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Eye-contact Perception in Schizophrenia:
Relationship with Symptoms and Socio-emotional Functioning

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Abstract

Accurately perceiving self-referential social signals, particularly eye contact, is critical to social adaptation. Schizophrenia is often accompanied by deficits in social cognition, but it is unclear whether this includes gaze discrimination deficits. This study investigated whether eye-contact perception is preserved or impaired and if it is related to symptoms and broader socio-emotional functioning in schizophrenia. Twenty-six participants with schizophrenia (SCZ) and 23 healthy controls (HC) made eye-contact judgments for faces in varying gaze direction (from averted to direct in ten 10%-increments), head orientation (forward, 30-degree averted), and emotion (neutral, fearful). Psychophysical analyses for forward faces showed that SCZ began endorsing eye contact with weaker eye-contact signal and their eye-contact perception was less of a dichotomous function compared with HC. SCZ were more likely than HC to endorse eye contact when gaze was ambiguous, and this over-perception of eye contact was modulated by head orientation and emotion. Over-perception of eye contact was associated with more severe negative symptoms. Decreased categorical gaze perception explained variance of socio-emotional deficits in schizophrenia after taking basic neurocognition into consideration, suggesting the relationship was not solely due to a general deficit problem. These results were discussed in relation to the nature of categorical gaze perception and its significance to clinical and functional presentations of schizophrenia.

Keywords: schizophrenia; social cognition; emotion; social functioning; negative symptoms

Eye-contact Perception in Schizophrenia:

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Schizophrenia is a severe mental disorder often accompanied by marked deficits in social cognition that significantly compromise social functioning (see Couture, Penn, & Robert, 2006 for a review). Accurately perceiving and interpreting social cues, particularly self-referential ones, constitute a critical component of social cognition and is crucial to social adaption. Deficits in processing self-referential social information may be particularly relevant to schizophrenic symptoms. For example, misinterpreting benign, irrelevant social signals as threatening and self-relevant (e.g., “They are watching me”) may be related to paranoid delusions. Patients who have difficulty interpreting self-referential social signals may withdraw from social interactions. Given the important role of self-referential information processing in social adaptation and its potential relationship with clinical symptoms in schizophrenia, insight into self-referential information processing in schizophrenia may inform the disease process and direct future diagnostic, treatment, and prevention strategies.

Among all forms of self-referential social signals, gaze direction is one of the most powerful ways to convey attention and intention in humans (Emery, 2000). It remains unclear whether gaze perception is impaired in schizophrenia. The present study aimed to clarify whether individuals with schizophrenia exhibit abnormal gaze perception and to elucidate the relationships between gaze perception and clinical variables.

Gaze Perception in Schizophrenia

To the best of our knowledge, only five studies have directly addressed the question whether gaze direction discrimination is impaired in schizophrenia and the findings have been conflicting. Two studies (Hooker & Park, 2006; Rosse, Kendrick, Wyatt, & Isaac, 1994) found

that individuals with schizophrenia (SCZ) are more likely than healthy controls (HC) to perceive averted gaze as looking at them. However, others (Franck et al., 1998, 2002; Kohler et al., 2008) have reported no group differences in gaze discrimination. These inconsistent findings are likely due to the wide methodological variations across studies, summarized in Table 1. It appears that SCZ's difficulty with gaze processing relates to making self-referential judgments rather than directional judgments. When asked to determine whether gaze was looking left or right, SCZ performed comparably to HC (Franck et al., 1998, 2002), suggesting that the basic perceptual function of discriminating gaze direction is preserved in schizophrenia. However, when the task was put in a self-referential context ("Is this person looking at you?"), SCZ were slower to respond (Franck et al., 2002; Hooker & Park, 2005). In addition, SCZ appeared to show a self-referential bias when faced with ambiguous signals. Studies using mostly averted faces (Rosse et al., 1994) or briefly presented backward-masked faces (Hooker & Parker, 2005) tended to find over-perception of eye contact in SCZ, likely due to the amplified level of ambiguity. When examining group difference at each gaze angle, Hooker and Park (2005) found that SCZ endorsed more eye contact for ambiguous gaze but not clearly direct and averted gaze. As we can see in Table 1, the question as to whether gaze perception is related to clinical symptoms remains unclear. The generally assumed that gaze perception is an important determinant of social cognition has also remained unexamined. These together suggest that it would be informative to examine self-referential gaze perception along the whole spectrum of gaze angles and its relationship with clinical and functional outcomes in schizophrenia.

Factors Influencing Normal Gaze Perception

Head Orientation. There is evidence that gaze judgment in healthy individuals is not solely based on gaze direction. Head orientation has been shown to be a particularly influential

factor of gaze perception. In primates, including humans, head orientation is helpful in determining the direction of others' attention when gaze direction is obscured (Emery, 2000). However, head orientation also affects perception of *seen* gaze. In particular, congruent gaze-head directions facilitate and incongruent ones interfere with the judgments of both gaze and head directions (Langton, 2000; Seyama & Nagayama, 2005). The effect of averted head orientation is likely due to its being a robust cue of head turn, a strong suggestion of directed-away social attention (Todorović, 2006, 2009). In fact, healthy individuals are more likely to reject direct gaze as looking at them when the head is averted compared to facing forward (Itier et al., 2007).

The effects of gaze direction and head orientation on eye-contact perception in schizophrenia have not been differentiated. However, the finding that SCZ were more likely than HC to make eye-contact judgment when presented with backward-masked ambiguous stimuli (i.e., face outline with no internal facial features) suggests a tendency to accept ambiguous social information as directed to self in schizophrenia (Hooker & Park, 2005). Therefore, when the face is averted, SCZ would be expected to endorse even more eye contact than HC. Since gaze direction and head orientation do not always line up in real life when eye-contact judgments need to be made, examining the interaction between gaze and head direction on eye-contact perception would provide an ecologically valid understanding of gaze perception in schizophrenia.

Emotion. Facial emotion is another powerful modulator of gaze perception, as it reveals information about one's mental state. Experimental studies have demonstrated that facial expression interferes with gaze judgment (Graham & LaBar, 2007; Lobmaier, Tiddeman, & Perrett, 2008). In particular, compared to neutral faces, fearful faces bias people to perceiving averted gaze (Tipples, 2006) and, likewise, averted gaze enhances the perception of fear, likely

because averted gaze matches the avoidance-oriented behavioral intent underlying fearful emotion (Adams & Kleck, 2005).

Threat-related emotions are of particular relevance to the study of schizophrenia. Since paranoid delusions involve the false perception of danger in one's environment, gaze information may be processed in a distinctive way when coupled with threat-related emotions. Because seeing fearful emotion with averted gaze in others is an important signal of danger in the environment, studying eye-contact perception in schizophrenia using fearful in addition to neutral face stimuli would allow more comprehensive understanding of perception of self-referential social information in the disorder. On the one hand, an elevated emotion effect in eye-contact perception may be expected in SCZ for their special sensitivity to negative emotions, as suggested by their heightened emotional response to daily stressors and negative life events (Myin-Germeys et al., 2003) and elevated neural response to threat-related images (Taylor, Phan, Britton, & Liberzon, 2005). This entails an expectation that SCZ show a stronger bias than HC to perceive gaze as averted (i.e., endorse eye contact less frequently) for fearful faces relative to neutral faces. On the other hand, a reduced emotion effect may be expected as SCZ have been shown to experience increased aversion to neutral stimuli (Cohen & Minor, 2010) and exhibit reduced emotion modulation of face encoding (Lynn & Salisbury, 2008) compared to HC. Empirical data are needed to demonstrate what effect threat-related emotions have on eye-contact perception in schizophrenia.

