

Running head: VISUAL AND EYE GAZE PROCESSING IN SCHIZOPHRENIA

Basic Visual Functioning and Eye Gaze Processing in Schizophrenia:
Relationship with Symptoms and Social Functioning

by

Mei Lun Mui

A Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of Bachelor of Science
with Honors in Brain, Behavior, and Cognitive Sciences from the
University of Michigan

2012

Advisors: Dr. Patricia Deldin and Ivy Tso

Author Note

Mei Lun Mui, Department of Psychology, University of Michigan, Ann Arbor

Correspondence concerning this article should be addressed to Mei Lun Mui, 530 Church
Street, Department of Psychology, University of Michigan, Ann Arbor, MI 48109. E-mail:
meilun@umich.edu

Abstract

Schizophrenia is a mental disorder that is associated with misinterpretation of social signals. This study investigated how individuals with schizophrenia perceive social information differently from mentally healthy individuals in two experiments. In Experiment 1, 28 individuals with schizophrenia and 24 healthy controls viewed a series of photos, each varying in emotion, head orientation, and gaze direction. The task was to judge whether the person in the photo was looking at them or not. It was hypothesized that individuals with schizophrenia would be more likely to perceive actors in the photos as looking at them at a higher rate than controls due to their tendency in perceiving self-referential signals. Individuals with schizophrenia were also expected to demonstrate more uncertainty in judgment due to their decreased categorical gaze perception. Both hypotheses were supported by the results. To investigate whether gaze perception dysfunction, if present, occurs at higher-level information processing (e.g. interpretation stage) or may be adequately explained by lower-level visual perception deficits. Same individuals completed the Contour Integration Task and Motion Coherence Task in Experiment 2 to measure their visual functioning in high-level integration and lower-level gain control, respectively. Basic visual perception was hypothesized to be impaired in schizophrenia, as exhibited by previous literature. Results only supported deficits in integration, but not in gain control. This study demonstrated that impaired visual integration significantly explained the abnormalities in categorical gaze perception and lower social-emotional functioning in schizophrenia.

Keywords: eye contact, visual perception, schizophrenia, negative symptoms, functional outcome

Basic Visual Functioning and Eye Gaze Processing in Schizophrenia:

Relationship with Symptoms and Social Functioning

Schizophrenia is a mental disorder that is associated with a wide range of social deficits. Individuals with schizophrenia often have interpersonal problems due to impairments in interpreting others' intentions (Kohler et al., 2008). Misinterpretation of social signals may be responsible for schizophrenic symptoms such as paranoid delusions (Franck et al., 2002). Individuals with paranoid schizophrenia suffer from thoughts of persecution and often falsely believe that other people are directing attention to them, which might lead to the avoidance of eye contact in order to minimize discomfort. It is also reasonable to expect that the inability to perceive social information accurately may contribute to the maintenance of negative symptoms such as social withdrawal. Being able to accurately perceive eye gaze direction is a fundamental element of social cognition that guides behavior in one's social environment (Etcoff & Magee, 1992). Misinterpreting social cues can significantly interfere with the daily functioning of individuals with schizophrenia. Since abnormalities in eye gaze perception may be explained by deficits in basic visual perception, it is important to understand the relationship between basic visual perception, eye gaze perception, and its functional outcome. This study may contribute to the development of rehabilitation targeting basic visual perception and eye gaze processing to improve daily functioning and social cognition of schizophrenia patients.

Eye-gaze Perception

Eye contact is a powerful social indicator of communicative intention. For instance, a direct gaze signals a potential social interaction, which can be positive or negative, whereas an averted gaze indicates that the person is attending to something else other than the observer (Itier & Batty, 2009). In fact, infants as young as two days old can discriminate direct gaze from

averted gaze, suggesting that gaze direction discrimination is an innate ability (Adams & Kleck, 2005). Since eye-contact perception has important functional consequences, the ability to discriminate eye gaze direction would improve our understanding of clinical symptoms and social functioning in schizophrenia.

Previous studies. Only a few studies have examined the difference in eye gaze perception in schizophrenia, and they yielded inconsistent results. Hooker and Park (2005) reported a self-referential bias in eye gaze perception in schizophrenia while other studies (Franck et al., 1998; Franck et al., 2002) showed that there was no group difference between SCZ and HC in gaze discrimination. The inconsistent findings could be a result of the wide variation in methodology such as the number of gaze angles and head orientations implemented. SCZ demonstrated no difference from HC in distinguishing left or right gaze (Franck et al., 1998, 2002), but the reaction time for patients was much longer in discriminating self-directed vs. non-self-directed gaze (Franck et al., 2002). The researchers speculated that the difference was due to excessive top-down processing in paranoid delusion and so eye gaze perception is associated with a higher level of analysis. However, when subjects were asked to judge whether or not a black square was centered in a white rectangle in a control geometric task (Hooker & Park, 2005), SCZ was significantly worse than HC in judging when the square was in the center, suggesting some difficulty in visual perception. However, the nature of basic visual perception in gaze perception is unknown.

Other factors influencing eye-contact perception. Under normal circumstances, only the direction of eye gaze is crucial in detecting others' communicative intentions. When eye gaze direction is ambiguous (i.e., not looking directly at you or directly away), head orientation is used to infer social intention (Emery 2000; Langton 2000). Head orientation has been shown

to interfere with discrimination of eye gaze direction in various studies (Langton, 2000; Seyama & Nagayama, 2005; Ricciardelli & Driver, 2008). On the one hand, the positive congruency effect has been demonstrated in the studies of Langton (2000) and Seyama and Nagayama (2005), where participants were faster at gaze perception when the eyes and the head were in the same direction (i.e., congruent directions) than when they are in opposite directions (i.e., incongruent directions). On the other hand, Ricciardelli and Driver (2007) were able to demonstrate a reverse congruency effect in which reaction time was faster when the head and the eyes were in opposite directions. Due to the discrepancy from previous studies, it is important to manipulate head orientation in order to better understand how head orientation interacts with eye gaze perception in schizophrenia individuals and controls.

Face stimuli used in the abovementioned studies did not vary in facial emotion. However, studies have shown that emotional expression of the face modulates perceived gaze perception (Adam & Kleck, 2005; Graham & LaBar, 2007; Lobmaier, Tiddeman, & Perrett, 2008). Direct gaze enhances the perception of approach-oriented emotions, such as anger and joy, whereas averted gaze enhances the perception of avoidance-oriented emotions, such as fear and sadness (Adam & Kleck, 2005). Moreover, fearful faces were shown in the study of Tipples (2006) to potentiate orientating attention to eye gaze. Individuals with schizophrenia suffering from paranoid delusions often mistakenly perceive danger in the environment. Since fearful faces could be a signal for danger in the environment, it would be of interest to examine how HC and SCZ respond to neutral and fearful stimuli differently when combined with various different head orientations and eye gaze directions.

Basic Visual Perception

Given that there is ample evidence suggesting abnormalities in basic visual perception in schizophrenia (Tadin et al., 2006). The role of basic visual perception deficits in abnormal gaze perception in schizophrenia, if any, should be given due considerations. The visual system consists of the parvocellular pathway (P-pathway) and the magnocellular pathway (M-pathway). The P-pathway conducts high-resolution visual information to the cerebral cortex and is involved in detail processing, whereas the M-pathway conducts low spatial resolution and rapid visual information (Butler et al., 2005). Gain control is a lower-level class of processing that is mostly exhibited in the M-pathway. It allows sensory systems to adapt and optimize their response to stimuli within a specific surrounding context. Examples of gain control are “pop-out” phenomena and motion perception. Impairments in gain control examined by motion perception have been shown in schizophrenia (Bidwell, Holzman, & Chen, 2006; Bulter et al., 2005; Kim, Wylie, Pasternak, Butler, & Javitt, 2006). Integration is a higher-level modulatory process that integrates the output of gain control. It guides behavior by linking individually coded local attributes of a scene into a global complex structure, such as gestalt grouping phenomena and object recognition. Integration has also been shown to be compromised in schizophrenia, demonstrated by difficulties in contour integration and detection (Butler et al., 2008; Kéri, Antal, Szekeres, Benedek, & Janka, 2002; Kozma-Wiebe et al., 2006; Slaghuis, 1998; Uhlhaas, Phillips, Mitchell, & Silverstein, 2006). Nevertheless, some studies found preserved function in integration but impairment in gain control in schizophrenia (Keleman et al., 2005; Tadin et al., 2006), demonstrating that the degree of visual impairment remains to be investigated.

