Altered Center-Surround Motion Inhibition in Schizophrenia

Yue Chen, Daniel Norton, and Dost Ongur

Background: Schizophrenia is a brain disorder that spans across biological and behavioral levels. The links between altered neural circuitry and abnormal behaviors are yet to be understood. Visual motion perception has been established in basic neuroscience and may provide an opportunity to link different levels of brain functions in schizophrenia. Center-surround interaction is a ubiquitous neural mechanism underlying the organization of visual information over different spatial locations.

Methods: We applied a psychophysical paradigm to examine center-surround interaction in schizophrenia. Patients ($n = 24$) and control subjects ($n = 33$) judged the direction of a moving random dot pattern (RDP, center) with and without the presence of another concentric surrounding RDP (surround).

Results: The presence of a moving surround shifted the perceptual judgments of center motion in the opposite direction from the surround in both subject groups but the magnitude of the perceptual shift was significantly larger in patients. The increased perceptual shift was not correlated with psychotic symptoms, which were mild in this patient sample, or antipsychotic medication.

Conclusions: The increased perceptual shift suggests that the putative surround suppression on visual motion perception is abnormally increased in schizophrenia. This result provides perceptual evidence for altered basic inhibitory control of visual motion context in schizophrenia.

Key Words: Neural suppression, perception, schizophrenic, spatial interaction, visual motion

A critical question in understanding the pathophysiology of schizophrenia concerns how altered neural circuitry (1–3) leads to abnormal behaviors in patients (4,5). To answer this question, it is useful to focus on those perceptual responses whose neurobiological bases have been established. Motion perception is such a response, as it is controlled by basic neural computation and has been extensively studied physiologically and psychologically.

Schizophrenia patients have shown deficient visual discrimination of motion directions (6,7) and speeds (8–10). While the perceptual deficit presumably involves the extrastriate cortex, the exact underlying neural mechanisms have not been systematically examined. Center-surround interaction plays a fundamental role in organizing spatially distributed signals for perception. In the visual system, center-surround interaction is generally characterized by suppression and facilitation of surround on neural response to central motion (11). The neural responses are suppressed by a surround containing the same direction of motion as the center and are facilitated by a surround containing the opposite direction of motion to the center (12). Perceptual responses to visual motion are mediated by direction-selective neural units, e.g., those selective to rightward direction are responsible for forming a percept of rightward motion. The consequence of surround suppression is a perceptual shift toward the opposite direction of central motion (13).

Examination of how motion signals in distinct spatial locations interact allows inference about the level and specificity of the neural mechanism(s) that may be implicated in schizophrenia. In this study, we controlled stimuli presented in the surround (moving vs. static, leftward vs. rightward motion) independent of the center and measured motion perception in the center. When the center and the surround moved in the same direction, decreased surround suppression would yield a perceptual shift toward the direction of central motion, whereas increased surround suppression would yield an additional perceptual shift toward the opposite direction. When the center and the surround moved in opposite directions, decreased and increased surround facilitation would yield a perceptual shift toward the opposite and the same direction of central motion, respectively. Given that decreased surround suppression in schizophrenia has been reported (14,15), we hypothesized that patients would show a perceptual shift toward central motion.

Motion perception involves neural interaction of visual signals across space and time. With this unique feature, studying the center-surround mechanism in connection with motion perception should yield insights into the relationship between altered neural organization and abnormal perceptual response in schizophrenia.

Methods and Materials

Subjects

Participants included 24 schizophrenia patients and 33 normal control subjects. Diagnoses for patients were based on a structured clinical interview (SCID-IV) and a review of all available medical records. The absence of Axis I psychiatric disorders for control subjects was assessed using a standardized interview based on the Structured Clinical Interview for DSM-IV Axis I Disorders—Non-Patient Edition (SCID-I/NP). Table 1 provides demographic information for the participants. Table 2 provides clinical information for the patients.

Stimulus

The target for motion discrimination, the center, was a random dot pattern (RDP) that contained two components. The signal component was a group of dots moving coherently in one direction (left or right) and the noise component was another

From McLean Hospital, Department of Psychiatry, Harvard Medical School, Belmont, Massachusetts.

Address reprint requests to Yue Chen, Ph.D., Room G06, Centre Building, 115 Mill Street, Belmont, MA 02478; E-mail: ychen@mclean.harvard.edu.

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Table 1. Subject Demographic Information

Group	Age (years)	Sex	Verbal IQ[a]	Education[a] (years)
Schizophrenia ($n = 24$)	41.1 (9.4)	F - 11 M - 13	105.5 (12.7)	14.5 (1.8)
Normal Control Subjects ($n = 33$)	35.8 (12.8)	F - 16 M - 17	112.8 (9.9)	16.4 (1.8)

F, female; IQ, intelligence quotient; M, male.

Means are reported above SD in parentheses. The two groups were matched on average age and sex.

[a]Statistically significant group differences ($p < .05$).

group of dots moving in random directions. The two components were interleaved spatially within a circular window (Figure 1). The surround was a concentric RDP containing only the signal component or static dots (Figure 1). Subjects reported their judgments about the direction of motion in the center.

