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Cone of Gaze in Positive Schizotypy: Relationship to Referential Thinking and Social Functioning

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Eye contact is an essential means of nonverbal communication, providing information about attention, emotion, mental state, facial expressions, and identity/gender (Itier & Batty, 2009). Although studies suggest that patients with schizophrenia endorse direct gaze more often than controls in ambiguous gaze circumstances, gaze perception in schizotypy remains unstudied. This study investigated whether individuals with positive schizotypic features incorrectly perceive that others are looking at them and whether this is related to referential thinking and psychosocial functioning. Schizotypic individuals (n = 33) and controls (n = 29) completed a newly developed measure of gaze perception, a cone of gaze task (Gamer & Hecht, 2007). Results reveal that individuals in the schizotypy group report feeling as though they are being looked at across a wider range of angles than controls. Consistent with our hypotheses, this wider cone of gaze is associated with increased referential thinking and poorer psychosocial functioning.

Keywords: schizotypy, schizophrenia, cone of gaze, eye contact, gaze

Social cognition refers to one's ability to perceive, interpret, and generate socially appropriate responses to others (Ostrom, 1984; see also Green et al., 2008; Pinkham et al., 2003). It is a multifaceted concept that includes both higher and lower level processing abilities: emotion perception (low-level), social perception (low-level), theory of mind (high-level), and attributional style (Mancuso, Horan, Kern, & Green, 2011). It is well established that schizophrenia patients exhibit deficits in social cognition and that these deficits are related to impaired functional outcome, including social behavior in the milieu, community functioning, social skills, and social problem solving (Couture, Penn, & Roberts, 2006; Kim, Doop, Blake, & Park, 2005; Mancuso et al., 2011; Penn, Spaulding, Reed, & Sullivan, 1996; Revheim & Medalia, 2004; Sergi, Rassovsky, Nuechterlein, & Green, 2006). In addition, studies have shown moderate mean effect sizes for social cognition deficits among those with a proposed latent liability for schizophrenia, including first-degree biological relatives and individuals with schizotypic traits (e.g., Baas, van't Wout, Aleman, & Kahn, 2008; Lavoie et al., 2013; Miller & Lenzenweger, 2012; Toomey, Seidman, Lyons, Faraone, & Tsuang, 1999). In conjunction, these studies suggest that social cognition likely plays an important role not only in the functional outcome of schizophrenia, but also in the development of the disorder (Baas et al., 2008; Couture, Penn, & Roberts, 2006; Kim et al., 2005; Lavoie et al., 2013; Mancuso et al., 2011; Miller & Lenzenweger, 2012; Penn et al., 1996; Revheim & Medalia, 2004; Sergi et al., 2006; Toomey et al., 1999). Thus, a better understanding of social cognition as a potential indicator of schizophrenia liability, otherwise known as an *endophenotype*, is an essential growing body of research (Gottesman & Gould, 2003; Gould & Gottesman, 2006; Lenzenweger, 2010; Lenzenweger, 2013; Meehl, 1962; Meehl, 1990). Given the multidimensional nature of social cognition, other aspects of the process should be investigated as well. The current study, therefore, focused on one specific aspect of social cognition among individuals with positive schizotypic traits: gaze perception, or one's ability to accurately perceive direct versus indirect eye contact.

Eye gaze detection is a National Institute of Mental Health (NIMH) Research Domain Criteria (RDoC) element that falls within the broader domain of social processes, more specifically reception of facial communication (Cuthbert, 2014; NIMH, 2015). Gaze direction provides important information about others attention and can communicate either a positive social engagement or a potential threat (Itier & Batty, 2009). The social importance of gaze and the well-established finding of social cognition deficits in schizophrenia has led researchers to assess gaze perception in schizophrenia. To our best knowledge, there are only nine studies assessing gaze perception in schizophrenia and the findings are mixed; five studies have found significant differences between patients and controls (Hooker & Park, 2005; Rosse, Kendrick, Wyatt, Isaac, & Deutsch, 1994; Tso, Carp, Taylor, & Deldin, 2014; Tso, Mui, Taylor, & Deldin, 2012; Walss-Bass, Fernandes, Roberts, Service, & Velligan, 2013), whereas four other studies have found no difference (Franck et al., 1998, 2002; Kohler et al., 2008;

