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Perceptual organization by proximity and similarity in schizophrenia

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Abstract

Perceptual organization represents a basic and essential function that occurs at an intermediate level of visual processing. Much of the previous research on perceptual organization in schizophrenia employed indirect measurements, or included factors beyond sensory processing. The aims of the present study were to determine the integrity of perceptual organization in schizophrenia, as well as to determine the stimulus duration necessary to perform perceptual organization. Psychophysical measurements were compared between patients with schizophrenia and matched control subjects. Participants viewed dot patterns briefly presented on a computer monitor, and indicated whether stimuli appeared grouped as vertical or horizontal lines. Grouping was based upon either relative proximity or similarity in color. Across trials, relative proximity or color similarity was progressively reduced until stimuli became bi-stable (perceived as either of two patterns of grouping), establishing the grouping threshold. In separate conditions, stimuli were immediately followed by a mask to limit processing. Stimulus duration was progressively reduced until stimuli became bi-stable, establishing the critical stimulus duration (CSD). Schizophrenia patients demonstrated elevated grouping thresholds for grouping by proximity as well as color similarity. In addition, CSD was significantly extended for the schizophrenia group, with a nearly four-fold increase in duration of processing. These results provide direct evidence of impairment in schizophrenia for perceptual organization based upon spatial relationships and feature similarity, and suggest deficits in low-level perceptual organization processes. Although this study did not directly investigate the physiological correlates underlying perceptual impairments, these results are consistent with a theory of impaired lateral connections within visual cortical areas in schizophrenia.

Keywords: Perceptual grouping; Gestalt; Color similarity proximity; Critical stimulus duration

1. Introduction

Perceptual organization describes the process of extracting perceptual objects from the initial retinal representation of stimuli. In this regard, perceptual organization enables observers to resolve elements of a complex scene into a series of unified forms. Perceptual organization occurs at an intermediate level of visual processing, preceded by the reception and encoding of basic stimulus features by the retina, and followed by interactions with more high-order processing (Finkel and Sajda, 1994). In this regard, perceptual organization is reliant upon the integrity of afferent signals and

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initial stimulus representations. In addition, higher-order processes, such as object recognition (Uttal, 1988) and memory (Humphrey and Kramer, 1999), may be degraded by impairment at the level of perceptual organization. Perceptual organization is a robust and dynamic process mediated by multiple interacting mechanisms. In this regard, perceptual organization is guided by both stimulus metrics as well as top–down factors (Beck and Palmer, 2002; Kimchi et al., 2002; Palmer et al., 2003).

When confronted with complex visual scenes, the brain automatically organizes them into a group of unified forms ("percepts") that can be analyzed as discrete objects. Such perceptual organization operates in accordance with two general principles. First, regularities that exist among stimulus elements are identified, based upon a variety of spatial/temporal cues. Second, associated components are integrated into coherent forms. To accommodate novel stimuli with speed and accuracy, processes underlying these functions are thought to follow neural algorithms that specify grouping patterns best suited to identify forms. Visual perceptual organization is reliant upon neural connections that integrate information across striate and extrastriate cortex. Integration systems are composed of lateral connections within local circuits (Dantzker and Callaway, 2000; McGuire et al., 1991; Stettler et al., 2002), as well as feedback connections that modify initial sensory representations (Angelucci et al., 2002; Bringuier et al., 1999; Kapadia et al., 1999).

Based upon tasks in which perceptual organization plays a role, it has been proposed that perceptual organization is abnormal in schizophrenia. For example, patients have been found to benefit less from perceptual grouping than control subjects in several tasks such as discrimination of disparate figures (Cox and Leventhal, 1978), numerosity judgments (Place and Gilmore, 1980; Wells and Leventhal, 1984), object sorting (Frith et al., 1983), and figure detection (Parnas et al., 2001). Furthermore, patients were impaired at identifying circles formed by collinear Gabor elements embedded in a field of randomly oriented elements (Silverstein et al., 2000). However, the number of studies examining basic levels of perceptual organization in schizophrenia remains limited, and there remains a need for further protocol development in this area. In order to understand the characteristics of perceptual organization capacities in schizophrenia, psychophysical measurements of visual function specific to organizational processes need to be made. Without such measurements, analysis of impairment at this stage of visual processing, and possible impact on higher levels of visual and cognitive function will remain incomplete.

The first aim of the present study was to determine the integrity of perceptual organization in schizophrenia. Two basic principles of grouping were explored that have not been examined previously in schizophrenia with these procedures: grouping by proximity and grouping by color similarity. Grouping by proximity refers to the tendency to perceptually group stimulus elements that are in close spatial proximity, which was engaged here by manipulating the relative proximity among elements. Grouping by similarity refers to the tendency to perceptually group elements that share stimulus features, which was engaged here by manipulating the degree of color similarity among elements. The integrity of perceptual grouping function was examined by progressively reducing the degree of intrinsic organization contained in the stimulus, by either reducing the difference in relative proximity, or the degree of similarity among elements. Psychophysical thresholds were established by using an up–down transformed response method, thereby more precisely quantifying deficits. Measurements from the up–down staircase procedure reflect stimulus levels at which subjects accurately organize stimuli with a long-run probability of 71% correct. Stimuli consisted of simple patterns and discrimination did not require learning new configurations, thereby minimizing top–down influence. These procedures have previously been used to isolate basic grouping capacities in other populations, including Alzheimer's disease (Kurylo et al., 1994, 2003; Kurylo, 2004), elderly individuals (Kurylo, 2006), and patients with acquired brain injury (Kurylo et al., 2006).

The second aim of this study was to determine the stimulus duration necessary for perceptual organization. These measurements differ from grouping thresholds in that at a fixed level of intrinsic stimulus organization the processing time necessary to perceptually organize patterns of elements was determined. Whereas schizophrenia patients are known to require longer exposure durations of stimuli in order to discriminate letters or patterns (Saccuzzo and Braff, 1981, 1986; Weiner et al., 1990; Slaghuis and Bakker, 1995; Butler et al., 1996, 2002; Schechter et al., 2003), stimulus durations necessary for perceptual grouping have not previously been determined. To accomplish this, stimuli were progressively decreased in duration until grouping patterns could no longer be discriminated. Test stimuli were immediately followed by the pattern mask, thereby maintaining experimental control over the test stimulus without introducing post-stimulus effects (Felsten and Wasserman, 1980). In this regard, the pattern mask served to disrupt iconic storage and associated attention factors that may otherwise play a role after the removal of the stimulus. As the stimulus duration is progressively