Few studies have examined the relationship between visual perceptual deficits and clinical symptoms and functional outcomes in schizophrenia, but there are at least some data

showing associations between impaired motion perception and negative symptoms (Tadin et al., 2006) and theory of mind deficits (Kelemen et al., 2005). More research data are needed to further illustrate the role of visual perception in clinical symptoms and socio-emotional functioning in the disorder.

The Present Study

This study aimed to investigate the relationship between basic visual perception, gaze perception, and clinical and social outcomes. Two groups of participants, SCZ and HC, performed a gaze perception task in Experiment 1 and visual perception tasks in Experiment 2. In the Gaze Perception Task, participants were asked to judge whether each face presented was looking at them or not. Since the nature of self-referential eye gaze is dichotomous, a psychophysical approach was used to examine eye-contact perception as a logistic function of eye-contact signal strength. This logistic function was used to estimate two psychophysical properties of eye-contact perception: thresholds and the rate of change of categorical shift. “Threshold” is the signal strength corresponding to the frequency of “yes, looking at me” responses. Thresholds are typically obtained by using a response cutoff value of 50% or 75%, but other response cutoffs may be used (e.g., base rate of “yes” response – 30%, as in Hooker & Park, 2005). A more comprehensive analysis was performed by using more than one response cutoff in this study. Moreover, the rate of change of categorical shift was used to examine if eye-contact perception was a less clear-cut categorical function in SCZ. Head orientation, gaze direction (i.e., eye-contact signal strength), and facial emotion were manipulated to examine their differential impact on eye-contact perception in SCZ. The hypotheses for Experiment 1 were: (1) SCZ would show a positive bias in determining whether eye gaze is directed to them or not;

and (2) There would be more uncertainty (i.e., less distinct categorical shift) when judging self-directed vs. non-self-directed gaze in SCZ.

In the visual tasks, SCZ and HC were compared for performance on tasks that measure visual gain control and integration. Partial correlations were then performed in order to better understand the role of visual perception in gaze perception and in clinical and social outcomes. It was hypothesized that: (1) SCZ would demonstrate impairment in basic visual perception; and (2) Abnormalities in basic visual perception would significantly explain abnormalities in eye-contact perception and would be correlated to clinical symptoms and broader social-emotional functioning in SCZ.

General Method

Participants

Participants were volunteers aged 18-60 recruited in the community through advertisement and referrals by clinicians of local mental health clinics or clinical researchers of the University of Michigan. Thirty individuals meeting DSM-IV criteria for schizophrenia/schizoaffective disorder and 24 healthy controls matched for age, sex, and parental education were recruited. However, only 28 out of 30 individuals with schizophrenia (SCZ) and 24 healthy controls (HC) recruited completed both the Gaze Perception Task and the visual tasks as some did not return for the visual tasks. Data from one SCZ and one HC were considered unreliable and were discarded because their responses approached chance level. All participants were tested for normal or corrected eyesight and provided written informed consent. This study was reviewed and approved by the Institutional Review Board (HUM 00020263).

Clinical Assessments

Participants were assessed by several questionnaires to better characterize their mental health. First, the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I) (First, Spitzer, Gibbon, & Williams, 1995) established or ruled out clinical diagnoses for all participants. Second, the Scale for Assessment of Positive Symptoms (SAPS; Andreasen, 1984) and the Scale for Assessment of Negative Symptoms (SANS; Andreasen, 1983) assessed SCZ for positive and negative symptoms, respectively. Third, the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT; Mayer, Salovey, & Caruso, 1999) assessed patients for their socio-emotional cognitive skills. For instance, participants had to identify emotion in human faces and rate the intensity of emotions presented.

Experiment 1: Eye-contact Perception

Method

Materials and procedure. Face stimuli were 528 photos in black and white composing of 6 actors, each varying in 3 factors: (1) emotion (neutral or fearful); (2) head orientation (forward or 30 degrees averted); and (3) gaze direction (from straight ahead to sideways in 10 increments). For each actor, photos with forward and 30° averted head orientation in neutral and evoked-fearful emotion were used. Since all original faces were looking forward, the iris area was edited by the software Photoshop to produce photos that had both direct (i.e., “looking at me”) and averted (i.e., “looking away”) gaze directions for each head orientation and emotion. A morphing program FaceMorpher 2.0, was used to morph photos of actors proceeding from looking forward (eye-contact signal strength = 1) to looking away to the side (eye-contact signal strength = 0), in ten 10% increments (see Figure 1). Lines were added to areas of the face such as the eyes and the nose in order to instruct the computer how to morph from the source photo to the target photo. A total of 528 photos were produced: 6 actors X 11 gaze directions X 2 head

orientations (forward or averted) X 2 emotions (neural or fearful) X 2 mirror images (original or horizontally flipped). There were 12 trials for each eye-contact signal strength in each head orientation and emotion.

The Gaze Perception Task was presented using the software E-prime 1.0. A total of 528 photos were presented in a pseudo-random order such that no photos of the same actor appeared consecutively. Participants judged whether the person in the photo was looking at or away from them. They pressed one button for “looking away from them” and another button for “looking at them.” The response buttons were counter balanced across subjects to prevent order effect.

Data analysis. A psychophysical approach was used to analyze the data. Individual participant’s data were fitted in a logistic function as shown in figure 2:

$$P = 1/(1 + c \cdot b^x) . \quad (1)$$

where P is the probability of “looking at me,” x is eye-contact signal strength, and c and b are constant parameters provided by the PASW Statistics 18 Curve Estimation (logistic) function. Categorical shift is defined as the signal strength where the participants perceive self-directed gaze 50 % of the time (i.e., *Equation 1* at $P = 0.5$). The slope indicates whether self-referential vs. non-self-referential gaze is a categorical function: the greater the slope, the more distinct the categorical perception because it indicates a sudden change in perception; a flatter slope indicates more ambiguity in the shift. It was estimated using the first derivative of *Equation 1*:

$$dP/dx = \{-\ln(b) \cdot e^{[-\ln(c) - \ln(b) \cdot x]}\} / \{1 + e^{[-\ln(c) - \ln(b) \cdot x]}\}^2 . \quad (2)$$

where e is exponential function. Since $x = -\ln(c)/\ln(b)$ when $P = 0.5$, *Equation 2* becomes: $dP/dx = -\ln(b)/4$. Nine threshold estimates of eye-contact perception, or signal strength, were calculated using response cutoffs from 10% to 90% for each participant. They were defined as the expected x values for $P = 0.1, 0.2, \dots, 0.9$. Both the slope of categorical shift and thresholds

were only calculated for forward faces since responses to averted faces did not approach logistic functions. Slope of categorical shift was analyzed using a 2 (emotions) \times 2 (groups) mixed model ANOVA; thresholds were analyzed using a 9 (response cutoff values) \times 2 (emotions) \times 2 (groups) mixed model ANOVA. All statistical analysis was carried out by PASW Statistics 18.

A mixed model 4-way ANOVA was performed to include the data on averted faces in the analysis of the difference between SCZ and HC at each eye-contact signal strength. Within-subjects variables were eye-contact signal strength (0, 0.1, ..., 1.0), head orientation (forward, averted), and emotion (neutral, fearful). The between-subjects factor was group (SCZ, HC) and the dependent variable was perceived eye-contact (proportion of “looking at me”). Huynh-Feldt adjustment was implemented for all ANOVAS in the case of sphericity assumption violation.

Results

Participant characteristics are shown in Table 1. SCZ and HC did not significantly differ in age, sex, and parental education. SCZ demonstrated poorer social-emotional functioning compared to HC as shown by their lower MSCEIT scores.

