perceptual organization reflects a widespread deficit in coordination of contextually related stimuli. So far, studies have mostly examined perceptual organization in one isolated cognitive domain. This leaves open the question of whether deficits in perceptual organization in visual perception, for example, are linked to dysfunctions in the organization of auditory input. Moreover, if context processing underlies the disorganization of thought and language in schizophrenia, then contextually mediated language deficits should correlate with impairments in context processing in perception. Future studies could use multiple measures of perceptual organization as well as context processing to examine whether perceptual organization in schizophrenia reflects a single breakdown in contextually mediated information processing in schizophrenia spectrum disorders.

Perceptual Organization, Electrophysiology, and Gamma-Band Oscillations in Schizophrenia Spectrum Disorders

One of the fundamental problems in current cognitive neuroscience is the question of how the brain constructs coherent object representations from neural information that is processed in different areas of the brain. Theoretical and empirical data indicate that synchronized correlated activity within the gamma frequency band (30–80 Hz) may serve as a temporal code for coherent object representations (Singer, 1999; Singer & Gray, 1995; von der Marlsburg & Schneider, 1986).

Perceptual organization is a paradigmatic example of binding in sensory systems of the brain where sensory input requires a dynamic neural mechanism to produce novel output (Watt & Phillips, 2000). Probability and strength of synchronization, for example, reflect elementary Gestalt criteria for perceptual grouping, such as proximity, collinearity, and common fate (Singer, 1999). There is evidence to suggest that schizophrenia may be characterized by abnormalities in gamma-frequency oscillations and that dysfunctional perceptual organization is related to these abnormalities (Spencer et al., 2003). Moreover, aberrant gamma-band activity has been demonstrated in cognitive tasks that require the processing of relevant versus irrelevant stimuli (Haig, Gordon, De Pascalis, Meares, & Baharamali, 2000) as well as in a visual-making paradigm (Green et al., 2003). There is also evidence to link differences in gamma-band activity with different symptom profiles in schizophrenia (for a review, see Lee, Williams, Breakspear, & Gordon, 2003), with the disorganization syndrome being the most likely symptom expression candidate of a reduction in gamma-band activity.

The available evidence suggests that deficits in both perceptual organization and gamma-band activity coexist in schizophrenia. In our view, linking these two areas of research represents one of the most promising approaches for the understanding of perceptual organization dysfunctions in schizophrenia spectrum disorders. To date, only the study by Spencer et al. (2003) has explicitly examined dysfunctional perceptual organization in relation to gamma-frequency oscillations in schizophrenia spectrum disorders, indicating that deficits in perceptual organization in schizophrenia may be related to reductions in evoked gamma-band activity. Future studies need to replicate these findings as well as address the question of whether deficits in perceptual organization in schizophrenia spectrum disorders are related to induced gamma-band oscillations.

According to Tallon-Baudry and Bertrand (1999), induced and evoked components of gamma-band activity need to be distinguished. Induced and evoked gamma responses represent different types of differential but complementary binding mechanisms. The early evoked component may be relevant for the signaling of precise temporal relationships between stimuli as the result of phase locking of stimulus onsets. In contrast, the induced gamma response may be more representative of the construction of object representations in a wide range of cognitive functions, including perception, attention, and memory (Tallon-Baudry & Bertrand, 1999), and is related to top-down influences that are shaped by the intrinsic dynamics of thalamocortical networks (Engel, Fries, & Singer, 2001). Because deficits in the processing of top-down mediated contextual information are critical for dysfunctions in perceptual organization in schizophrenia spectrum disorders (e.g., Silverstein, Bakshi, et al., 1998; Silverstein, Knight, et al., 1996; Silverstein, Matteson, & Knight, 1996), further research should therefore examine induced gamma-band oscillatory activity in relationship to perceptual organization in schizophrenia spectrum disorders.