The Present Study

To address whether individuals with schizophrenia show abnormal eye-contact perception, this study used a psychophysical approach to examine eye-contact perception as a function of eye-contact signal strength. Face stimuli that cover the full range of gaze directions,

from averted to direct gaze, with gradual increments, were used. A relatively large number of trials (12) for each gaze direction were used to ensure reliable measures. Gaze at these different averted angles then represents a full spectrum of “eye-contact signal strength” that ranged from 0 (averted gaze) to 1.0 (direct gaze). Participants made yes-no responses to the question “Looking at me?” for each face. The faces were presented in a pseudo-random order, so that the chance of direct or averted gaze in each trial was unpredictable, avoiding bias due to anticipation. Although the majority of the responses would be “no,” this bias to respond “no” induced by the experiment structure was equal across individuals, thus not affecting the comparisons between individuals or diagnosis groups.

Since the self-referential nature of gaze is putatively dichotomous, the percentage of “yes” responses along the continuum of eye-contact signal strength was theorized to resemble a logistic function. Two particular psychophysical properties were estimated using this logistic response function: thresholds and rate of change of categorical shift. In psychophysics, “threshold” refers to the signal strength corresponding to “yes” responses at a certain frequency. For example, sensory threshold and absolute threshold, two frequently used thresholds, are the signal strength where “yes” responses are given 75% and 50% of the time, respectively. Response cutoff values other than 50% and 75% may also be used. For instance, Hooker and Park (2005) chose a response cutoff of 30% because it was the base rate of “yes” responses in their study. In this study, multiple response cutoffs (ranging from 10% to 90%) were used to obtain multiple thresholds, in order to compare with results of previous studies (Franck et al., 2002; Hooker & Park, 2005) and explore the threshold that most effectively discriminates between SCZ and HC. It is important to note that for this eye-contact perception paradigm, unlike sensory detection paradigms, “yes” is not necessarily the correct response. Therefore,

lower thresholds (i.e., perceiving eye contact with weaker signal) are not necessarily better than higher thresholds and, in fact, likely to be problematic. Further, rapid changes from non-self-referential to self-referential gaze perception indicates more clearly dichotomous perception (i.e., from “no” to “yes”) whereas gradual changes indicate more uncertainty in deciding the self-referential nature of gaze. Therefore, the rate of change of categorical shift, defined as the slope of the response function where “yes” responses are given 50% of the time, was measured. In addition to varying gaze direction, the face stimuli in this study also varied in head orientation and facial emotion so that their effects on eye-contact perception in schizophrenia could be examined.

Hypotheses

- 1) SCZ would show a positive bias and experience more uncertainty than HC in eye-contact perception. This entails predictions that: a) SCZ would endorse eye contact more often than HC, especially for ambiguous gaze (i.e., medium eye-contact signal strengths); b) SCZ would show lower eye-contact perception thresholds than HC; c) SCZ would show decreased rate of change of categorical shift relative to HC; d) SCZ’s positive bias would be accentuated for averted relative to forward head orientation.
- 2) Abnormalities in gaze perception (over-perception of eye contact, decreased categorical perception) in SCZ would be associated with higher symptom severity and poorer socio-emotional functioning.

Method

Participants

SCZ were volunteers aged 18 to 60 meeting DSM-IV criteria for schizophrenia or schizoaffective disorder. They were recruited through advertisements in the community and

referrals by clinicians of local community mental health clinics or clinical researchers of the University of Michigan. Exclusion criteria for SCZ included: unable to give informed consent, have other active Axis-I disorders (except anxiety and depressive disorders), and a history of alcohol or substance abuse/dependence in the past 6 months. HC were recruited from advertisements in the community and referrals by other researchers. Exclusion criteria for HC included: lifetime Axis-I disorders, and history of psychosis and bipolar disorder among first-degree relatives. Each participant had at least 20/30 vision according to a Snelling chart. Written informed consent was obtained from each participant after complete description of the study was given.

The participants of this study also participated in another experiment examining basic visual perception; 22 SCZ and 22 HC of this study participated in an event-related potential (ERP) experiment on gaze discrimination. Since these experiments are out of the scope of this paper, the results are not included in this report and will be reported elsewhere.

Assessments

Clinical diagnoses were established or ruled out using the Structured Clinical Interview for DSM-IV (SCID; First et al., 1995) by a trained graduate student in clinical psychology, with 80% of the cases confirmed by consensus of another trained graduate student. SCZ were assessed for positive symptoms using the Scale for Assessment of Positive Symptoms (SAPS; Andreasen, 1984) and negative symptoms with the Scale for Assessment of Negative Symptoms (SANS; Andreasen, 1983). Inter-rater reliability as indexed by concordance correlation for these clinical ratings is displayed in Table 3.

All participants completed the Brief Assessment of Cognition for Schizophrenia (BACS; Keefe et al., 2004) and the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT;

Mayer, Salovey, & Caruso, 1999). The BACS and the MSCEIT are the performance-based measures of neurocognition and emotion-related social cognitive skills, respectively, recommended by the National Institute of Mental Health (NIMH) Measurement and Treatment Research to Improve Cognition in Schizophrenia (MATRICS) committee (Green, Olivier, Crawley, Penn, & Silverstein, 2005).

Experimental Material and Task

Face materials for the Eye-Contact Perception Task were adopted from Gur et al. (2002). Black-and-white pictures of six actors in forward and 30° averted head orientation in neutral and evoked-fearful emotion were extracted from the original pool of 3-dimensional images for editing. Since all original faces were looking straight ahead, Photoshop was used to edit the iris area to create direct gaze for faces in averted head orientation and averted gaze for faces in forward head orientation. Then, morphing software was used to create varying gaze direction, from averted (0 eye-contact signal strength) to direct (1.0 eye-contact signal strength) with ten 10% increments (see Figure 1 for illustration). A total of 528 faces were produced and used for the experiment: 12 trials (6 actors \times 2 mirror images) for each of the 11 eye-contact signal strengths in each of the four combinations of head orientation (forward, averted) and emotion (neutral, fearful).

The Eye-Contact Perception Task was presented using the software E-prime 1.0. The faces were presented in a pseudo-randomized order such that no consecutive trials were faces of the same actor (in order to avoid potential illusory eye motion). Participants were required to press a button to indicate if they feel that the person is “looking at me” and another button to indicate “looking away.” To reduce variance introduced by time pressure in SCZ, a population known to have slower reactions and more vulnerable to psychological stress (Docherty & Hebert,

1997; Tso, Grove, & Taylor, in press), the task imposed no time constraint for response. The task typically took 10-15 minutes to complete. Button pressing was counter-balanced across participants.