Positive bias in eye gaze perception. SCZ and HC were compared on their eye-contact threshold obtained using various response cutoffs (see Figure 3). The average threshold of SCZ across all response cutoffs ($M = 0.63$, $SD = 0.17$) was only marginally lower than that of HC ($M = 0.73$, $SD = 0.18$), $F(1, 47) = 3.73$, $p = .059$. However, group difference was dependent on cutoff value as the significant Cutoff Value \times Group interaction, $F(1.02, 48.02) = 5.49$, $p = .023$, indicated that when the response cutoff value was 60% or lower, SCZ demonstrated significantly lower threshold than HC. The emotion component did not affect this interaction, $F(1.02, 48.03) = 0.91$, $p = .345$.

SCZ and HC showed significant difference in eye gaze processing as demonstrated by the response patterns presented in Figure 4. SCZ ($M = 33\%$, $SD = 12\%$) was more like to perceive the faces as looking at them than HC did ($M = 23\%$, $SD = 12\%$), $F(1, 47) = 7.93$, $p = .007$. SCZ and HC also exhibited different response patterns with respect to head orientations and emotions. In the significant interaction of Gaze \times Head \times Group, $F(7.544, 354.567) = 2.08$, $p = .040$, group difference along the signal strength continuum for forward head orientation simulated a quadratic function, $F(1, 47) = 9.74$, $p = .003$, in which positive bias by SCZ was only prominent in medium signal strengths. However, group difference for averted head orientation resembled a linear function, $F(1, 47) = 4.12$, $p = .048$, in which positive bias by SCZ occurred mostly at high signal strengths (see Figure 5a). In the significant interaction of Gaze \times Emotion \times Group, $F(4.73, 222.289) = 4.36$, $p = .001$, SCZ displayed highest positive bias at medium signal strengths for neutral faces but at high signal strength for fearful faces (see Figure 5b).

Decreased categorical perception. SCZ ($M = 2.50$, $SD = 0.62$) were shown to have decreased slope compared to HC ($M = 2.87$, $SD = 0.62$), $F(1, 47) = 4.39$, $p = .042$, suggesting more uncertainty in the judgment of self-directed eye gaze. There was no group difference across different emotions, $F(1, 47) = 0.00$, $p = .991$.

Discussion

The Gaze Perception Task examined the difference and abnormality in the eye gaze perception in individuals with schizophrenia. The results supported the first hypothesis that SCZ would be more likely than HC to perceive faces as looking at them, consistent with previous studies (Hooker & Park, 2005; Rosse et al., 1994). Furthermore, as demonstrated by the group difference in eye-contact thresholds, SCZ perceive eye gaze as self-directed earlier in the eye-contact signal strength continuum.

Head orientation variables exhibited different effects on eye gaze perception in SCZ and HC. In forward faces, SCZ's positive bias was the strongest among medium signal strengths, where eye gaze directions were the most ambiguous, while demonstrating little difference from HC at high signal strengths, where gaze direction were more direct. This suggests that SCZ's difficulty with eye-contact perception only occurs when eye gaze direction is ambiguous. In averted faces, SCZ's positive bias was the strongest among high signal strengths due to the low endorsement rate of HC (<50% of "yes, looking at me" response). Since it is generally more difficult to identify direct gaze on averted faces (Rosse et al., 1994), this again suggests that SCZ over-endorse eye-contact as self-referential in ambiguous gaze directions, whereas HC tended to perceive them as non-self-referential.

SCZ and HC also demonstrated differences in eye gaze perception when the emotions of the faces were varied. SCZ's positive bias was more prominent in neutral emotion among medium signal strengths, and in fearful emotion among high signal strengths. This was due to a negative bias (i.e., a tendency to perceive averted gaze) in gaze perception with fearful faces compared to neutral faces in HC (Adam & Kleck, 2005; Tipples, 2006). This can be explained by the tendency of HC to filter out negative information and direct attention away from negative events (Bradley, Mogg, & Lee, 1997), whereas SCZ are more likely to perceive neutral and positive stimuli as more negative (Cohen & Minor, 2010).

The second hypothesis, that there would be more uncertainty (i.e., less rapid categorical shift) when judging self-directed vs. non-self-directed gaze in SCZ, was also supported. SCZ showed a shallower slope compared to HC in both neutral and fearful emotions with forward head orientation. Steeper slopes indicated more dichotomous perception in HC (i.e., clear

boundary between two categories), and shallower slopes indicated that eye-contact perception was less of a clear-cut categorical function in SCZ.

Previous studies have demonstrated a tendency for SCZ to blame others for negative events (Janssen et al., 2006). This study showed that this externalizing bias is evident in the perception of ambiguous social signals without direct consequences. Both the externalizing bias and increased uncertainty in eye gaze perception may be a result of the inability to recruit brain regions (e.g., paracingulate cortex, temporo-parietal junctions) that are critical in tasks requiring theory of mind in schizophrenia (Walter et al., 2009).

Experiment 2: Basic Visual Perception

Method

Materials and procedure. Two computerized visual tasks were implemented in this experiment; both were presented using the software Matlab. Participants were first presented with the Contour Integration Task (density version and jitter version), followed by the Motion Coherence Task (see figure 6 and 7, respectively). Since these tasks were presented using an adaptive method with a 3-up-1-down staircase algorithm, the number by trials varied across participants. The task was terminated after a participant made 12 performance reversals. A chin rest was used to control for the distance between the participant and the computer. Participants were instructed to focus on accuracy rather than speed. Both versions of the Contour Integration Task and the Motion Coherence Task were completed twice to obtain an average threshold of each task.

The Motion Coherence Task was used to measure visual gain control ability. Participants were presented with moving dots on the computer screen for 1000ms. Some dots moved in one direction (either right, left, up or down) while other distractors moved in random

directions. Participants were required to indicate the direction of the coherently moving dots in 5 seconds. They responded by pressing the left-arrow, right-arrow, up-arrow or down-arrow button on the keyboard to indicate the direction they perceived. A practice with feedback was administered to ensure participants' understanding of the task. In this task, fewer dots moved in the same direction as the level of difficulty increased.

The Contour Integration Task was used to measure visual integration. Two versions (i.e., density version and jitter version) were implemented because both have been used in previous studies, and it is unclear which is more effective in measuring integration. Stimuli were a series of images of Gabor elements; each image contained one contour formed by Gabor elements among a background of distractor Gabor elements. For the density version, difficulty increased as the amount of distractor Gabor elements increased. For the jitter version, difficulty increased as the jitter angles of the Gabor elements that form the contour increased. Participants were asked to locate the contour (either on the left or right side of the screen) by pressing the left-arrow or right-arrow button on the keyboard. Each image was presented for 5 seconds, and participants had to respond within the presentation time. In order to ensure understanding of the task, participants did a practice task of the density version before the actual tasks.

Data analysis. Thresholds were transformed into z-scores with reference to HC's mean and standard deviation on each task. Outliers, defined as scores exceeding 3 standard deviations from the participant's group mean, were discarded. The two groups' (i.e., SCZ and HC) z-scores on the two versions of Contour Integration Tasks and Motion Coherence Task were compared with t-tests using PASW Statistics 18. Pearson correlations were used to investigate the relationship between performance on Gaze Perception Task, Contour Integration Task, Motion Coherence Task, symptoms, and social-emotional functioning in SCZ. Partial correlation was

also performed to examine the effect of visual perception in abnormal gaze perception and socio-emotional deficits in SCZ.

Results

Participants of Experiment 2 were the same as those of Experiment 1, with the only exception that data of the density version of the Contour Integration Task contained one fewer HC for missing data due to corruption of the electronic data file.

Group differences in visual perception. HC performed better in both versions of the Contour Integration Tasks: density version, ($F(1, 46) = 1.65, p = .040$); jitter version, ($F(1, 47) = 3.04, p = .004$). HC and SCZ did not differ significantly in the performance in the Motion Perception Task, $F(1, 47) = 0.21, p = .425$ (see figure 8).

Relationships with eye gaze perception, symptoms, and functional outcome. Pearson correlations between SCZ's performance on the visual tasks, Gaze Perception Task, and clinical variables are presented in Table 2. Better visual integration (as measured with the jitter version of the Contour Integration Task) was correlated with more rapid categorical shift and better MSCEIT in SCZ. A positive bias in self-referential gaze perception (i.e., increased percentage of "yes, looking at me" for low/medium signal strengths, and lower thresholds using medium/high response cutoffs) was associated with higher SANS and poorer MSCEIT. Decreased categorical gaze perception (i.e., lower slope of categorical shift) was associated with worse MSCEIT scores.