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Tso et al., 2015). These inconsistent findings have been understood largely in terms of methodological differences across studies and two conclusions have emerged. First, patients with schizophrenia tend to endorse direct gaze more than controls when gaze is ambiguous, but not when gaze is overtly direct or indirect (e.g., Hooker & Park, 2005; Tso et al., 2012). Thus, still-photo gaze paradigms that include too few gaze angles or merely include overtly direct (0°) and overtly averted (e.g., 50°) angles may not adequately capture group differences between patients and controls. Therefore, the current study sought to address this methodological concern by using a newly developed cone of gaze paradigm (CoG) that uses the full range of gaze angles from overtly direct to indirect (e.g., 0–50°) with 1° increments (Gamer & Hecht, 2007). Second, studies have found that patients perform similarly to controls when asked to discriminate right versus left gaze, (Franck et al., 1998, 2002), but exhibit biases when asked to make self-referential judgments (i.e., looking at me vs. not looking at me; Franck et al., 2002; Hooker & Park, 2005; Rosse et al., 1994; Tso et al., 2012, 2014). Thus, it has been postulated that the gaze-perception bias in schizophrenia is self-referential in nature rather than a mere deficit in directional judgment (Franck et al., 2002; Hooker & Park, 2005; Rosse et al., 1994; Tso et al., 2012, 2014). Although the existing literature provides preliminary evidence for a self-referential gaze bias, no prior study actually measures the relationship between gaze perception and self-referential thinking, a form of subtle reality distortion in which one experiences otherwise neutral events, objects, and/or interactions with other people as having special, significant, self-relevant meaning (Lenzenweger, Bennett, & Lilenfeld, 1997). Therefore, the current study sought to gain leverage on the possible self-referential nature of gaze-perception bias by not only using a self-referential gaze task, as has been done in previous studies, but by also quantifying referential thinking through a self-report measure.

From the standpoint of schizotypic research participants, no prior study has assessed gaze perception in relation to schizotypy as present in nonpsychotic individuals. All previous studies of gaze perception have used chronic schizophrenia samples. The study of nonpsychotic schizotypic individuals is consistent with the RDoC initiative, which uses a dimensional approach to disorders rather than the traditional categorical approach (Cuthbert, 2014; NIMH, 2015). The RDoC framework emphasizes the inclusion of participants with a wide range of functioning, thus allowing researchers to map developmental trajectories of various psychological disorders. Reliance solely on clinically ill schizophrenia patients conditions all findings on expressed disease status; thus, patients no longer provide leverage on the developmental question regarding the presence of gaze-perception biases prior to the onset of diagnosable disease. Furthermore, RDoC emphasizes the biological basis of psychopathology with a prospect of using genetics and neuroscience research to guide future classification systems (Cuthbert, 2014; NIMH, 2015). As previously indicated, the study of those with a latent liability for schizophrenia has the potential to guide genetic research through the study of endophenotypes (Gottesman & Gould, 2003; Gould & Gottesman, 2006; Lenzenweger, 2013). These concerns, taken together, suggest the need for investigation of gaze perception in a nonclinical, nonpsychotic, schizotypy-characterized sample. Therefore, the current study sought to gain leverage on whether gaze perception has the potential to serve as an endophenotype for schizophrenia by investigating this process in relation to positive schizotypy (Gottesman & Gould, 2003; Gould & Gottesman, 2006; Lenzenweger, 2013).

This study builds on previous research through (a) the use of a positive schizotypy sample, consistent with the RDoC framework; (b) the use of a newly developed continuous gaze perception paradigm that includes the full range of gaze angles from overtly direct to indirect with 1° increments; and (c) measuring referential thinking as it relates to gaze perception. We hypothesized that (a) the positive schizotypy group would endorse direct gaze across a wider range of angles than controls; (b) the schizotypy group would experience greater uncertainty relative to controls, as evidenced by greater reaction times (RTs); and (c) wider gaze cones would be associated with referential thinking as well as other plausibly related social cognition relevant constructs. Regarding our second hypothesis, we hypothesized greater RTs in schizotypy because previous studies have found greater RTs in patients, which has been interpreted as greater uncertainty (e.g., Franck et al., 2002; Hooker & Park, 2005). Regarding our third hypothesis, we hypothesized that social anhedonia, social functioning, and social affiliation would be related to gaze perception because of previous research indicating that gaze perception in schizophrenia is related to negative symptoms and emotion related social–cognitive skills and because of the previously described relationship between social cognition and functional outcome (Couture et al., 2006; Tso et al., 2012). All of our a priori hypotheses were directional in nature.

Method

Participants

Participants were recruited from the State University of New York at Binghamton. Approximately 1,034 individuals completed our screening questionnaires: Perceptual Aberration Scale (PAS; Chapman, Chapman, & Raulin, 1978), Magical Ideation Scale (MIS; Eckblad & Chapman, 1983), and the Jackson Infrequency Scale (JIF; Jackson, 1984). Individuals who scored ≥2 standard deviations above the sample mean on the PAS ($\overline{X}$ = 4.54; $\sigma_{\bar{x}}$ = 4.68) or MIS ($\overline{X}$ = 7.04; $\sigma_{\bar{x}}$ = 5.01) and ≤3 on the JIF were eligible for inclusion in the positive schizotypy group. Controls were selected at random from a subpool of participants who scored no higher than 0.5 standard deviations above the sample means on the PAS and/or MIS and ≤3 on the JIF. Of the 1,034 individuals that completed our screening questionnaires, 180 individuals that met these predefined inclusion criteria were invited to participate in the study. Of those invited to participate, 69 participants completed the laboratory portion of the study. Upon arrival to the experiment, participants were asked additional screening questions to ensure that potential study participants were clear of features that might adversely impact their laboratory performance. Participants were excluded if (a) they had been under the influence of drugs or alcohol in the 24 hr preceding the study, (b) they knew either of the human models in the computer task, and/or (c) they reported being previously hospitalized and diagnosed with schizophrenia, major depression, and/or bipolar disorder. Of the 69 individuals that completed the laboratory portion of the experiment, a further 7 participants were excluded from the data analysis for varying reasons (e.g., random responding, substance use, and missing data). This left 33 individuals in the schizotypy group (12 male and 21 female) and 29 individuals in the control group (9 male and 20 female). All participants were undergraduate students with the exception of one graduate student. See Table 1 for participant characteristics. Participants were compensated with either credit toward their psychology courses or a chance to win one of three $25 Visa gift cards. The present study was fully approved prior to data collection by the State University of New York at Binghamton Institutional Review Board.