Statistical Analyses

The data were first analyzed using a psychophysical approach (see Figure 2 for illustration). For each participant, his/her data (percentage of “yes, looking at me” responses against eye-contact signal strength) were fitted in a logistic function:

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

where P is the percentage of “looking at me” responses, x is eye-contact signal strength, and c and b are constant parameters provided by the PASW Statistics 18 Curve Estimation (logistic) function. Nine thresholds of eye-contact perception were obtained using response cutoffs from 10% to 90%, calculated by finding the expected x values for $P = 10\%$, 20% , ..., 90% . The rate of change of the categorical shift was defined as the slope of *Equation 1* at $P = 50\%$. This 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 $P = 50\%$, *Equation 2* becomes:

$dP/dx = -\ln(b)/4$. Note that while most of the participants’ data for forward faces fit well into a logistic function and fitting in terms of R^2 did not differ between SCZ ($M = 0.80$, $SD = 0.08$) and HC ($M = 0.82$, $SD = 0.08$), $F(1, 47) = 1.11$, $p = .298$, responses to averted faces did not approach logistic functions. As a result, this part of analyses was performed for forward faces only.

Threshold of eye-contact perception was subject to a 9 (response cutoffs) \times 2 (emotions) \times 2 (groups) mixed model ANOVA; slope of categorical shift was analyzed using a 2 (emotions) \times 2 (groups) mixed model ANOVA.

In order to include the data on averted faces in the analysis, a mixed model 4-way ANOVA was performed, with eye-contact signal strength (Gaze: 0, 0.1, ..., 1.0), head orientation, and emotion as within-subjects variables, group as between-subjects factor, and percentage of “looking at me” responses as dependent variable. Huynh-Feldt adjustment was used for all ANOVAs in case of violation of the sphericity assumption.

Relationships between eye-contact perception measures and clinical/functional variables were examined using Pearson’s correlations and multiple regressions. Due to the very limited variance on the SAPS Bizarre Behavior and Inappropriate Affect subscales, these two subscores were excluded from the correlation analyses. Pairwise correlations were visually inspected for violations of assumptions and outliers, and cases with Cook’s Distance $> 4/n$ (Bollen & Jackman, 1990) were subject to further investigations. All statistical analyses were performed using PASW Statistics 18.

Results

Participant Characteristics

Twenty-eight SCZ and 24 HC completed the task. Data of one SCZ and one HC were discarded as their responses approached chance level and were therefore deemed unreliable. Data of another SCZ participant were lost due to corruption of the electronic data file. The remaining 26 SCZ and 23 HC participants, whose data were used in subsequent analyses, were well matched for age, sex, and parental education. As expected, SCZ had poorer socio-emotional functioning than HC as suggested by their lower MSCEIT scores. See Table 2 for details of participant characteristics.

Abnormal Eye-Contact Perception in Schizophrenia

Over-perception of eye contact. Eye-contact perception thresholds of SCZ and HC obtained using different response cutoffs are presented in Figure 3. SCZ’s mean threshold across

response cutoffs ($M = 0.63$, $SD = 0.18$) was only marginally lower than HC's ($M = 0.73$, $SD = 0.18$), $F(1, 47) = 3.73$, $p = .059$. However, the Cutoff Value \times Group interaction, $F(1.02, 48.02) = 5.49$, $p = .023$, indicated that SCZ showed significantly lower threshold than HC when threshold was obtained using a response cutoff of 60% or lower. This Cutoff Value \times Group interaction did not vary by emotion, $F(1.02, 48.03) = 0.92$, $p = .345$. These together suggested that SCZ began endorsing eye contact earlier along the continuum of eye-contact signal strength.

Response patterns of SCZ and HC in each of the four head/emotion conditions are presented in Figure 4. Overall, SCZ ($M = 33\%$, $SD = 12\%$) were more likely than HC ($M = 23\%$, $SD = 12\%$) to perceive gaze as looking at them, $F(1, 47) = 7.93$, $p = .007$. Further, group differences along the signal strength spectrum varied by head orientation and emotion, as indicated by the significant Gaze \times Head \times Group interaction, $F(4.73, 222.29) = 4.36$, $p = .001$ (Figure 5 a) and Gaze \times Emotion \times Group interaction, $F(4.73, 222.29) = 2.08$, $p = .040$ (Figure 5 b).

Decreased categorical perception. SCZ ($M = 2.48$, $SD = 0.63$) showed reduced slope of categorical shift compared to HC ($M = 2.87$, $SD = 0.63$), $F(1, 47) = 4.64$, $p = .036$. The group difference was constant across emotions, $F(1, 47) = 0.05$, $p = .830$, although categorical shift occurred more rapidly for neutral ($M = 2.79$, $SD = 0.75$) than fearful faces ($M = 2.56$, $SD = 0.62$), $F(1, 47) = 8.71$, $p = .005$.

Relationship with Clinical and Functional Variables

Correlations between eye-contact perception measures and clinical and functional variables among SCZ participants are summarized in Table 3. In general, eye-contact perception was not associated with antipsychotic dose and SAPS. SANS was associated with higher percentages of “yes” responses and lower thresholds. Over-perception of eye contact (i.e.,

increased percentage of “yes” response for low/medium but not high signal strengths, and decreased thresholds obtained using low/medium but not high response cutoffs) was significantly correlated with lower BACS and MSCEIT scores. Higher slope of categorical shift was correlated with better MSCEIT.

To make sure that the relationship between eye-contact perception and MSCEIT was not solely driven by general deficits in schizophrenia, regression analyses using a model comparison approach were performed to isolate the effects of eye-contact perception variables from that of BACS on MSCEIT. The slope of categorical shift was the only eye-contact perception variable that explained significantly more variance of MSCEIT *in addition to* BACS (Table 4).

Among HC, slope of categorical shift, but not other eye-contact perception variables, was also correlated with MSCEIT ($r = .51, p = .026$). Group membership (SCZ, HC) significantly predicted MSCEIT ($r = .40, p = .013$), but this correlation became non-significant after the effect of slope of categorical shift was partialled out ($r_p = .20, p = .229$), suggesting that lower MSCEIT scores in SCZ could be largely accounted for by their reduced categorical function in eye-contact perception. Figure 6 illustrates that the linear relationship between MSCEIT and slope of categorical shift was comparable between SCZ and HC.

Discussion

This study examined whether individuals with schizophrenia have abnormal perception of self-referential gaze, what factors influence this perception, and its relationship with clinical symptoms and socio-emotional functioning. The results supported our hypotheses that SCZ are more likely than HC to perceive gaze as directed to them and experience more ambiguity as operationalized by reduced categorical perception compared to HC. In addition to gaze direction,

both head orientation and emotion of the face stimuli were shown to be influential factors of eye-contact perception in schizophrenia. Furthermore, abnormalities in eye-contact perception (over-perception of eye contact and reduced categorical perception) were significantly associated with more severe negative symptoms, poorer neurocognition, and lower emotional intelligence in schizophrenia, supporting the relevance of gaze perception to clinical and functional outcomes in the disorder.