As discussed in Experiment 1, SCZ demonstrated reduced categorical gaze perception compared to HC as indicated by the shallower slope. Nevertheless, the correlation between group member and categorical gaze perception became non-significant when the effect of the jitter version of the Contour Integration Task ($r_p = .245, p = .097$) or the density version of the

Contour Integration Task ($r_p = .281, p = .056$) was partialled out, suggesting that reduced categorical gaze perception in SCZ could be largely explained by their deficits in visual integration. Group membership (SCZ, HC) correlated with MSCEIT ($r = .395, p = .013$), with SCZ showing lower MSCEIT scores. This correlation became non-significant after partialling out the effect of the slope of categorical shift ($r_p = .200, p = .229$) or low signal strength ($r_p = .273, p = .098$) or medium signal strength ($r_p = .272, p = .098$), suggesting that SCZ's poorer socio-emotional functioning could be significantly explained by decreased categorical gaze perception and positive bias in gaze perception. Further, the correlation between group membership and MSCEIT became non-significant after the effect of the jitter version of the Contour Integration Task ($r_p = .296, p = .075$) or the density version of the Contour Integration Task ($r_p = .319, p = .054$) was partialled out, once again suggesting that deficits in visual integration could significantly explain the lower MSCEIT scores in SCZ.

Discussion

The results showed that SCZ had preserved lower-level visual perceptual function, gain control, as measured with the Motion Coherence Task, but demonstrated deficits in a higher-level visual perceptual function, integration, as measured with the Contour Integration Task. This is consistent with previous studies in Contour Integration Tasks in which the ability of integration among SCZ is compromised (Kozma-Wiebe et al., 2006; Uhlhaas et al., 2006). However, there was no group difference in the performance of the Motion Coherence Task, conflicting with previous studies (Keleman et al., 2005; Tadin et al., 2006). Methodology differences in measuring gain control could result in conflicting results. This study measured gain control with motion coherence by presenting dots that moved in four directions at various coherencies. Tadin et al. (2006) measured with direction discrimination by drifting a patch of

white bars either leftward or rightward. Kelemen et al. (2005) measured with contrast discrimination by moving a target strip with dots that was placed in the middle of two other strips that moved in the same directions (rightward or leftward). Given the different stimuli, designs, and tasks implemented in previous studies, gain control may be measured using different paradigms, and some paradigms may be more sensitive than others in discriminating SCZ from HC. Since no difference in gain control was shown between SCZ and HC in this study, direction and/or contrast discrimination tasks may be a better measure of gain control than the Motion Coherence Task.

The jitter version of the Contour Integration task appeared to be a more reliable measure of integration than the density version, as it more effectively discriminate SCZ from HC (as suggested by the same group difference but smaller standard error compared to the density version), and it correlated significantly with other important variables, including eye gaze perception, symptoms, and functioning outcome. This suggests that variance of jitter angles may be a more sensitive measure of visual integration than variance of density.

General Discussion

Since deficits in visual integration could significantly explain abnormalities in eye gaze perception (as demonstrated by decreased categorical gaze perception), and integration is a holistic approach to perception that integrates output of gain control, this result suggests that eye gaze perception requires input from more than one variable (i.e., from the eye gaze direction of a stimuli). In order to process eye gaze direction accurately, other elements of the face such as head orientation, face contour, and emotion also need to be considered. Therefore, the inability to evaluate all associated features of a face can be problematic in communication in schizophrenia. Moreover, impairment in integration also explained lower socio-emotional

functioning (as measured by MSCEIT), suggesting that problems in social cognition may arise from the inability to accurately integrate relevant social information from the environment.

Basic visual perception was correlated with lower-level social cognition (categorical perception) and in higher-level analysis of interpretation of intention (socio-emotional functioning), indicating that deficits at the perceptual level may disrupt later stages of cognitive processes.

Abnormalities in eye gaze perception in SCZ can explain poorer socio-emotional functioning. Since decreased categorical gaze perception and positive bias was associated with poorer socio-emotional functioning in schizophrenia, the decreased ability in differentiating other's facial emotion may contribute to the incorrect interpretation of emotion, which may result in inappropriate thoughts and reactions. An over-perception of self-referential signals can interfere with their interpretation of others' emotion and hence, intention. Moreover, positive bias in SCZ was correlated with negative symptoms. An over-perception of self-referential signal can translate into ubiquitous threat and danger in the environment, which may lead to core negative symptoms such as social withdrawal in order to avoid discomfort.

Limitations

This study has several limitations. Even though major confounding variables such as age, sex, and parental education were controlled by matching the demographics of controls to those of patients, it was not possible to control the effects of medication on task performance. Since all individuals with schizophrenia were medicated, it is possible that the difference in performance of patients was a result of medication rather than schizophrenia itself. Moreover, since all of the patients suffered from schizophrenia chronically, their performance could potentially be different from that of patients with early onset schizophrenia.

Conclusions

This study demonstrated that individuals with schizophrenia exhibited abnormalities in gaze processing characterized by decreased categorical perception and positive bias in the judgment of self-referential eye gaze. They were both found to be associated with more severe negative symptoms and lower socio-emotional functioning. These abnormalities could be significantly explained by their deficits in holistic visual perception, suggesting the critical role of basic visual perceptual deficits in higher-level social cognition in schizophrenia.

References

- Adams, R. B. Jr., & Kleck, R. E. (2005). Effects of direct and averted gaze on the perception of facially communicated emotion. *Emotion*, 5(1), 3-11. doi: 10.1037/1528-3542.5.1.3.
- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorder* (4th ed.). Washington, DC: American Psychiatric Association.
- Andreasen, N.C. (1983). *Scale for the Assessment of Negative Symptoms* (SANS). University of Iowa, Iowa City, IA.
- Andreasen, N. C. (1984). *Scale for the Assessment of Positive Symptoms* (SAPS). University of Iowa, Iowa City, IA.
- Bidwell, L., Holzman, P. S., & Chen, Y. (2006). Aging and visual motion discrimination in normal adults and schizophrenia patients. *Psychiatry Research*, 145(1), 1-8. doi:10.1016/j.psychres.2005.05.019.
- Bradley, B. P., Mogg, K., & Lee, S. (1997). Attentional bias for negative information in induced and naturally occurring dysphoria. *Behaviour Research and Therapy*, 35, 911-927. doi:10.1016/S0005-7967(97)00053-3.
- Brittain, P., Ffytche, D. H., McKendrick, A., & Surguladze, S. (2010). Visual processing, social cognition and functional outcome in schizophrenia. *Psychiatry Research*, 178(2), 270-275. doi:10.1016/j.psychres.2009.09.013.
- Butler, P. D., Silverstein, S. M., & Dakin, S. C. (2008). Visual perception and its impairment in schizophrenia. *Biological Psychiatry*, 64(1), 40-47. doi:10.1016/j.biopsych.2008.03.023
- Butler, P. D., Martinez, A., Foxe, J. J., Kim, D., Zemon, V., Silipo, G., & ... Javitt, D. C. (2007). Subcortical visual dysfunction in schizophrenia drives secondary cortical impairments. *Brain: A Journal of Neurology*, 130(2), 417-430. doi:10.1093/brain/awl233.

- Butler, P. D., Zemon, V., Schecter, I., Saperstein, A. M., Hoptman, M. J., Lim, K. O., & ... Javitt, D. C. (2005). Early-stage visual processing and cortical amplification deficits in schizophrenia. *Archives of General Psychiatry*, 62(5), 495-504.
doi:10.1001/archpsyc.62.5.495.
- Cohen, A.S., & Minor, K.S. (2010). Emotional experience in patients with schizophrenia revisited: Meta-analysis of laboratory studies. *Schizophrenia Bulletin*, 36, 143-150. doi: 10.1093/schbul/sbn061.
- Etcoff, N.L., Magee, J.J., 1992. Categorical perception of facial expressions. *Cognition* 44, 227-240.
- Emery, N. J. (2000). The eyes have it: The neuroethology, function and evolution of social gaze. *Neuroscience & Biobehavioral Reviews*, 24, 581-604. doi: 10.1016/S0149-7634(00)000257.
- First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. (1995). *Structured Clinical Interview for DSM-IV Axis I Disorders, Patient Edition (SCID-P)*, version 2.0. *Biometrics Research*, New York.
- Franck, N., Daprati, E., Michel, F., Saoud, M., Dalery, J., Marie-Cardine, M., & Georgieff, M. (1998). Gaze discrimination is unimpaired in schizophrenia. *Psychiatry Research*, 81(1), 67-75. doi: 10.1016/S0165-1781(98)00082-1.
- Franck, N., Montoute, T., Labruyere, N., Tiberghien, G., Marie-Cardine, M., Dalery, J., d'Amato, T., & Georgieff, N. (2002). Gaze direction detection in schizophrenia. *Schizophrenia Research*, 56(3), 225-234. doi: 10.1016/S0920-9964(01)00263-8.