Self-Report Measures

The PAS (Chapman et al., 1978) and MIS (Eckblad & Chapman, 1983) were used for participant selection. The PAS and MIS are often used as measures for identifying positive schizotypy, and a robust empirical literature supports their construct validity as measures of schizotypy (see Lenzenweger, 2010 for overview). Thus, our positive schizotypy sample included individuals who report having unusual perceptual experiences as well as odd beliefs that would be considered invalid by conventional standards (Chapman et al., 1978; Eckblad & Chapman, 1983). This positive schizotypy classification is not to be confused with the clinical diagnosis of schizotypal personality disorder, which is a disorder primarily characterized by interpersonal deficits in addition to schizotypic cognitive and perceptual aberrations (APA, 2013). In our sample, the PAS and MIS were highly correlated ($r = .835$), and most participants were elevated on both measures. In our sample, the control group PAS and MIS means are as follows: PAS = 0.24 ± 0.44 and MIS = 0.83 ± 1.17. The schizotypy group PAS and MIS are as follows: PAS = 15.39 ± 5.95 and MIS = 17.06 ± 3.85. The JIF (Jackson, 1984) was used to assess invalid, dishonest, and/or random responding. All participants completed the following self-report measures: The Referential Thinking Scale, a measure of one's tendency to interpret neutral events as having special, self-relevant meaning (Lenzenweger et al., 1997), the Social Anhedonia Scale Brief, a measure of one's ability to experience pleasure from social interactions (Reise, Horan, & Blanchard, 2011), the Social Closeness Scale, a personality measure of one's sociability, affection/warmness, how much one values close relationships, and welcomes social support (Patrick, Curtin, & Tellegen, 2002); a revised version of the Social Adjustment Scale, a psychosocial functioning measure of work performance, social/leisure activities, family relations, romantic relations, and friend relations over the last 2 weeks (Weissman & Bothwell, 1976); the International Personality Disorder Examination Screen, a screening measure for personality disorders (IPDE-S; Loranger, 1999); and the Beck Depression Inventory, a measure of cognitive, affective, and physiological symptoms of depression (Beck, Steer, & Brown, 1996).

Table 1
Participant Characteristics

Characteristic	Schizotypy (n = 33) %	Control (n = 29) %	χ^2	p
Age			.703	.704
18–19	66.7	69.0		
20–24	30.3	24.1		
25–35	3.0	6.9		
Sex			.196	.658
Male	36.4	31.0		
Female	63.6	69.0		
Ethnicity			15.164	.004*
White/Caucasian	39.4	86.2		
African American	12.1	3.4		
Hispanic	6.1	.0		
Asian	30.3	10.3		
Other	12.1	.0		

Note. Despite an imbalance in ethnicity across the two participant groups, this difference was not significantly related to performance on the cone of gaze task. A one-way analysis of variance (ANOVA) with ethnicity as the between-subjects factor (five levels) and decentering direct head orientation cone width as the dependent variable revealed that the various ethnic groups did not differ significantly on the decentering cone variables, $F(4, 57) = 1.412$, $p = .242$, collapsed across the participant groups. Moreover, a between-subjects ANOVA revealed that there was not a significant Group × Ethnicity interaction on the decentering cone variable, $F(2, 54 = .782$, $p = .463$, whereas the group main effect remained consistent with our main analysis, $F(1, 54) = 2.905$, $p = .094$, and is significant at the one-tailed level as predicted ($p = .047$). We also conducted these analyses for the right and left head orientation and the results were largely the same.
* $p < .05$.

Laboratory Gaze Perception Measure

For this study, we developed a new laboratory task, the cone of gaze task, adapted from Gamer and Hecht (2007), and performance on this task served as our measure of gaze perception (see Figure 1). The CoG task was developed using sequential photographs of models moving their eyes right and left. The colored, full-face images were taken using the iPhone 5s burst mode as two models (one male and one female, both with light hair/light eyes) tracked a moving target 0° to 50° with their eyes. Photographs were taken across three different head orientations (direct 0°, averted 20° left, and averted 20° right). The models took approximately 5 s to track the target as it moved from 0° to 50°, and 10 photographs were taken every 1 s, which provided us with approximately one photograph per 1° increment. Thus, participants were able to use a joystick to move the model's eyes with approximately 1° increment.