Results

Moving Surround

The presence of a moving surround shifted motion perception in control subjects and to a greater extent in patients, as indicated by changed proportions of trials reported as rightward (Figure 2). To compare the magnitudes of the perceptual shift between groups, we used the difference of the proportions of trials reported as rightward when the surround was and was not present (Figure 3). Analysis of variance (ANOVA) (group, coherence, and surround direction) showed that the perceptual shift was significantly greater 1) in patients than in control subjects ($F = 28.67$, $p < .001$), and 2) when the surround moved in the same direction as central motion, as opposed to the opposite direction ($F = 10.22$, $p = .002$). The group difference appeared to be greater when the center and the surround moved in the same direction, yet the interaction between surround direction and group did not reach a statistically significant level ($F = 3.53$, $p = .06$). In both groups, the perceptual shift was greatest when central and surrounding motion moved in the same direction and at 40% coherence (Figure 3).

The perceptual shift was not correlated with perception of central motion or with the low level of psychotic symptoms or antipsychotic medications (Supplement 1).

Static Surround

Analysis of variance (coherence and group) showed that with static surround perceptual shift did not differ significantly between the groups ($F = .435$, $p = .51$) and differed significantly across coherence levels ($F = 2.16$, $p = .019$). The group-coherence interaction was not significant ($F = 1.17$, $p = .31$) (Figure 4).

Table 2. Clinical Information on the Patient Sample

Illness Duration (years)	19.2 (10.5)
Remission Status	15 outpatients, 9 inpatients
PANSS - Positive	16.0 (7.6)
PANSS - Negative	13.9 (6.2)
PANSS - General	31.3 (11.2)
CPZ (mg)	554.2 (409.2)

CPZ, chlorpromazine; PANSS, Positive and Negative Syndrome Scale.

Mean (SD).

The patients were recruited from a private psychiatric hospital; 10 patients had a diagnosis of schizophrenia and 14 patients had a diagnosis of schizoaffective disorder.

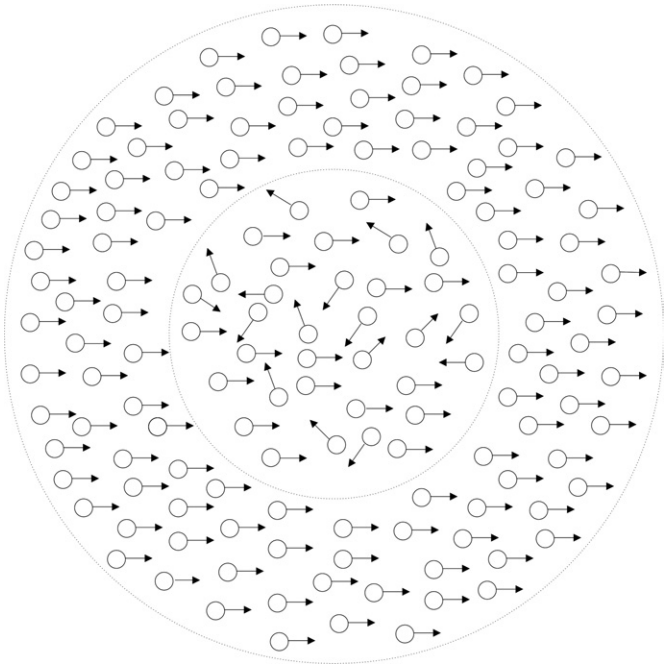

Figure 1. Schematic illustration of the stimulus configuration. The random dot pattern (RDP, center) contains 1) dots moving coherently along one direction (e.g., right) and 2) dots moving in random directions. Stimulus duration was 390 msec. The proportion of the trials reported as rightward motion was measured as a function of the 11 motion coherence levels (0, ±5%, ±10%, ±20%, ±40%, and ±100%, with negative values indicating leftward direction and positive values indicating rightward direction and three types of surround (leftward, rightward, and static). The size of the center was 7 degrees in diameter. All dots, except for those in the static surround, moved at 7 degrees/sec. The size of the outer boundary of the concentric surround was 14 degrees. RDP, random dot pattern.

Discussion

The finding of an increased perceptual shift in patients suggests that center-surround interaction is altered in schizophrenia. The directional specificity of the increased perceptual shift, i.e., occurring mostly when the center and surround moved in the same direction (Figure 3), suggests that alteration of center-surround interaction is primarily due to a stronger suppression rather than facilitation from surround (12).

The increased surround suppression points to an excessive inhibitory control of motion processing, likely mediated by gamma-aminobutyric acid (GABA)ergic neurotransmission, in the associated neural circuitries (16). Studies in aging found age-associated decreases in GABA-mediated inhibition (17) and reduced surround suppression on motion perception (18). The increased surround suppression, found in this study, and the reduced surround suppression, found in a previous study, in schizophrenia suggest that abnormalities in inhibitory control of motion processing are multifaceted in nature (14,19).

The perceptual shift in patients peaked at intermediate to high levels of motion coherence (Figure 3). The dependence of surround modulation on signal strength is analogous to the finding that center-surround interaction in schizophrenia is weakened for high-contrast stimuli (14). Both results suggest that suppressive surround modulation is abnormal in schizophrenia when salient motion stimuli (such as those with high contrast or intermediate motion coherence) adequately activate the neural circuitry.