- Graham, R., & LaBar, K. S. (2007). Garner interference reveals dependencies between emotional expression and gaze in face perception. *Emotion, 7*(2), 296-313. doi:10.1037/1528-3542.7.2.296.
- Hooker, C., & Park, S. (2005). You must be looking at me: The nature of gaze perception in schizophrenia. *Cognitive Neuropsychiatry, 10*(5), 327-345. doi: 10.1080/13546800444000083.
- Itier, R., & Batty, M. (2009). Neural bases of eye and gaze processing: The core of social cognition. *Neuroscience and Biobehavioral Reviews, 33*, 843-863. doi:10.1016/j.neubiorev.2009.02.004.
- Janssen, I., Versmissen, D., Campo, J. A., Myin-Germeys, I., van Os, J., & Krabbendam, L. (2006). Attributional style and psychosis: Evidence for an externalizing bias in patients but not in individuals at high risk. *Psychological Medicine, 36*(6), 771-778.
- Kee, K., Horan, W., Wynn, J., Mintz, J., & Green, M. (2006). An analysis of categorical perception of facial emotion in schizophrenia. *Schizophrenia Research, 87*, 228-237. doi:10.1016/j.schres.2006.06.001.
- Kelemen, O., Erdélyi, R., Pataki, I., Benedek, G., Janka, Z., & Kéri, S. (2005). Theory of mind and motion perception in schizophrenia. *Neuropsychology, 19*(4), 494-500. doi:10.1037/0894-4105.19.4.494.
- Kemner, C., Foxe, J. J., Tankink, J. E., Kahn, R. S., & Lamme, V. F. (2009). Abnormal timing of visual feedback processing in young adults with schizophrenia. *Neuropsychologia, 47*(14), 3105-3110. doi:10.1016/j.neuropsychologia.2009.07.009.

- Kéri, S., Antal, A., Szekeres, G., Benedek, G., & Janka, Z. (2002). Spatiotemporal visual processing in schizophrenia. *The Journal of Neuropsychiatry and Clinical Neurosciences*, 14(2), 190-196. doi:10.1176/appi.neuropsych.14.2.190.
- Kohler, C. G., Loughhead, J., Ruparel, K., Indersmitten, T., Barrett, F., Gur, R., & Gur, R. C. (2008). Brain activation during eye gaze discrimination in schizophrenia. *Schizophrenia Research*, 99, 286-293. doi: 10.1016/j.schres.2007.09.038.
- Kozma-Wiebe, P., Silverstein, S. M., Fehér, A., Kovács, I., Ulhaas, P., & Wilkniss, S. M. (2006). Development of a world-wide web based contour integration test. *Computers in Human Behavior*, 22(6), 971-980. doi:10.1016/j.chb.2004.03.017.
- Kim, D., Wylie, G., Pasternak, R., Butler, P. D., & Javitt, D. C. (2006). Magnocellular contributions to impaired motion processing in schizophrenia. *Schizophrenia Research*, 82(1), 1-8. doi:10.1016/j.schres.2005.10.008.
- Langton, S. R. H. (2000). The mutual influence of gaze and head orientation in the analysis of social attention. *The Quarterly Journal of Experimental Psychology*, 53A(3), 825-845. doi: 10.1080/027249800410562.
- Lobmaier, J., Tiddeman, B., & Perrett, D. (2008). Emotional expression modulates perceived gaze direction. *Emotion*, 8(4), 573-577. doi: 10.1037/1528-3542.8.4.573.
- Mayer, J. D., Salovey, P., & Caruso, D. R. (1999). *Mayer-Salovey-Caruso Emotional Intelligence Test*. North Tonawanda, NY: Multi-Health Systems Inc.
- Ricciardelli, P., & Driver, J. (2008). Effects of head orientation on gaze perception: How positive congruency effects can be reversed. *The Quarterly Journal of Experimental Psychology*, 61(3), 491-504. doi:10.1080/17470210701255457.

- Rosse, R. B., Kendrick, K., Wyatt, R. J., & Isaac, A. (1994). Gaze discrimination in patients with schizophrenia: Preliminary report. *American Journal of Psychiatry*, *151*(6), 919-921.
- Seyama, J., & Nagayama, R. S. (2005). The effect of torso direction on the judgment of eye direction. *Visual Cognition*, *12*(1), 103-116. doi: 10.1080/13506280444000111.
- Slaghuis, W. A. (1998). Contrast sensitivity for stationary and drifting spatial frequency gratings in positive- and negative-symptom schizophrenia. *Journal of Abnormal Psychology*, *107*(1), 49-62. doi:10.1037/0021-843X.107.1.49.
- Tadin, D., Kim, J., Doop, M. L., Gibson, C., Lappin, J. S., Blake, R., & Park, S. (2006). Weakened center-surround interactions in visual motion processing in schizophrenia. *The Journal of Neuroscience*, *26*(44), 11403-11412. doi:10.1523/JNEUROSCI.2592-06.2006.
- Tipples, J. (2006). Fear and fearfulness potentiate automatic orienting to eye gaze. *Cognition and Emotion*, *20*(2), 309-320. doi: 10.1080/02699930500405550.
- Uhlhaas, P. J., Phillips, W. A., Mitchell, G., & Silverstein, S. M. (2006). Perceptual grouping in disorganized schizophrenia. *Psychiatry Research*, *145*(2-3), 105-117. doi:10.1016/j.psychres.2005.10.016.
- Walter, H., Ciaramidaro, A., Adenzato, M., Vasic, N., Ardito, R. B., Erk, S., & Bara, B. G. (2009). Dysfunction of the social brain in schizophrenia is modulated by intention type: An fMRI study. *Social Cognitive & Affective Neuroscience*, *4*(2), 166-176. doi: 10.1093/scan/nsn047

Note

Mei Lun Mui, Department of Psychology, University of Michigan, Ann Arbor.

I would like to express my gratitude to Dr. Patricia Deldin for all her support and guidance. I would also like to thank Ivy Tso for her encouragement and invaluable assistance. This thesis would not have been possible without your collaboration and help. I have learned so much from this lab and on this research project. Thank you!

Table 1

Participant Characteristics

Variable	SCZ (<i>n</i> = 27)		HC (<i>n</i> = 23)		<i>t</i> / χ^2	<i>P</i>
	Range	Mean \pm <i>SD</i>	Range	Mean \pm <i>SD</i>		
Age	19 – 60	43.9 \pm 12.5	19 – 59	43.5 \pm 13.1	0.11	.913
Sex (male/female)	--	19/7	--	18/5	0.18	.674
Parental education	4 – 21	14.9 \pm 3.8	9 – 20	15.0 \pm 2.8	-0.12	.905
SAPS	0 – 12	5.4 \pm 3.6	--	--	--	--
SANS	0 – 12	4.2 \pm 3.1	--	--	--	--
MSCEIT overall ^a	60.8 – 136.3	91.1 \pm 19.3	80.2 – 140.8	106.5 \pm 17.4	-2.62	.013
Perceiving Emotions ^a	67.0 – 129.4	93.8 \pm 13.6	86.6 – 146.2	109.3 \pm 18.5	-3.09	.004
Using Emotions ^a	65.8 – 127.2	96.0 \pm 16.5	78.5 – 162.2	110.8 \pm 20.3	-2.63	.012
Understanding Emotions ^a	70.5 – 130.5	95.1 \pm 17.2	72.4 – 130.8	106.0 \pm 15.4	-2.23	.031
Managing Emotions ^a	66.4 – 149.5	89.7 \pm 18.9	71.6 – 149.2	102.3 \pm 17.6	-2.34	.024

- a. Due to missing data, the overall score of MSCEIT was only available for 20 SCZ and 19 HC: Perceiving Emotions subscore (22 SCZ, 19 HC); Using Emotions subscore (22 SCZ, 21 HC), Understanding Emotions subscore (24 SCZ, 21 HC); Managing Emotions subscore (25 SCZ, 21 HC).