The CoG paradigm comprises two adjustment tasks: decentering and centering of a model's eyes. During the decentering task, each participant observed a model looking directly at him or her (0°) and was instructed to move the model's eyes from center until the first point at which he or she was no longer looking at the participant. This decentering task assesses the width of each participant's gaze cone and served as our primary measure of gaze perception (see Figure 1). The *decentering gaze cone* is best understood as the "range of width wherein [a person] feels looked at" and is calculated by measuring the distance between the left and right angles selected during the decentering task (Gamer & Hecht, 2007, p. 706). During the centering task, each participant was presented with a model looking 50° to the right and 50° to the left and was instructed to move the model's eyes toward the center until the first point at which he or she was looking at the participant. According to Gamer and Hecht (2007), this centering task provides a measure of the central point of the gaze cone (see Figure 1). This variable is calculated by averaging the participant's selected gaze angles for the centering task, which is done separately for the direct, right, and left head orientations.

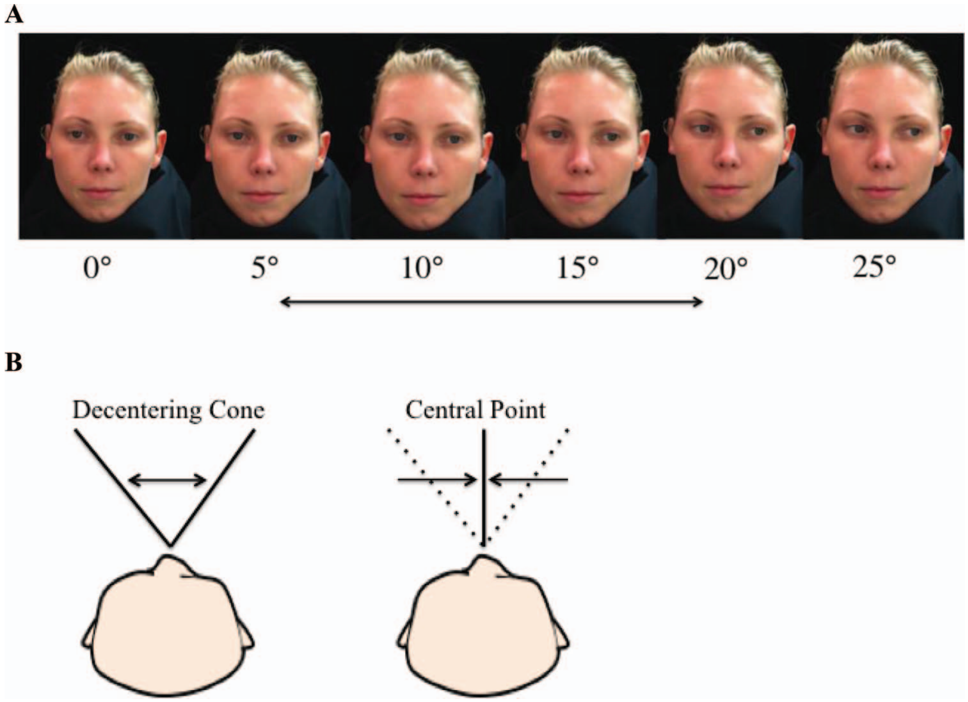

Figure 1. Cone of gaze (CoG) task during which participants used a joystick to move models' eyes right/left for a centering and decentering task. Panel A represents sample stimuli used in the task. Panel B represents the dependent variables collected from the task. See the online article for a color version of this figure.

During the task, participants had their head in a chin rest approximately 16 in. away from the computer screen. They were given both visual and verbal instructions and were encouraged to make their selection as soon as they noticed the "looking at me/not looking at me shift." If the participant stopped moving the joystick for 10 s, a computer voice prompted them to make their selection. If the participant stopped moving the joystick for 20 consecutive s, they were automatically directed to the next trial. Consistent with gaze perception studies in schizophrenia, we used RT as our measure of uncertainty (e.g., Franck et al., 2002; Hooker & Park, 2005). Each participant completed four practice trials prior to the start of each task. Each adjustment task consisted of 24 trials; there were two models, four conditions per model (direct head orientation with eyes moving right, direct head orientation with eyes moving left, right averted head orientation with eyes moving right, and left averted head orientation with eyes moving left), and each condition was presented three times. The centering and decentering tasks were counterbalanced, and each task was presented in one of three pseudorandom orders, resulting in a total of nine possible pseudorandom order combinations.

The three head orientations had discernibly different characteristics, not only in terms of the stimuli, but also in terms of possible cone width. For example, in the averted conditions, models were only able to move their eyes in the same direction as their averted head orientation, whereas models were able to move their eyes in both directions for the direct head orientation. Consequently, the maximum width of the direct head orientation decentering cone was 100°, whereas the maximum width for the averted conditions was 50°. Therefore, separate gaze cones and central points were calculated the direct, right, and left head orientations. The head presentations represent, in short, what can be thought of as three separate tests, one per head orientation.