Nature of Abnormalities in Eye-contact Perception in Schizophrenia

A positive bias in eye-contact perception in schizophrenia was shown by the results of lower thresholds and higher rate of eye-contact endorsement in SCZ compared to HC. The eye-contact threshold gap between SCZ and HC was maximal at the lowest response cutoffs and gradually disappeared as response cutoff went up, suggesting that eye-contact perception in schizophrenia is characterized by an earlier readiness (in the gaze direction spectrum) to contemplate that gaze may be directed to self. This finding helps explain the discrepancy between the findings from Hooker & Park (2005) and Franck et al. (2002), where the former found a significant difference in eye-contact perception threshold between SCZ and HC using a lower response cutoff and the latter found no group difference using a higher cutoff.

Examination of the group differences in percentage of “yes” responses along the continuum of gaze directions revealed that SCZ’s difficulty is most prominent when gaze direction is ambiguous. For forward faces, SCZ showed the strongest positive bias when the eye-contact signal strength was medium (i.e., gaze direction was ambiguous), consistent with Hooker and Park’s (2005) finding. It should be emphasized that SCZ’s performance was indistinguishable from HC’s when signal strength was strong (i.e., direct gaze), suggesting that their difficulty with eye-contact perception was specific to ambiguous gaze and is unlikely due to a general deficit

problem. For averted faces, however, SCZ showed most elevated eye-contact perception for strongest eye-contact signal strengths. This was due to HC's low eye-contact endorsement rate (< 50% of the time) for direct gaze in averted head orientation. While this low endorsement rate may be reflecting a combined effect of people's general poorer ability to detect direct gaze from averted faces (Itier et al., 2007; Rosse et al., 1994) and the imperfect face stimuli used in this study (see below for further discussion), at the same time this suggests that HC perceived the presumably direct gaze as ambiguous. Then, the results for averted faces once again showed that over-perception of eye contact in SCZ is most prominent when gaze direction is ambiguous.

Together with the finding that SCZ's eye-contact perception was less dichotomous than HC's, this study showed that individuals with schizophrenia experience more uncertainty when determining the self-referential nature of gaze and a self-directed bias is activated when gaze is ambiguous. Previous studies have shown that SCZ have a tendency to blame others for negative events (Janssen et al., 2006). This study further showed that this externalizing bias applies to the perception of ambiguous social signals without direct consequences. This attributional bias and the observed uncertainty in gaze perception may be reflecting the failure to recruit critical brain regions (e.g., paracingulate cortex, temporo-parietal junctions) in tasks involving theory of mind (i.e., attribution of intention to others) in schizophrenia (Walter et al., 2009). While neurobiological interventions targeting these brain functions are yet to be developed and tested (Green & Horan, 2010), results of studies using psychosocial interventions to improve social cognition in schizophrenia have been encouraging (Horan et al., 2009; Horan, Kern, Green, & Penn, 2008; Roberts & Penn, 2009). The modifiability of social cognition in the disorder through psychosocial methods lends support to the development of training targeting at perception and interpretation of ambiguous social signals.

Modulation of eye-contact perception by fearful emotion was reduced in schizophrenia. The largest group difference in eye contact endorsement rate for neutral faces occurred when eye-contact signal was medium, whereas the largest group difference for fearful faces occurred later in the spectrum of signal strength. This was because HC endorsed eye contact less frequently for direct gaze shown in fearful compared to neutral faces (consistent with previous reports of a bias to perceive averted gaze from fearful faces: Adam & Kleck, 2005; Tipples, 2006), while SCZ's eye-contact perception was affected in the same direction but to a lesser extent. The reduced modulation by fearful emotion among SCZ may be related to the tendency to experience elevated negative emotional responses to neutral faces in schizophrenia as discussed earlier (Cohen & Minor, 2010). Examining the interaction between subjective emotional response and processing of self-referential social information in future studies would inform the underpinning of this reduced emotion (at least fearful) modulation. Moreover, given that disruptions in basic visual perception have been frequently reported in schizophrenia, it is reasonable to ask and address in future studies the question as to whether abnormal gaze perception in schizophrenia is related to deficits in basic visual perception (*cf.* Sergi & Green, 2003).

Relationships with Symptoms and Socio-emotional Functioning

The present study showed that negative symptoms, particularly avolition/amotivation, were associated with a self-referential bias in gaze perception (more "yes" responses and lower thresholds). This finding was unlikely caused by artifacts such as slower response and lower motivation. The task had no time limit and thus the observed positive bias could not be attributed to mistakes due to time out. More importantly, those who are less motivated to do well on the task would make equally more mistakes along the continuum of eye-contact signal strength (i.e.,

endorse eye contact more frequently for low and medium signal strengths but less frequently for high signal strengths), but this was not the case. The connection between negative symptoms and a self-referential bias may seem counter-intuitive, but as noted in qualitative work exploring the subjective dimension of negative symptoms, patients with schizophrenia describe an increased self-awareness and constant perplexity about the relations between self and the external world, which often result in motor slowing and social withdrawal (Sass & Parnas, 2003). As such, the self-referential bias observed in negative symptoms may be reflecting one of the aspects of self-disturbances as described in the schizophrenia literature. This is consistent with research data showing deficits in brain regions that are responsible for self-referential processing (e.g., medial prefrontal cortex, anterior cingulate cortex) in schizophrenia (Brunet-Gouet & Decety, 2006) and a common factor underlying negative symptoms and theory-of-mind deficits (Woodward, Mizrahi, Menon, & Christensen, 2009).

The lack of association between positive symptoms, especially paranoid delusions, and self-referential bias in gaze perception deserves some comments. Patients with these symptoms often complain that they *know* that their experiences/thoughts are false, yet they *feel* real to them. Given that research has generally found modest or no correlations between positive symptoms and functional impairment (Harvey et al., 1998; Kurtz, Wexler, Fujimoto, Shagan, & Seltzer, 2008) and that most of the self-referential positive symptoms observed in our sample were mild to moderate, it is plausible that many participants with these symptoms were able to respond to the gaze task intellectually, despite their inconsistent internal feelings. Nevertheless, without substantiating data, this remains a speculation and needs further investigation to verify.

The present study confirmed the widely accepted assumption that eye-contact perception is critical to broader socio-emotional functioning in schizophrenia. Over-perception of eye

contact and reduced categorical perception were significant associated with MSCEIT in schizophrenia. Notably, the relationship between reduced categorical eye-contact perception and MSCEIT in SCZ persisted after controlling for basic neurocognition (BACS), suggesting that the relationship could not be completely attributed to a general deficit problem. Also noteworthy was that this relationship was present in comparable strength among HC, suggesting that the importance of clear-cut categorical gaze perception to broader socio-emotional functioning applies to both individuals with and without schizophrenia. In fact, MSCEIT difference between SCZ and HC disappeared after controlling for slope of categorical shift, suggesting that the observed compromised socio-emotional deficits in schizophrenia may lie in the ambiguity in discriminating the self-referential nature of social signals. This is an intriguing finding in that a measure of supposedly high-level socio-emotional reasoning was correlated with a lower-level social cognition (gaze perception). However, if we consider a core ability tapped by the MSCEIT—the ability to efficiently put boundaries between categories of major socio-emotional entities, including perceptual ones such as facial expressions and more abstract ones such as labels of complex emotions, the connection between MSCEIT and categorical gaze perception becomes illuminated. In addition, the MSCEIT Managing Emotion branch, which requires higher reasoning in complex socio-emotional contexts, showed lower correlations with categorical gaze perception compared to other MSCEIT branches, further supporting that efficient mental categorization of socio-emotional concepts is an underlying factor of the connection between MSCEIT and gaze perception. Therefore, it appears that categorical gaze perception may involve processing at the perceptual level as well as, to some degree, the interpretation level.