Note. SAPS = Sum of global subscores on the Scale for the Assessment of Positive Symptoms;

SANS = Sum of global subscores on the Scale for the Assessment of Negative Symptoms;

MSCEIT = Mayer-Salovey-Caruso Emotional Intelligence Test

Table 2

Correlations between Basic Visual Perception, Eye Gaze Perception, Clinical and Functional Variables among SCZ

Variable	1.	2.	3.	4.	5.	6.	6a.	6b.	6c.	6d.
1. Motion	--									
2. Contour-density	.05	--								
3. Contour-jitter	-.01	.55**	--							
4. SAPS total	.30	-.09	.00	--						
5. SANS total	-.08	.07	-.08	.20	--					
6. MSCEIT overall	.00	.36	.46†	-.11	-.15	--				
6a. Perceiving Emotion	.01	.29	.12	-.01	.11	.83**	--			
6b. Using Emotion	.20	.33	.45*	.07	-.13	.78***	.69**	--		
6c. Understanding Emotion	-.13	.40†	.50*	-.07	.00	.90***	.71***	.60**	--	
6d. Managing Emotion	-.15	.33	.53**	-.34	-.24	.71***	.29	.45*	.64**	--
P ("looking at me")	.11	.09	-.03	-.09	.44*	-.45*	-.40†	.38†	-.42*	-.10
At low signal strengths ^a	.02	.00	-.27	-.01	.43*	-.60**	-.46*	.55**	-.49*	-.31
At medium signal strengths ^a	.22	.04	-.19	.00	.49*	.56*	-.40†	-.48*	-.52**	-.27
At high signal strengths ^a	.07	.16	.18	-.19	.33†	-.21	-.30	-.15	-.24	.15
Threshold										
Using low response cutoffs ^b	-.12	.04	.25	-.05	-.36†	.52*	.44*	.50*	.50*	.20
Using medium response cutoffs ^b	-.18	-.09	.08	-.04	-.42*	.37	.34	.38†	.40†	.09
Using high response cutoffs ^b	-.22	-.22	-.12	-.01	-.42*	.12	.14	.17	.22	-.06
Slope of categorical shift of eye-contact perception	.08	.27	.45*	-.05	.04	.65*	.45*	.47*	.42*	.45*

a. Low signal strengths: 0 – 0.3; Medium signal strengths: 0.4 – 0.6; High signal strengths: 0.7 – 1.0.

b. Low response cutoffs: 10% - 30%; Medium response cutoffs: 40% – 60%; High response cutoffs: 70% - 90%.

† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .00$

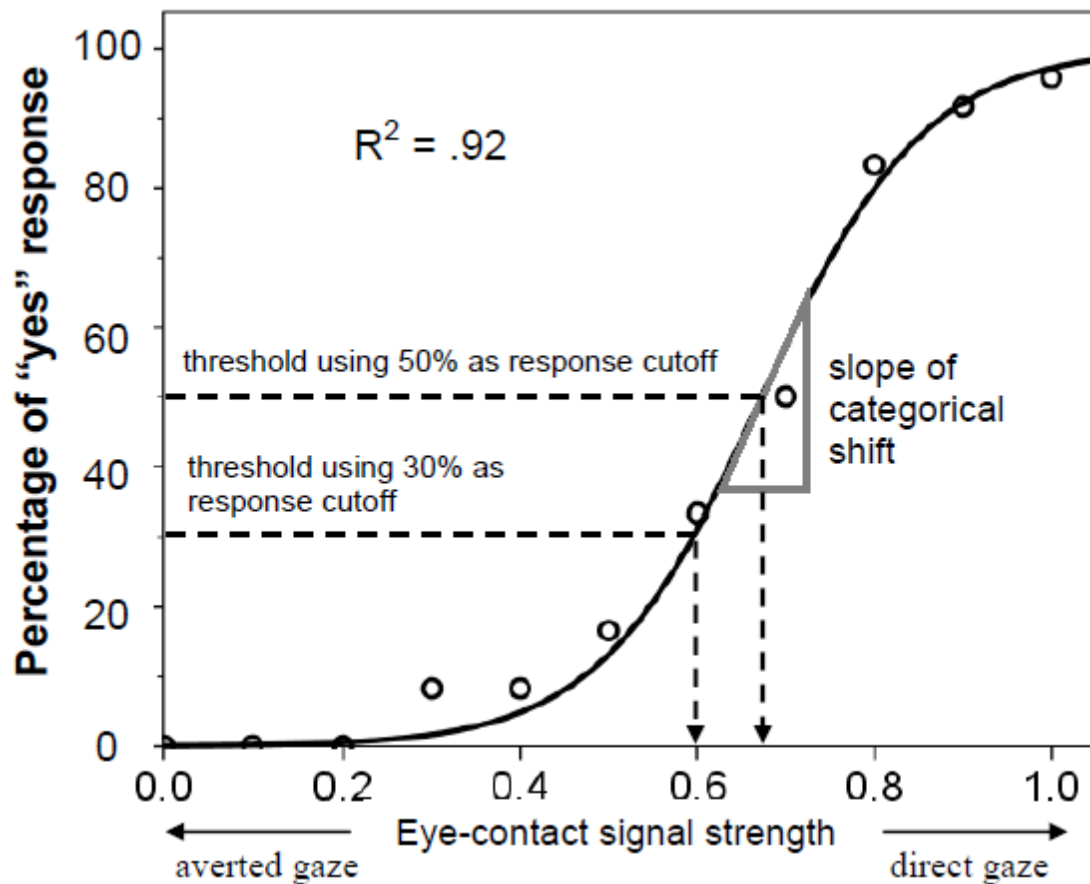


Figure 2. An example of the estimation of psychophysical properties of a participant's eye-contact perception. Nine threshold estimates of eye-contact perception, or signal strength, were calculated using response cutoffs from 10% to 90%. Categorical shift is defined as the signal strength where the participants perceive self-directed gaze 50 % of the time (i.e., Percentage of "yes, looking at me" response = 50%). The slope indicates whether self-referential vs. non-self-referential is a categorical function: the greater the slope, the more distinct the categorical perception because it indicates a sudden change in perception; a flatter slope indicates more ambiguity in the judgment of eye-gaze direction.