Statistical Analysis

To test for group differences in gaze cone width, gaze cone central point, and RT, we used one-way multivariate analysis of variance (MANOVA; Harris, 1985; Morrison, 1990), followed by directional *t* tests for each of the three head orientations consistent with our a priori hypotheses. Directional *t* tests offer greater statistical power in the context of substantive directional hypotheses. The MANOVA approach provides a powerful omnibus test of the group effect across the three different head orientations, considered simultaneously. Moreover, we note that we used the one-way MANOVA approach as we found in preliminary analyses using a repeated measures analysis of variance approach that there were no significant interactions between the participant group and head orientation variables for the decentering cone width and central point performance indexes. Effect size estimates are Cohen's *d* and partial eta squared. The data were modestly nonnormal and normalizing transformations (log and square root) were used to reduce skewness that remained for some variables even after transformation. Pearson correlation coefficients were used to examine the relationship among gaze perception, referential thinking, and social cognition relevant constructs collapsed across both groups.

Results

Participant Characteristics

Table 1 summarizes the participant demographics. Sixty-two participants were included in the data analysis. There were 33 individuals in the positive schizotypy group (12 male and 21 female) and 29 individuals in the control group (9 male and 20 female). The two groups did not significantly differ on age, education, or sex. There was a significant group imbalance for ethnicity; however, the findings cannot be explained by participant ethnicity (see Table 1 note for details).

Decentering Task: Width of the Cone of Gaze

The gaze cone width was calculated by measuring the distance between the left and right angles selected during the decentering task (see Figure 1). Separate gaze cones for the direct, right, and left head orientations were calculated. The maximum width for the direct head orientation was twice the maximum width as averted conditions; therefore, we calculated proportion scores by dividing the direct cone by the maximum width of 100° and dividing the right and left cones by the maximum width of 50°.

For the decentering task, a one-way MANOVA was conducted to assess group differences on gaze cone width across all three head orientations. This analysis, by various criteria (i.e., Pillai, Hotelling, Roy, and Wilks), yielded a significant group effect, $F(1, 58) = 3.358$, $p = .025$, $\eta_p^2 = 0.148$, such that the positive schizotypy group had wider gaze cones (see Figure 2). Follow-up directional t tests reveal that the schizotypy group had wider gaze cones for the direct head orientation, $t(60) = -1.976$, $p = .027$ (one-tailed), $d = 0.50$. In the averted conditions, the schizotypy group had significantly wider gaze cones in the left orientation, $t(60) = -2.203$, $p = .016$ (one-tailed), $d = 0.56$, but not the right, $t(60) = -1.242$, $p = .11$ (one-tailed), $d = 0.32$. The two significant tests were associated with "medium" sized effects. These findings were not accounted for by participant ethnicity (see Table 1 note).

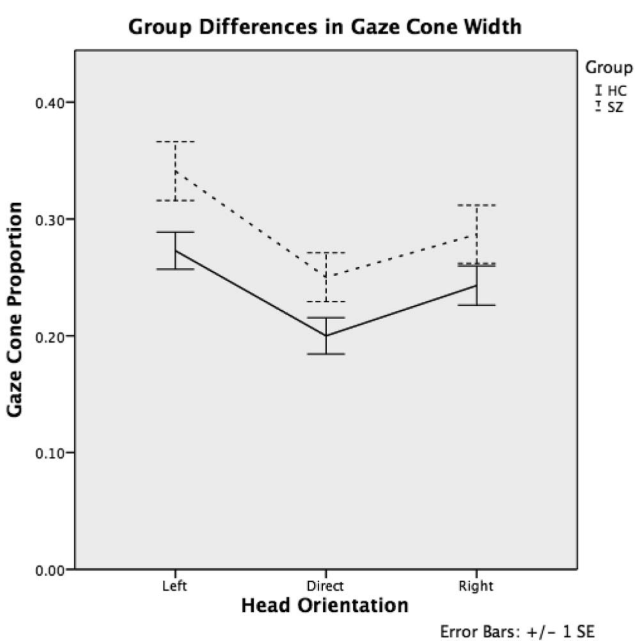

Figure 2. The positive schizotypy group had significantly wider gaze cones than controls. Group means and standard deviations are available on request. The gaze cone proportion scores represent original, untransformed values, and the statistical results refer to analysis of the transformed values. HC = control; SZ = schizotypy.

Centering Task: Central Point of the Gaze Cone

The gaze cone central point (see Figure 1) was calculated by averaging participant's selected gaze angles for the centering task; this was done separately for the direct, right averted, and left averted conditions.[1] For the centering task, a one-way multivariate analysis of variance (MANOVA) was conducted to assess group differences on central point across all three head orientations. This analysis, by various criteria (i.e., Pillai, Hotelling, Roy, and Wilks), yielded a nonsignificant group effect, $F(1, 58) = 1.330$, $p = .273$, $\eta_p^2 = 0.064$. In the absence of a significant omnibus test for the group effect, nonsignificant follow-up t tests are not reported (data available from the corresponding author).