Limitations

As discussed before, response patterns for forward and averted head orientations were significantly different. Although people are generally less able to detect direct gaze from averted faces (Itier et al., 2007; Rosse et al., 1994), the eye-contact endorsement rate found in this study (~50%) was substantially lower than the commonly observed range (70% - 90%), pointing to the possibility that the editing of the gaze of the original averted faces was not perfectly convincing even though an prior informal in-house validation was performed. Ideally, images should be generated by taking pictures of actors instructed to look at different pre-marked directions in front of a camera. However, it would have been extremely challenging to have actors pose fearful repeatedly for all gaze angles. Whether or not the lack of fit of participants' responses into a logistic function reflects the true nature of eye-contact perception for averted faces remains a topic to be addressed.

Participants with schizophrenia of this study were mostly chronic, medicated patients. Since schizophrenia tends to run a chronic course and most patients with schizophrenia in North America are treated with medications, the results of this study inform eye-contact perception in the typical person with the disorder. Replications in the early and prodromal phases of illness would help evaluate the effects of medications and illness chronicity on eye-contact perception. Comparisons with other psychiatric disorders (e.g., bipolar disorder, autism) would also provide information about the specificity of eye-contact perception deficits to schizophrenia.

Conclusions

The present study showed that individuals with schizophrenia exhibited abnormal eye-contact perception characterized by over-attribution of self-directed intention to ambiguous gaze and more uncertainty when determining the self-referential nature of gaze. These abnormalities

are related to more severe negative symptoms and deficits in broader socio-emotional functioning in schizophrenia and warrant further investigations.

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Table 1

Summary of Methodological Differences and Major Findings of Previous Gaze Perception Studies in Schizophrenia

Study	N	Head angles	Gaze angles	Task(s)	Stimulus presentation	# of trials	Statistical analysis strategy	Major findings	Relationship with symptoms
Franck et al. (1998)	22 SCZ 36 HC	0°	0°, ±15°, ±30°	Looking left/right?	Stimulus: no time limit, until response given	30 trials (6 trials per gaze angle)	Mann-Whitney U-tests to compare group medians of percentage of “left” responses	No group difference for each gaze angle	No group differences between paranoid ($n = 11$) and non-paranoid ($n = 11$) SCZ
Franck et al. (2002)	32 SCZ 32 HC	0°	7 angles from 0° to ±30°	Task 1: Looking left/right Task 2: Looking at me/elsewhere	Stimulus: no time limit, until response given	130 trials per task (10 trials per gaze angle)	Kruskal-Wallis tests to compare group medians of absolute threshold (AT)	No group differences in AT	No group differences in AT between paranoid ($n = 20$) and non-paranoid ($n = 12$) SCZ
Hooker & Park (2005)	15 SCZ 19 HC	0°	0°, ±20°, ±30°, ±40°, ±50°, ±55°	Task 1: Direct gaze? y/n Task 2: Black square centered to white rectangle? y/n	Stimulus: 30 ms Backward mask: 75 ms ISI: 30 ms, 60 ms, 180ms	For each task, 96 trials for gaze angle of 0° and 48 trials for each other gaze angle	ANOVA to test effects of task, gaze angle, ISI, and group on rate of “yes” responses	SCZ endorsed direct gaze more often than HC for gaze angle of ±20°	Performance uncorrelated with demographic and clinical variables
Kohler et al. (2008)	13 SCZ 12 HC	0°, ±4°, ±8°	0°	Looking at me/away?	Stimulus: 1 s ISI: 16 s	8 trials for head angle of 0° and 4 trials for each other head angle	ANOVA to test effects of head angle and group on rate of correct responses	No group differences for each head angle	Not examined
Rosse et al. (1994)	24 SCZ 25 HC	0°, ±2.5°, ±5°, ±10°, ±20°	9 angles for each head angle	Looking directly at me? y/n	Stimulus: no time limit, until response given	40 trials in total	MANCOVA to test group differences in gaze discrimination specificity, sensitivity, and positive bias, controlling for age and education	SCZ showed lower specificity, higher sensitivity and positive bias than HC	Paranoid SCZ ($n = 12$) higher on sensitivity and positive bias than non-paranoid SCZ ($n = 12$)

Note. Gaze angle of 0° means looking straight ahead; Head angle of 0° means facing forward to the viewer.

Table 2

Participant Characteristics

Variable	SCZ (<i>n</i> = 26)		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
Education	10 – 18	13.6 \pm 2.0	12 – 21	16.4 \pm 2.6	-4.17	< .001
Parental education	4 – 21	14.9 \pm 3.8	9 – 20	15.0 \pm 2.8	-0.12	.905
BACS	-2.46 – 2.07	-0.96 \pm 1.12	- 2.65 – 1.85	0.39 \pm 1.02	-4.22	< .001
Duration of illness	1 – 41	24.4 \pm 12.8	--	--	--	--
CPZeq (mg daily)	0 – 2000	453 \pm 511	--	--	--	--
SAPS	0 – 12	5.4 \pm 3.6	--	--	--	--
Hallucinations	0 – 4	1.6 \pm 1.6	--	--	--	--
Delusions	0 – 4	2.0 \pm 1.6	--	--	--	--
Bizzare Behavior	0 – 2	0.4 \pm 0.6	--	--	--	--
Thought Disorder	0 – 3	1.1 \pm 1.3	--	--	--	--
Inappropriate Affect	0 – 2	0.4 \pm 0.7	--	--	--	--
SANS	0 – 12	4.2 \pm 3.1	--	--	--	--
Flat Affect	0 – 4	1.4 \pm 1.2	--	--	--	--
Alogia	0 – 3	0.4 \pm 0.7	--	--	--	--
Avolition	0 – 3	0.7 \pm 0.9	--	--	--	--
Anhedonia	0 – 4	1.8 \pm 1.4	--	--	--	--
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 number of subjects for the MSCEIT scores varied: overall score (20 SCZ, 19 HC); Perceiving Emotions branch (22 SCZ, 19 HC); Using Emotions branch (22 SCZ, 21 HC); Understanding Emotions branch (24 SCZ, 21 HC); and Managing Emotions branch (25 SCZ, 21 HC).

Note. BACS = Brief Assessment of Cognition for Schizophrenia composite score, with reference to normal data of 83 healthy controls (30% female; age = 40.5 \pm 11.7; parental education = 16.2

± 2.6 years) from multiple studies by our research team; CPZeq = Antipsychotic dose in chlorpromazine equivalent; SAPS = Scale for the Assessment of Positive Symptoms; SANS = Scale for the Assessment of Negative Symptoms; MSCEIT = Age- and gender-adjusted scores on the Mayer-Salovey-Caruso Emotional Intelligence Test.