At the biological level, synchronization of firing has been linked to the activity of NMDA receptors, and reduced activity of NMDA receptors is now considered to be a major factor in schizophrenia. For example, NMDA channels can activate rhythmic bursting (Daw, Stein, & Fox, 1993), and NMDA currents may have a rapidly decaying component with a time constant short enough to support fast-bursting synchronization of oscillations. Recent research suggests that NMDA channels may be pathological in schizophrenia spectrum disorders (for reviews of this issue, see Olney & Farber, 1995; Phillips & Silverstein, 2003), suggesting that hypoactivity of NMDA receptors may also be involved in producing perceptual organization deficits in schizophrenia. Future research, therefore, could determine whether NMDA antagonists (e.g., PCP, MK-801, ketamine) impair perceptual organization in animals, naturalistic effects of these agents on perceptual organization in humans, the effects of NMDA agonists (e.g., glycine) and agents with similar effects on perceptual organization, and psychological phenomena (e.g., disorganization) to which perceptual organization is related.

Summary

Throughout the history of schizophrenia research, basic sensory processing in schizophrenia spectrum disorders has rarely been considered an important starting point for probing into the cognition and biology of these disorders. This review, however, suggests that there is reliable evidence to conclude that perceptual organization is impaired in schizophrenia spectrum disorders and that dysfunctions in the organization of sensory information may prove to be relevant for a wider understanding of the cognitive, behavioral, and biological abnormalities of the disorder. Specifically, deficits in perceptual organization may reflect a wider deficit in the coordination of contextually related information across space and time, at both the cognitive and neural levels (Phillips & Silverstein, 2003).

The most consistent finding from studies in schizophrenia spectrum disorders is that dysfunctional perceptual organization is manifested as a reduced responsiveness to the organizational qualities of stimuli. This is strongly supported by the phenomenology of visual perception in schizophrenia and by experimental studies in which dysfunctional perceptual organization in schizophrenia patients and subjects with schizophrenia spectrum disorders resulted in performance advantages over control groups. This is in contrast to the majority of studies of cognitive dysfunctions in schizophrenia spectrum disorders, which report results that are confounded by the predictions of a generalized deficit hypothesis. We therefore conclude that this indicates that dysfunctions in perceptual organization in schizophrenia spectrum disorders are primary and not secondary to other cognitive deficits.

Our review has furthermore shown that deficits in perceptual organization in schizophrenia spectrum disorders are moderated by a number of clinical and nonclinical parameters. Specifically, deficits in perceptual organization in schizophrenia spectrum disorders depend on (a) tasks parameters, especially on how much the stimuli have prepotent structure, versus how much they are novel and rely on dynamic grouping, and top-down or stimulus-driven modulation; and (b) clinical parameters, such that the deficit is expressed mainly among patients with disorganized schizophrenia and/or those with histories of poor premorbid social functioning, which are themselves related (Farmer et al., 1983; Gureje, Aderibigbe, & Obikoya, 1995).

Current theorizing about the role of synchronous oscillations within the gamma-band range as a mechanism for the binding of stimulus features and the construction of coherent object presentations may be crucial for understanding dysfunctional perceptual organization in schizophrenia spectrum disorders. Theoretical and empirical evidence has provided substantial support for this view and the evidence reviewed indicates that schizophrenia spectrum disorders are characterized by abnormalities within the gamma-band range. From this, it follows that impairments in perceptual organization in schizophrenia spectrum disorders may be isomorphically related to impairments in the synchronization of neural responses within the gamma band, such that reduced organization in the visual field is accompanied by reduced coordination of the underlying brain processes. The relevance of future investigations into the relationship between disorganized perceptual processes and gamma-band activity goes beyond understanding of disordered mental and brain processes in schizophrenia, however. One of the central concerns of current cognitive neuroscience is the relevance of coordinating processes in the brain that complement the localization of functions to produce coherent neural and cognitive activity (Phillips & Silverstein, 2003; Phillips & Singer, 1997). The study of disordered brain–mind relationships in schizophrenia spectrum disorders may prove useful for such purposes. By demonstrating the behavioral and cognitive consequences of

deficits in coordinating processes, their functional role in normal cognitive activity can be made clearer.

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