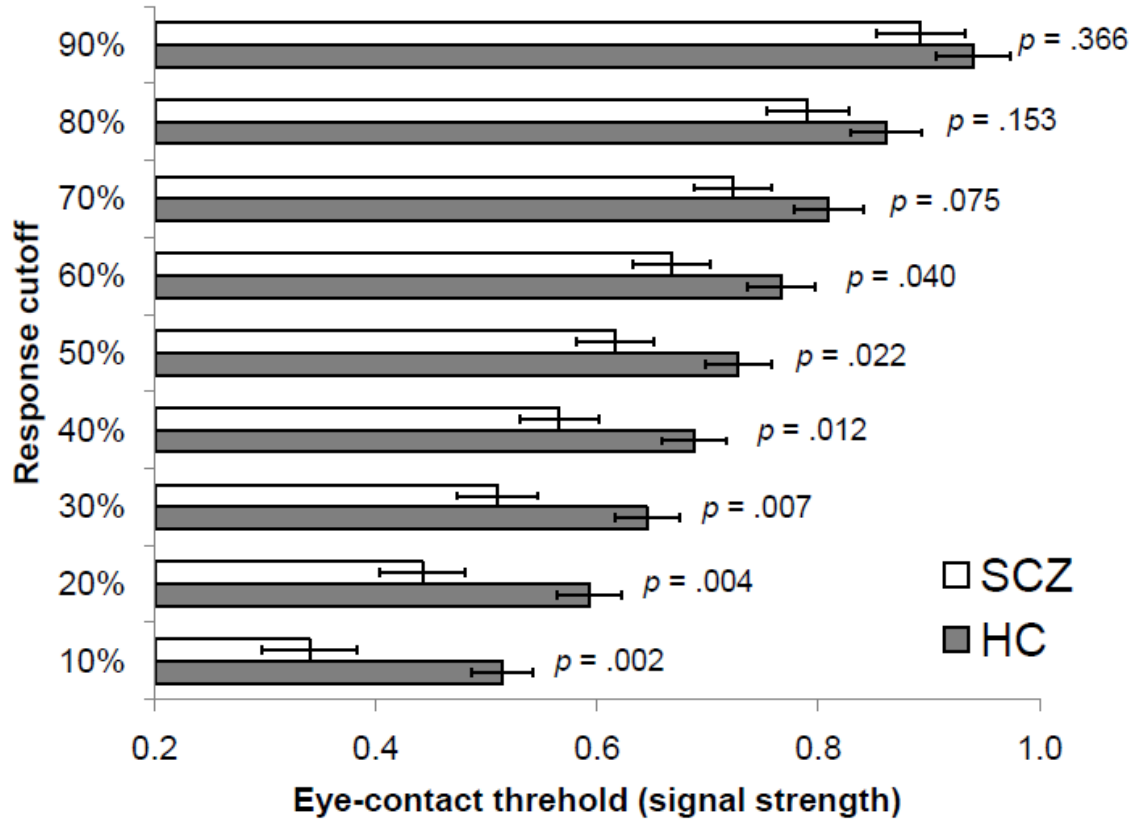


Figure 3. Group difference in eye-contact perception threshold for forward head orientation (including both neutral and fearful emotions) varied by different response cutoff values.

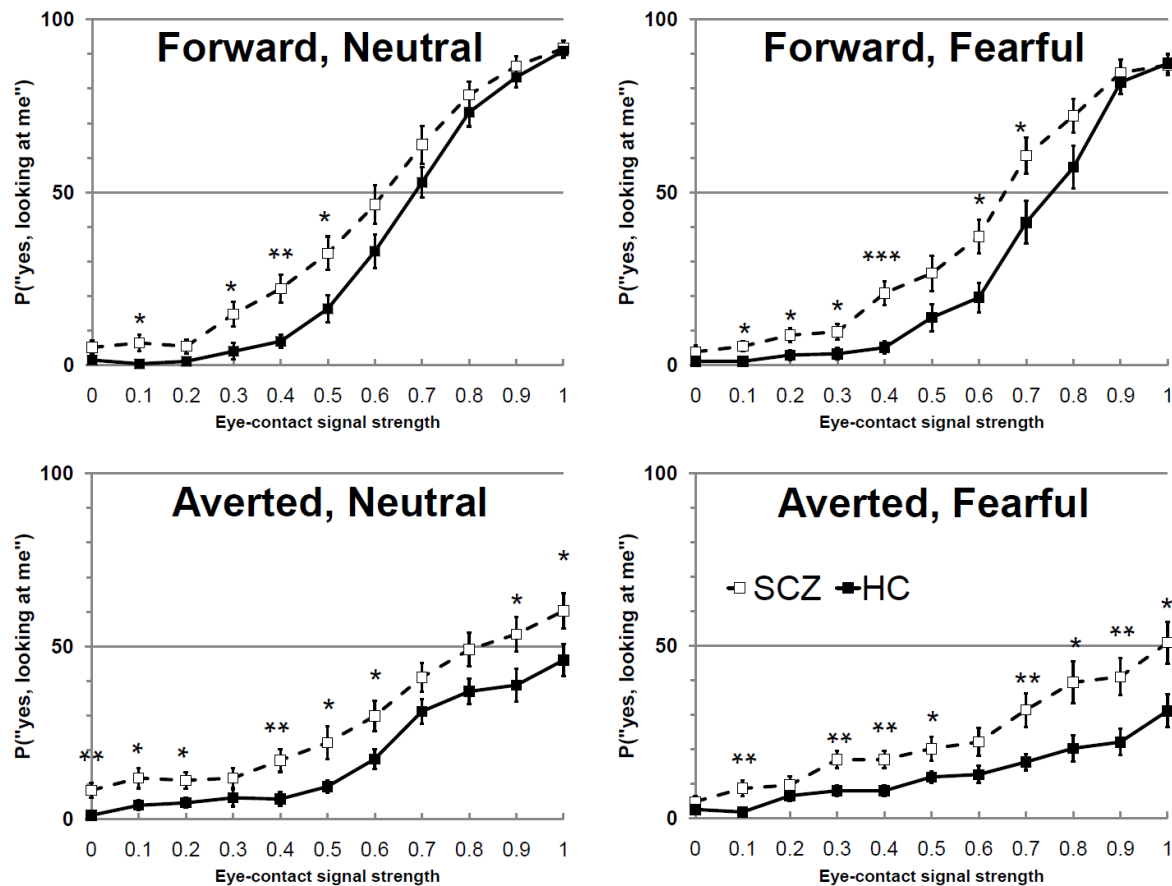


Figure 4. The percentage of "yes, looking at me" responses by group (SCZ: dashed line; HC: solid line) along the gaze continuum in 4 different face conditions. Upper left: Forward head orientation and neutral emotion. Upper right: Forward head orientation and fearful emotion. Lower left: 30° averted head orientation and neutral emotion. Lower right: 30° averted head orientation and fearful emotion.

* $p < .05$. ** $p < .01$. *** $p < .001$.

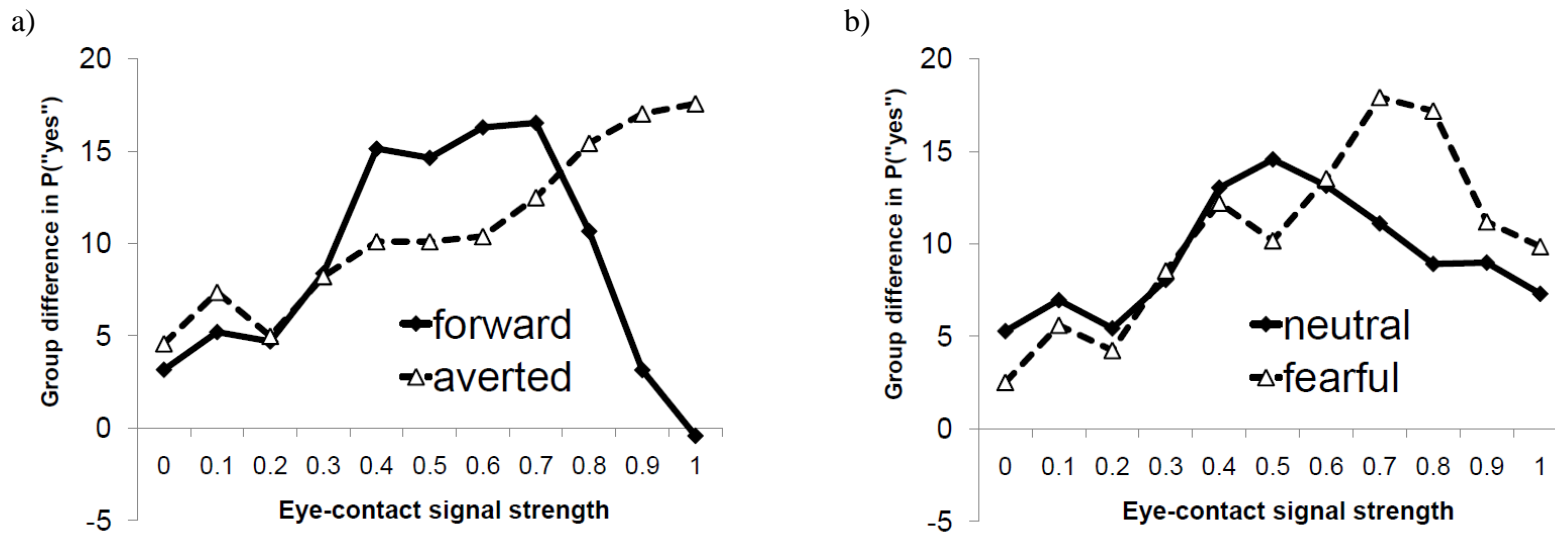


Figure 5. Group differences (SCZ – HC) in percentage of “yes, looking at me” along the eye-contact signal strength continuum when varied by head orientation and emotion. a) Gaze \times Head \times Group interaction: group difference along the signal strength continuum for forward head orientation simulated a quadratic function, $F(1, 47) = 9.74, p = .003$. However, group difference for averted head orientation resembled a linear function, $F(1, 47) = 4.12, p = .048$. b) Gaze \times Emotion \times Group: SCZ displayed highest positive bias at medium signal strengths for neutral faces but at high signal strength for fearful faces.