Table 3

Correlations between Eye-contact Perception, Clinical and Functional Variables among SCZ

Variable	1.	2.	3.	3a.	3b.	3c.	4.	4a.	4b.	4c.	4d.	5.	6.	6a.	6b.	6c.	6d.
1. CPZeq	--																
2. Duration of illness	.17	--															
3. SAPS total	.00	-.08	(.81)														
3a. SAPS Hallucinations	.10	-.23	.61**	(.89)													
3b. SAPS Delusions	-.15	.11	.79***	.32	(.89)												
3c. SAPS Thought Disorder	.13	.05	.70**	.06	.51**	(.54)											
4. SANS total	-.04	.20	.20	-.08	.26	.27	(.83)										
4a. SANS Flat Affect	.01	.40*	.13	-.24	.21	.30	.75***	(.75)									
4b. SANS Alogia	-.02	.28	.33 [†]	-.01	.36 [†]	.55**	.59**	.41*	(.69)								
4c. SANS Avolition	-.10	.18	.20	-.05	.27	.09	.70***	.27	-.31	(.81)							
4d. SANS Anhedonia	-.01	-.01	.02	.05	.04	-.01	.81***	.42*	-.22	.49*	(.64)						
5. BACS	.07	-.45*	-.02	.30	-.02	-.08	-.07	-.12	-.17	-.31	.24	--					
6. MSCEIT overall	-.11	-.51*	-.10	.34	-.09	-.33	-.15	-.44 [†]	-.01	-.15	.16	.57**	--				
6a. Perceiving Emot	.06	-.28	-.01	.20	.11	-.18	.11	-.21	.17	.05	.32	.39 [†]	.83***	--			
6b. Using Emot	-.12	-.50*	.07	.41 [†]	.11	-.21	-.13	-.46*	.11	-.09	.12	.54**	.78***	.69***	--		
6c. Understanding Emot	.08	-.46*	-.07	.41*	-.16	-.23	-.00	-.19	-.11	-.28	.39 [†]	.68***	.90***	.71***	.60**	--	
6d. Managing Emot	-.30	-.40*	-.34	.22	-.38 [†]	-.45*	-.24	-.43*	-.14	-.25	.07	.52**	.71***	.29	.45*	.64***	--
P("looking at me")																	
At low signal strengths ^a	.06	.34 [†]	-.01	-.17 [†]	-.09	.04	.43*	.19	.12	.58***	.35 [†]	-.51**	-.60**	-.46*	-.55**	-.49*	-.31
At medium signal strengths ^a	-.13	.44*	-.00	-.21*	.09	-.21	.49*	.26	.22	.61***	.34 [†]	-.51**	-.56*	-.40 [†]	-.48*	-.52**	-.27
At high signal strengths ^a	-.28	.33	-.19	-.12	-.02	-.25	.33 [†]	.13	.14	.42*	.28	-.22	-.21	-.30	-.15	-.24	.15
Threshold																	
Using low response cutoffs ^b	.14	-.35 [†]	-.05	.12	-.04	-.05	-.36 [†]	-.16	-.27	-.44*	-.23	.57**	.52*	.44*	.50*	.50*	.20
Using medium response cutoffs ^b	.27	-.36 [†]	-.04	.08	-.11	.01	-.42*	-.20	-.31	-.45*	-.31	.47*	.37	.34	.38 [†]	.40 [†]	.09
Using high response cutoffs ^b	.36 [†]	-.32	-.01	.03	-.16	.07	-.42*	-.20	-.30	-.39 [†]	-.35 [†]	.28	.12	.14	.17	.22	-.06
Slope of categorical shift	-.28	-.09	-.05	.16	.07	-.10	-.04	.01	.14	-.17	.11	.40*	.58**	.36 [†]	.52*	.39 [†]	.50*

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%.

Note. Numbers in parentheses are inter-rater reliability indexes (concordance correlations) for the corresponding clinical scales.

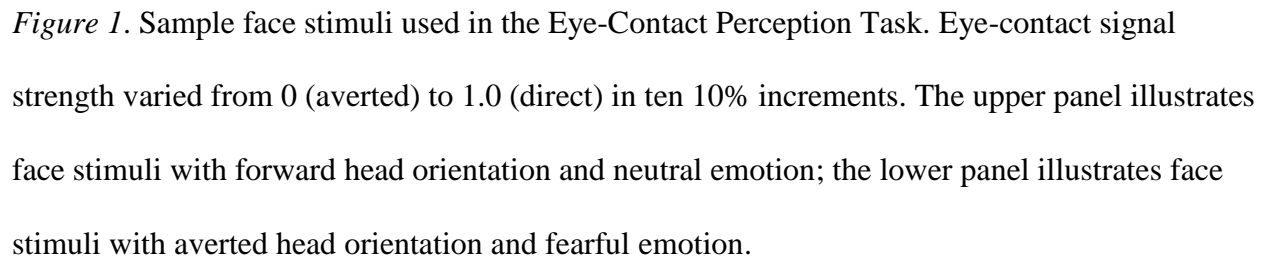
† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table 4

Hierarchical Regression on MSCEIT among SCZ

Model/Predictor	Model statistics				Variable statistics		
	r^2	Δr^2	ΔF	p	β^a	t	p
Reduced model	.32	.32	8.48	.009			
BACS					.57	2.91	.009
Full model	.48	.16	5.18	.036			
BACS					.28	1.31	.208
Slope of categorical shift					.49	3.34	.036

a. Standardized beta.