RT

Mean RTs were calculated for the direct, right, and left head orientations for both the decentering and centering tasks. Separate multivariate one-way MANOVAs were conducted for each task. The decentering analysis, by various criteria (i.e., Pillai, Hotelling, Roy, and Wilks), yielded a significant group effect, $F(1, 58) = 3.044$, $p = .036$, $\eta_p^2 = 0.136$, such that the positive schizotypy group had greater RTs (see Figure 3). Follow-up directional t tests reveal that the schizotypy group had greater RTs for the direct head orientation, $t(54.517) = -1.852$, $p = .035$ (one-tailed), $d = 0.46$ (unequal variances, Levene's test used). In the averted conditions, the schizotypy group's RT did not significantly differ from controls: left head orientation, $t(60) = -1.069$, $p = .145$ (one-tailed), $d = 0.27$, and right orientation, $t(60) = -0.502$, $p = .31$ (one-tailed), $d = 0.13$. The centering task RT analysis, by various criteria (i.e., Pillai, Hotelling, Roy, and Wilks), yielded a nonsignificant group effect, $F(1, 58) = 0.916$, $p = .439$, $\eta_p^2 = 0.045$. In the absence of a significant omnibus test for the group effect here, nonsignificant follow-up t tests are not reported (available on request from the corresponding author).

Correlations Between Individual Difference Measures and the CoG Task

Correlations between gaze perception variables and clinical variables for the entire sample are summarized in Table 2. In general, wider gaze cones were not significantly associated with social anhedonia, affiliation, paranoid personality traits, or depression. However, as predicted a priori, wider gaze cones were

[1] To be consistent with previous studies (e.g., Gamer & Hecht, 2007), analyses were conducted using the central point. One could also construct a cone for this purpose and we did so as well. The results using the cone dependent variable were highly similar to those obtained with the central point. Details on this data approach and statistical results are available from the corresponding author.

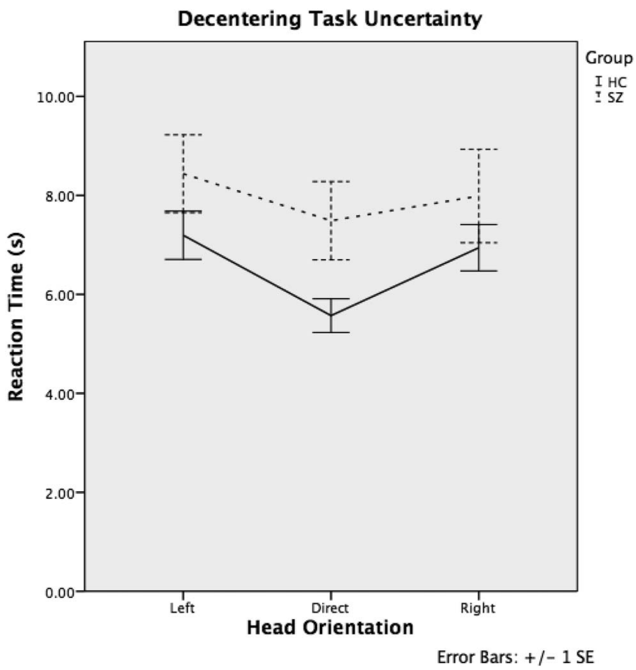

Figure 3. Schizotypic individuals had significantly greater RTs than controls during the decentering gaze task. Group means and standard deviations are available upon request. The means represent original, untransformed values, and the statistical results refer to analysis of the transformed values. HC = control; SZ = schizotypy.

significantly associated with higher levels of schizotypic referential thinking (see Figure 4). Furthermore, wider gaze cones were significantly associated with poorer social functioning (see Figure 5).

Discussion

This study was the first to examine the self-referential nature of gaze perception in positive schizotypy using a newly developed

Table 2
Pearson Correlations Between Individual Difference Measures and Cone of Gaze Laboratory Task

Variable	1	2	3	4	5	6
1. Cone	—					
2. REF	.416**	—				
3. SASSR	−.258*	−.487**	—			
4. PAR	.049	.391**	−.337**	—		
5. SAS	.105	.543**	−.577**	.501**	—	
6. SCS	−.071	−.326**	.493**	−.316*	−.763**	—
7. BDI-II	.181	.569**	−.851**	.413**	.698**	−.497**

Note. Correlations were computed using nontransformed data. Cone = direct head orientation decentering cone; REF = Referential Thinking Scale; SASSR = Social Adjustment Scale-Self Report; PAR = Paranoid Personality Disorder Scale; SAS = Social Anhedonia Scale (Brief Version); SCS = Social Closeness Scale – Multidimensional Personality Questionnaire; BDI-II = Beck Depression Inventory-II. Correlations were also conducted with the averted head orientations, and the results were largely the same. To be conservative and to take into account distributional properties of the variables, we also evaluated these associations using the nonparametric Spearman rho, and the results were largely the same.
* $p < .05$. ** $p < .01$.