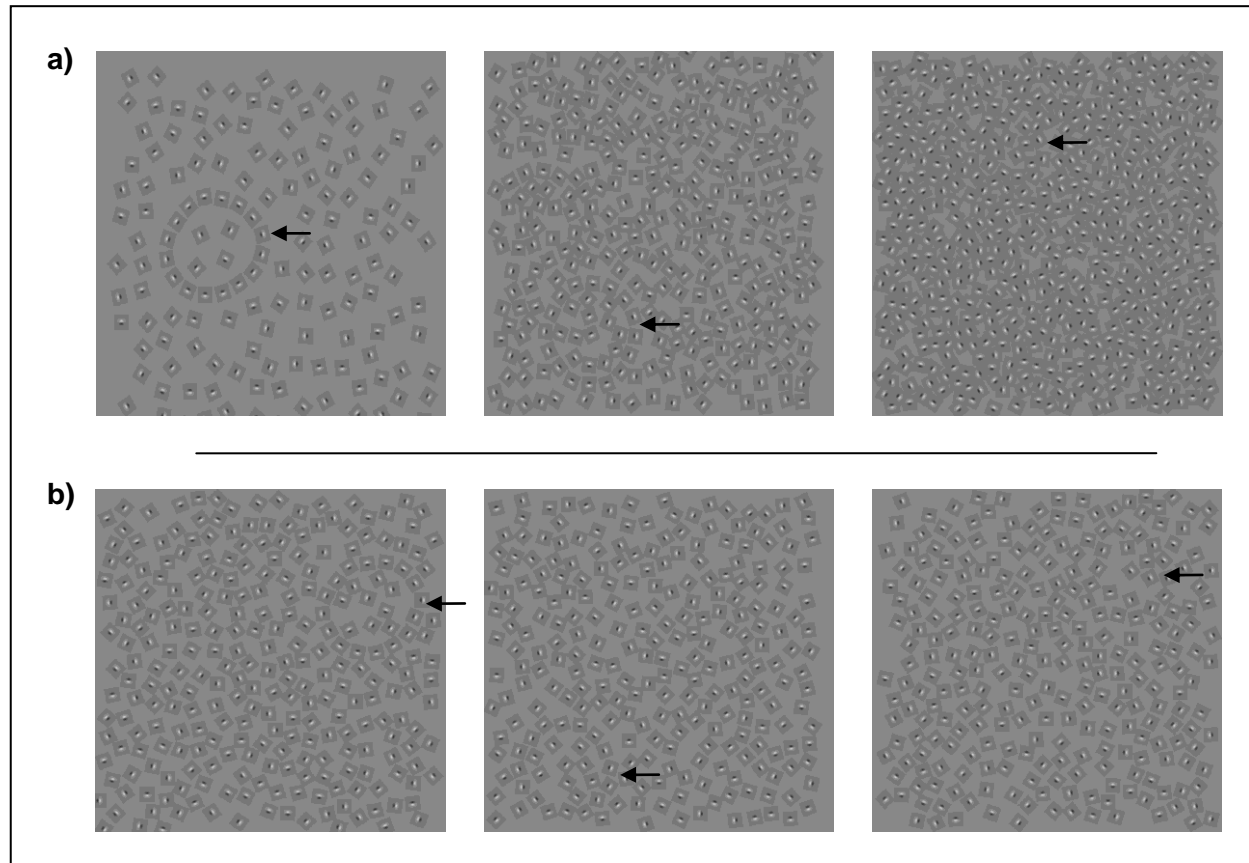


Figure 6. Contour Integration Task: a) Density version, and b) Jitter version. Locations of the contours are indicated for the black arrows. For the density version, difficulty increased as the amount of distractor Gabor elements increased. For the jitter version, difficulty increased as the jitter angles of the Gabor elements that form the contour increased.

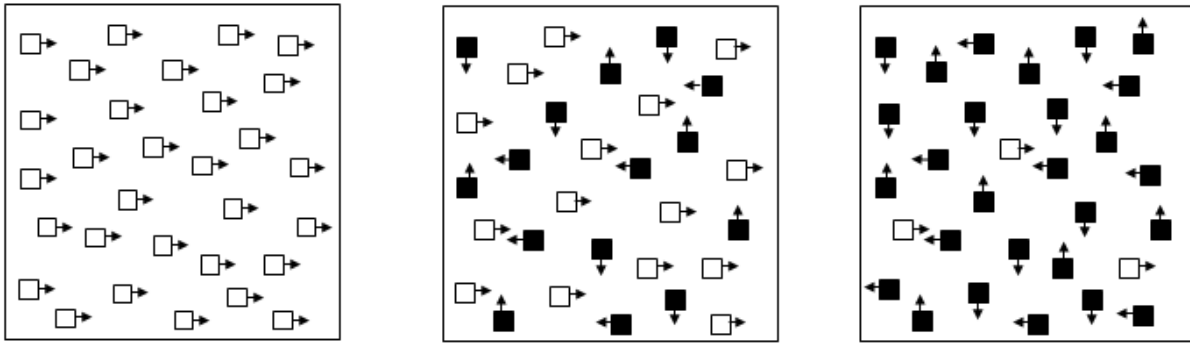


Figure 7. Motion Coherence Task: Gabor elements on the computer screen moving to the right at 100%, 50%, and 10% coherency. Participants were required to indicate the direction of the coherently moving dots.

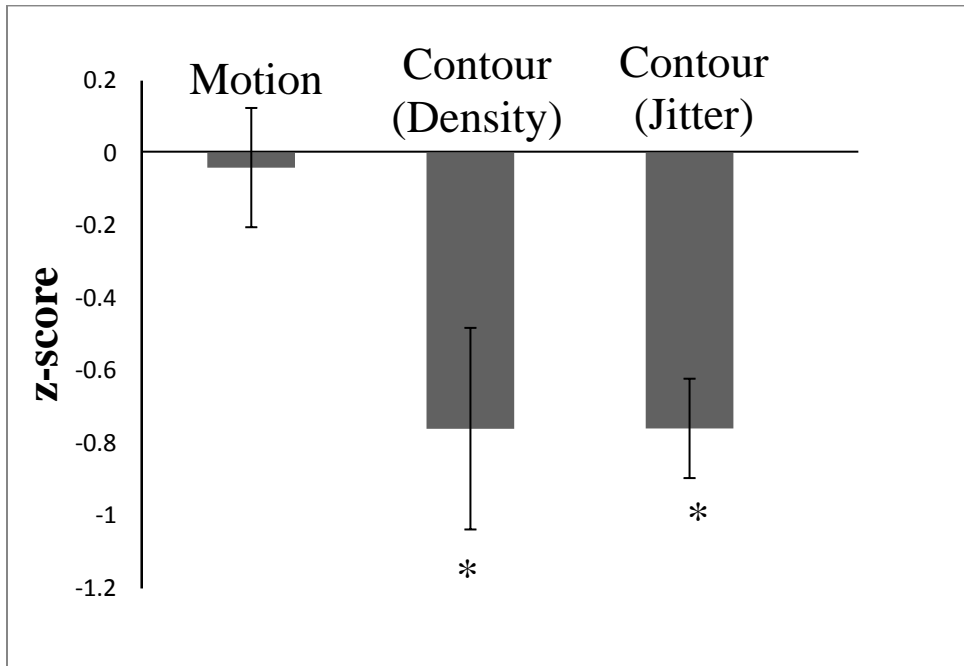


Figure 8. Estimated thresholds (in z-scores) on the Motion Coherence Task and both version of the Contour Integration Task in SCZ compared to HC. Lower scores indicate worse performance on the task. $*p < .05$.