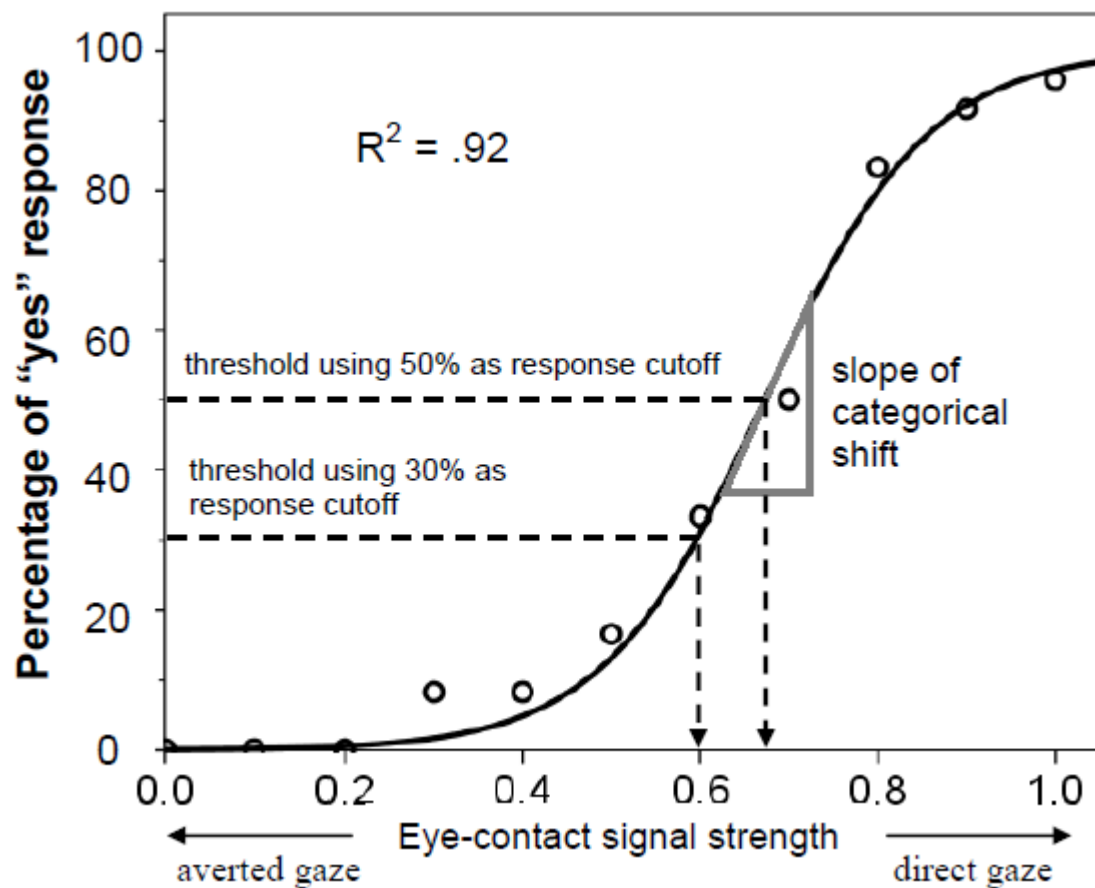


Figure 2. An example of the estimation of psychophysical properties of a participant's eye-contact perception. Nine thresholds of eye-contact perception were obtained using response cutoffs from 10% to 90% (shown in graph only thresholds obtained using 30% and 50% response cutoffs). Note that the unit of threshold is the same as eye-contact signal strength, as "threshold" is defined as the signal strength corresponding to certain frequency of "yes" responses. The rate of change of the categorical shift from non-self-referential to self-referential gaze was defined as the slope of the logistic function when percentage of "yes, looking at me" responses = 50% (i.e., when the predominant response changes from "no" to "yes").

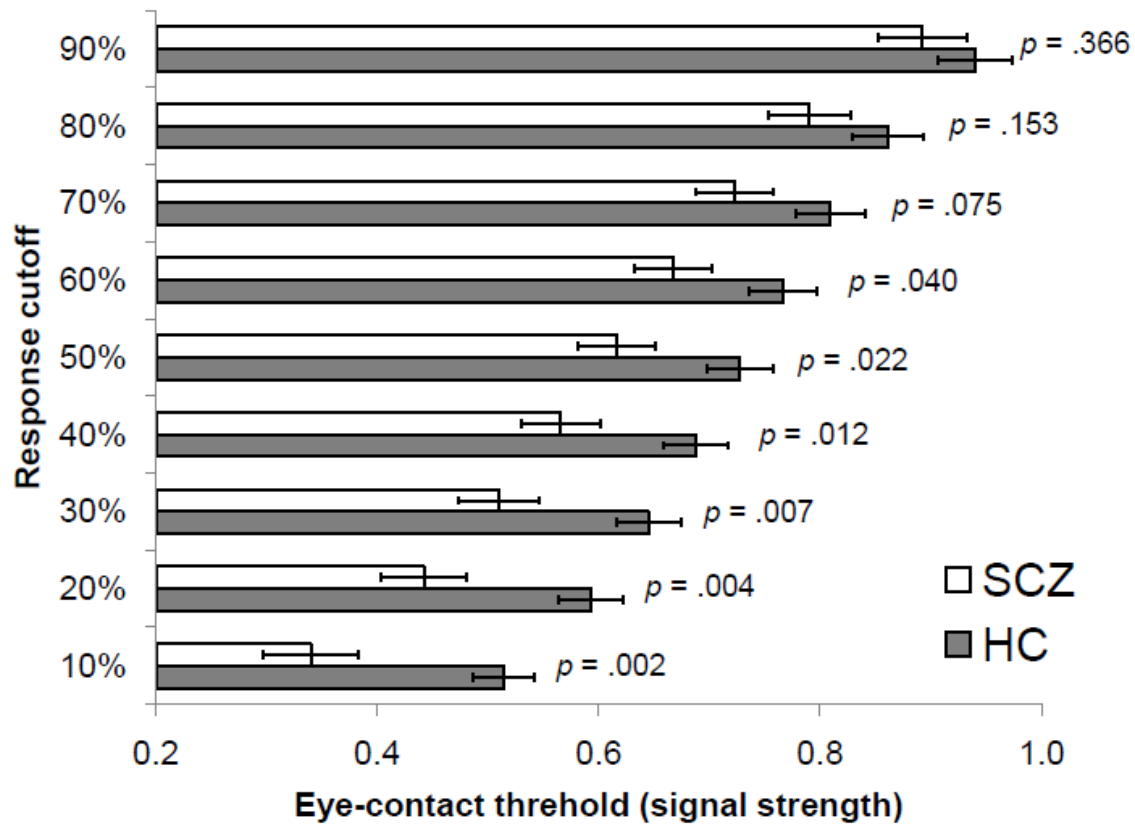


Figure 3. Group difference in eye-contact perception threshold for forward faces (collapsed across neutral and fearful) varied by response cutoff (criterion used to obtain threshold).