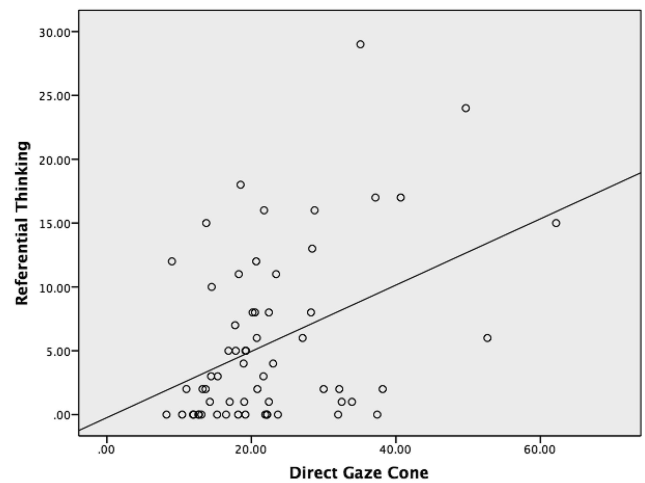

Figure 4. Relationship between the direct gaze cone and referential thinking. Individuals that experience neutral events as having special self-relevant meaning tend to perceive direct gaze across a wider range of angles than those who score low on referential thinking.

gaze measure. The results were consistent with our hypothesis that the schizotypy group would report feeling as though they are being looked at across a wider range of angles than controls. As we found this gaze bias in schizotypic individuals, who do not suffer from the impact of disease chronicity and/or institutionalization, this bias may represent an uncontaminated connection to likely schizophrenia liability. This finding provides additional support to prior results from patient samples that found that antipsychotic medication was not significantly associated with gaze perception in schizophrenia (Hooker & Park, 2005; Tso et al., 2014). Moreover, wider gaze cones in our nonpsychotic schizotypic participants provide further evidence that social cognition deficits may

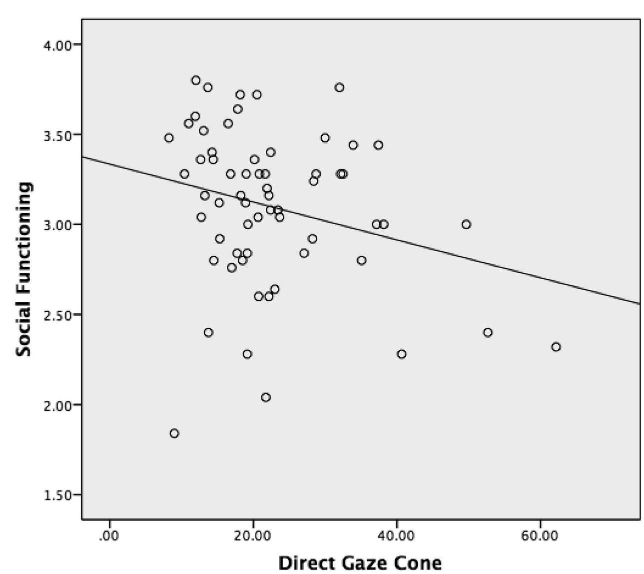

Figure 5. Relationship between the direct gaze cone and social functioning. Individuals that perceive direct gaze across a wider range of angles had poorer psychosocial functioning than those with smaller gaze cones.

have utility as an endophenotype for schizophrenia (e.g., Lavoie et al., 2013; Miller & Lenzenweger, 2012).

Our finding that the schizotypy group differed from controls in their gaze cone width, but not their central point, suggests that group differences emerge primarily in ambiguous gaze circumstances. One would expect the central point of the gaze cone to be at or around 0°, which would be considered overtly direct gaze, whereas the decentering gaze cone width represents more ambiguous gaze angles. Thus, our finding that groups differ in the decentering cone width, but not the central point (when direct gaze is overt) is consistent with previous findings that patients and controls differ when presented with ambiguous angles, but not when gaze is overtly direct (0°) or averted (50°; Franck et al., 2002; Hooker & Park, 2005; Tso et al., 2012; Tso et al., 2014). Furthermore, the finding that the schizotypy group had greater RTs during the decentering task suggests that schizotypic individuals experience greater uncertainty during gaze perception. These findings are consistent with the literature on gaze perception in schizophrenia, which finds that patients experience greater uncertainty than controls when differentiating direct and indirect gaze (Franck et al., 2002; Hooker & Park, 2005; Tso et al., 2012; Tso et al., 2014). Follow-up analyses revealed that schizotypic individuals had greater RTs than controls for the direct, but not the averted head orientations. In the direct head orientation, the RTs for the schizotypy group were markedly variable in comparison to controls. Although the schizotypy group remained variable in the averted conditions, the controls became more variable, which likely impacted our ability to detect significant group differences in RT for the averted conditions (see Figure 3). Future research is needed to determine whether schizotypic individuals experience more uncertainty than controls when differentiating direct from indirect gaze.