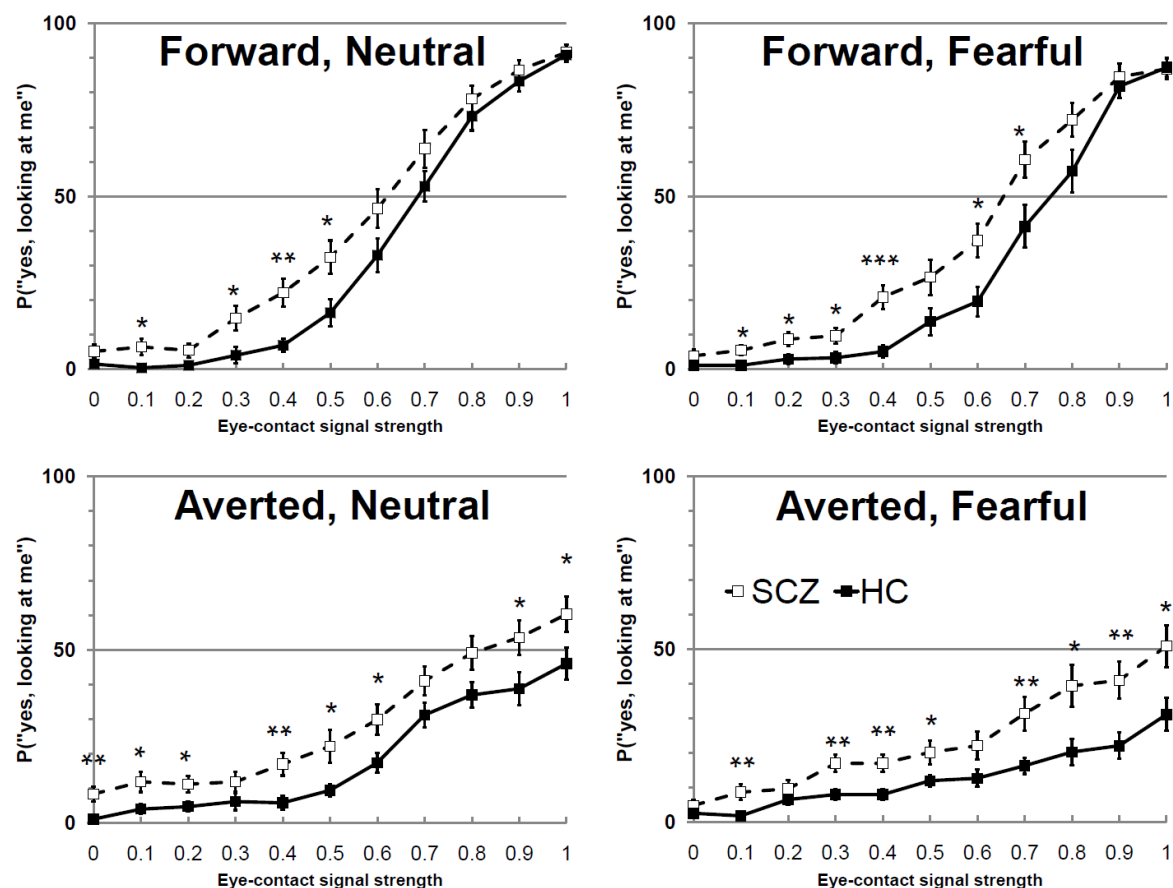


Figure 4. Percentage of "yes, looking at me" responses by group (SCZ: dashed line; HC: solid line) along the gaze continuum in each of the face conditions. Upper left: Face stimuli in forward head orientation and neutral emotion. Upper right: Face stimuli in forward head orientation and fearful emotion.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

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

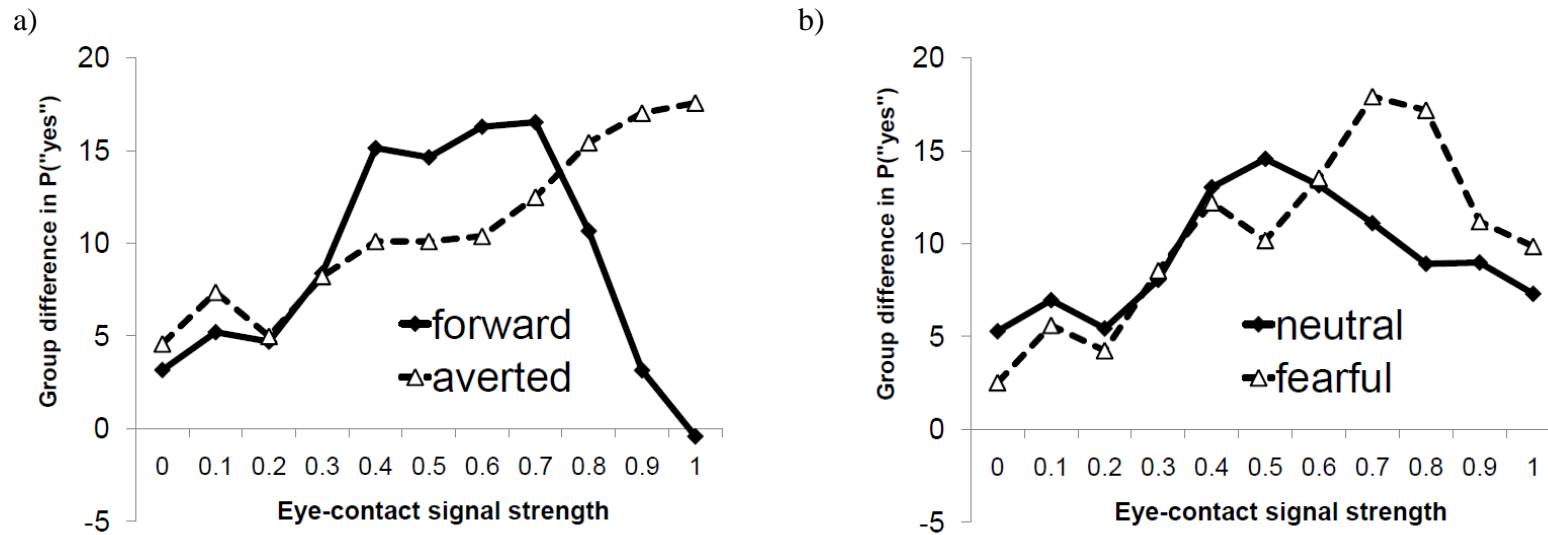


Figure 5. Group differences along the eye-contact signal strength continuum varied by head orientation and emotion. a) Gaze × Head × Group interaction: The lines depict group differences (SCZ – HC) in percentage of “yes, looking at me” responses for faces in forward and averted head orientations, respectively. Group difference along the continuum of signal strength for forward head orientation resembled a quadratic function, $F(1, 47) = 9.74, p = .003$, where SCZ over-perceived eye contact most at medium signal strengths. However, for averted head orientation, the group difference resembled a linear function, $F(1, 47) = 4.12, p = .048$, where SCZ over-perceived eye contact most at high signal strengths. b) Gaze × Emotion × Group interaction: The lines depict group differences (SCZ – HC) for neutral and fearful faces, respectively. For neutral faces, SCZ over-perceived eye contact most at medium signal strengths, whereas for fearful faces the group difference was amplified and the peak occurred later in the signal strength continuum.

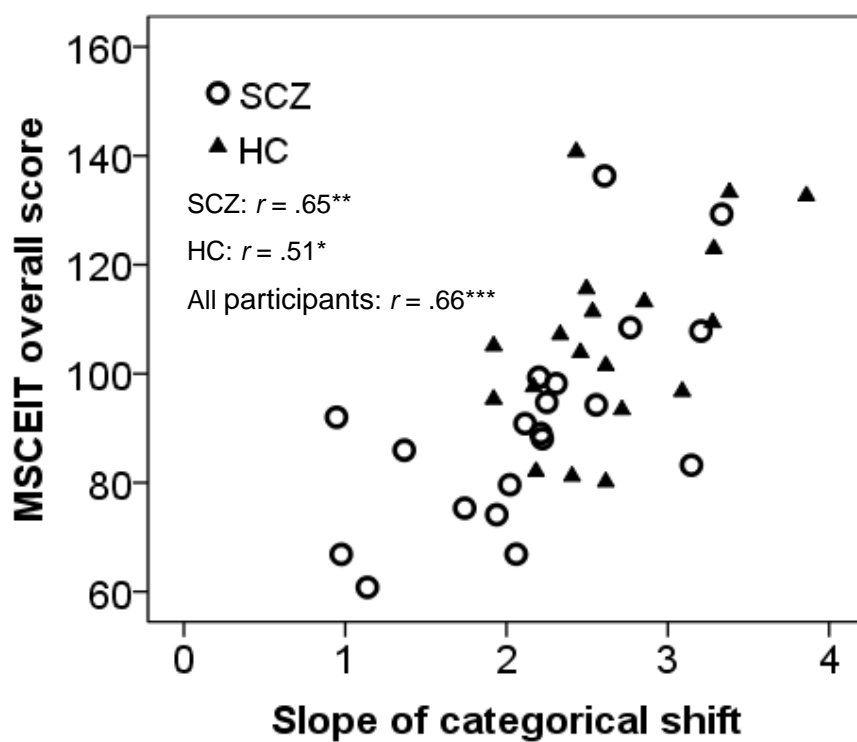


Figure 6. SCZ and HC showed comparable relationship between slope of categorical shift and MSCEIT overall score. * $p < .05$. ** $p < .01$. *** $p < .001$.