As predicted, our results indicated that wider gaze cones were associated with greater levels of schizotypic referential thinking (Lenzenweger et al., 1997). This finding suggests that those who have a proclivity to interpret environmental factors as having self-relevant meaning are more likely to interpret others' gaze as being directed toward them. Although previous studies have speculated that the gaze bias in schizophrenia is self-referential rather than a mere directional deficit, the current study is the first study to quantify the relationship between referential thinking gaze perception. Thus, lending additional support for the self-referential gaze bias explanation for inconsistent findings in the schizophrenia literature (e.g., Franck et al., 2002; Hooker & Park, 2005). Additionally, the current study found that wider gaze cones were associated with poorer psychosocial functioning. This is consistent with the finding that the schizophrenia gaze bias is associated with poorer emotion related social–cognitive skills (Tso et al., 2012). The relationship between gaze perception and poorer social functioning is noteworthy because successful social interactions rely on one's ability to accurately interpret both verbal and nonverbal social cues. Thus, if patients and schizotypic persons are unable to accurately perceive others' gaze, they may respond inappropriately to others' social cues, may receive negative feedback from others, and may consequently have poorer overall social functioning. This is consistent with broader findings that poor social perception in schizophrenia is related to poorer social problem solving, social behavior in the milieu, and community functioning (Couture et al., 2006; Kim et al., 2005; Penn et al., 1996; Revheim & Medalia, 2004; Sergi et al., 2006). Although, having a wider gaze cone was related to poorer social functioning, it was not related to measures of sociability or social anhedonia. Although Tso et al. (2012) found that the gaze bias in schizophrenia was associated with negative symptoms in general, they did not find a significant relationship for the anhedonia subscale; thus, our findings are consistent with that study. One potential explanation for this particular finding is that schizotypic individuals might want to engage in social interactions and experience pleasure when they do so, but perhaps experience more difficulty socializing due to inaccurate perception of others' gaze. Finally, we found that gaze perception is *not* associated with paranoia personality traits as measured by the IPDE-S. This finding is consistent with the schizophrenia literature, which found that gaze perception is not related to paranoid delusions or positive symptoms more broadly (Tso et al., 2012). It has been suggested that this finding may be the result of participants responding intellectually rather than emotionally to the computer task; thus future studies should seek to use gaze measures with improved ecological validity (Tso et al., 2012).

Several caveats should be kept in mind when considering our results. First, the current study was limited by a smaller sample size as compared to large-scale questionnaire investigations. Second, we drew our sample from a large population of nonpsychotic undergraduate participants who were self-selected (though clearly not a methodological feature unique to this study). Although our screening measures have a robust empirical literature in support of their construct validity (see Lenzenweger, 2010 for overview), neither measure is used in clinical practice nor is there a set cut-off score for interpretation. In the current study, we used the field standard advocated by the Chapmans for schizotypy participant selection (two standard deviations above the group mean), which is a conservative cut-off designed to help ensure true positive selection (even at the expense of false negatives) in laboratory studies. As with all psychometric measures, however, the PAS and MIS are fallible. Thus, we cannot know for certain if all of our putative schizotypy positive participants are "true" or "genuine" schizotypes; that is, they unambiguously carry a liability for schizophrenia (see Lenzenweger, Jensen, & Rubin, 2003 for extended discussion). At present, there is no accepted schizophrenia liability criterion that we could assess within these participants to determine if they are bona fide or genuine schizotypes. Therefore, it would be useful to replicate this study using another group of schizotypic participants selected from another population (e.g., community-based sample of schizotypes, a clinical sample of schizotypal personality disorder patients, and/or first-degree biological relatives of schizophrenia patients). Third, although our selection strategy was not a traditional extreme groups approach, and controls were randomly selected from a wide swath of the PAS/MIS distribution space, the potential normal participant pool was positively skewed such that most screened participants had low values. Therefore, the control group had quite low scores on the PAS and MIS, making it possible that our effect-size estimates may have been impacted by our selection approach (Preacher, Rucker, MacCallum, & Nicewander, 2005). Thus, replication in another sample that includes participants with a wider range of PAS/MIS scores would be helpful in determining gaze perception's potential to serve as an endophenotype.

Fourth, we note that we did not include a third participant group for additional between-subjects comparisons. The inclusion of a psychiatric comparison group equivalent would provide information about the specificity of gaze biases in schizophrenia and schizotypy. Finally, the current study used a time constraint, which may have impacted participants' RTs. Although the purpose of this time constraint was to increase ecological validity by imitating social interactions where people are required to make snap judgments about gaze, it is possible that the time constraint increased psychological distress among schizotypy participants, impacting our findings. Therefore, it is possible that a similar gaze task without a time constraint would yield different results.

In summary, we found that positive schizotypic individuals endorse direct gaze across a wider range of angles than do controls and that this gaze-perception bias is associated with increased referential thinking and poorer social functioning. These findings provide further evidence that the gaze bias in schizophrenia likely represents a true manifestation of the disease and that social cognition has the potential to serve as an endophenotype for schizophrenia liability.

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