Journal of Abnormal Psychology
2016, Vol. 125, No. 7, 894–906

0021-843X/16/$12.00 http://dx.doi.org/10.1037/abn0000198

Attentional Processing of Emotional Faces in Schizophrenia: Evidence From Eye Tracking

Seon-Kyeong Jang, Sujin Kim, Chai-Youn Kim, Hyeon-Seung Lee, and Kee-Hong Choi
Korea University

Severe emotional disturbances such as anxiety and depression have been closely related to aberrant attentional processing of emotional stimuli. However, this has been little studied in schizophrenia, which is also characterized by marked emotional impairments such as heightened negative affect and anhedonia. In the current study, we investigated temporal dynamics of motivated attention to emotional stimuli in schizophrenia. For this purpose, we tracked eye movements of 22 individuals with schizophrenia or schizoaffective disorder (ISZs) and 19 healthy controls (HCs) to emotional (i.e., happy, sad, angry) and neutral face pairs presented either for 500 ms or 1,500 ms. Initial fixation direction and viewing time at 3 successive intervals (0–500, 500–1,000, 1,000–1,500 ms) were calculated. The results showed that both ISZs and HCs were more likely to orient initial fixations and exhibited longer viewing times to emotional than neutral faces. However, compared with HCs, ISZs allocated less attention to overall faces during the late stage (1,000–1,500 ms) when one of the paired faces displayed negative emotions. Furthermore, positive symptoms were highly associated with initial fixation avoidance to angry faces while depressive symptoms were related to later avoidance of angry faces. Both social amotivation and poor interpersonal functioning were closely related to diminished sustained attention to happy faces. This suggests that early attentional capture of emotional salience may be relatively preserved in schizophrenia, but the people with this disorder display an atypical late attentional process characterized by generalized attentional avoidance of negative stimuli. Of note, aberrant attentional processes of social threat and reward were closely associated with major symptoms and functioning in this disorder.

General Scientific Summary
People with schizophrenia showed relatively intact early attentional capture by emotional salience but exhibited an atypical late attentional process characterized by generalized attentional avoidance of negative stimuli. Aberrant attentional processes of social threat and reward were closely associated with major symptoms and functioning in this disorder.

Keywords: attention bias, eye tracking, schizophrenia symptoms, depression, motivated attention

Supplemental materials: http://dx.doi.org/10.1037/abn0000198.supp

Social–cognitive impairments are hallmarks of schizophrenia and closely linked to functional outcomes of afflicted individuals. They are often considered endophenotypic markers observed in the early prodromal phase of the illness, as well as in the schizophrenic's unaffected family members (Bora & Pantelis, 2013; Couture, Penn, & Roberts, 2006). Emotion processing is one of the most frequently studied areas of social cognition in schizophrenia research; individuals with schizophrenia (ISZs) exhibit difficulty identifying and discriminating emotions, elevated negative emotionality, and altered neural responses to emotional stimuli (Cohen, Najolia, Brown, & Minor, 2011; Dowd & Barch, 2010; Penn, Sanna, & Roberts, 2008). Although abundant research on emotion in schizophrenia has been conducted over decades, few studies have explicitly focused on attentional processing of emotional stimuli in this mental condition.

Investigating attentional processing of emotion has a large potential to provide insight on emotional functioning and affective processes related to schizophrenia. Attentional prioritization of motivationally significant stimuli, a process often called "motivated attention," is a cardinal feature of the human attention system; it is assumed to adaptively function to ensure that organisms allocate limited resources to significant stimuli in the environment and thus facilitate survival (Lang & Bradley, 2010).

This article was published Online First August 15, 2016.

Seon-Kyeong Jang, Sujin Kim, Chai-Youn Kim, Hyeon-Seung Lee, and Kee-Hong Choi, Department of Psychology, Korea University.

This work was supported by the National Research Foundation of Korea (NRF). Grant funded by the Korean Government (MSIP; NRF-2015R1A5A7037674), awarded to Platinum Aging Research Center, and a grant of the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health & Welfare, Republic of Korea (HM15C1121), awarded to Kee-Hong Choi.

We thank Kyoung-Eun Lee, Chae-Eun Lim, Yun-ji Cha, and Eun-Jin Lee for their assistance in data collection.

Correspondence concerning this article should be addressed to Kee-Hong Choi, Department of Psychology, Korea University, Liberal Arts Building 122, Sungbuk-Ku, Anam-Dong, Seoul 136-701, South Korea. E-mail: keehongchoi@gmail.com

Studies have found that people allocate more attention to emotional stimuli, such as threat and reward-related events, than neutral stimuli. This has been verified by many studies investigating hemodynamic and electrical brain activity, as well as gaze behaviors to emotional stimuli (M. M. Bradley et al., 2003; Calvo & Lang, 2004; Hajcak, Dunning, & Foti, 2009). Examining this basic ability to modulate attention by emotional stimuli would be informative to determine the nature and degree of emotional impairment in schizophrenia.

Although few, recent studies have suggested that ISZs may have intact motivated attention. For example, it was demonstrated that both ISZ and healthy groups exhibited larger late, positive potentials to task-irrelevant emotional stimuli than neutral counterparts in the target-detection task (Horan, Foti, Hajcak, Wynn, & Green, 2012), a putative evoked response-potential (ERP) index of motivated attention. Intact emotional modulation of ERP components was also observed when patients passively viewed affective pictures (Horan, Wynn, Kring, Simons, & Green, 2010). However, a functional magnetic resonance-imaging (fMRI) study found that compared with healthy individuals, ISZs showed diminished ventral limbic activation and dorsal frontal deactivation to task-irrelevant unpleasant stimuli, as well as recued limbic deactivation and dorsal frontal activation to neutral target stimuli during the target-detection task (Dichter, Bellion, Casp, & Belger, 2010). This result indicates aberrant attentional processes of emotional stimuli in ISZs, which is at odds with studies mentioned earlier.

The discrepancy is likely to partly reflect the use of different methods, that is, weakness in spatial and temporal resolution of ERP and fMRI, respectively; this discrepancy requires exploiting diverse measures, including eye tracking to study motivated attention in schizophrenia. It also suggests that emotional attention in this disorder is multifaceted. One possibility is that attention deployment to emotional stimuli dynamically changes with ongoing stimuli processing in schizophrenia. Consistent with this idea, attentional processing of emotional stimuli changes from early vigilance to late avoidance of threatening stimuli in anxiety disorders (Mogg, Bradley, De Bono, & Painter, 1997). Whereas aberrant attention in the early period of emotional stimuli processing has been related to problems associated with initial orienting and early appraisals of stimuli, that in the late stages has been related to strategic control of attention or atypical stimuli elaboration processes (Sagliano, Trojano, Amoriello, Migliozzi, & D'Olimpio, 2014). To date, temporal dynamics of attention to emotional stimuli, especially in the late stage, has not been systematically examined in schizophrenia and its related disorders.

Another area of investigation that may reveal cognitive and affective bases of schizophrenia is attentional deployment to specific types of emotional stimuli, such as reward and threat. In the literature, attentional biases to specific emotional stimuli and psychopathology have correlated. For example, anxious individuals have been found to exhibit vigilant attention to threat (Fani et al., 2012; Mogg, Philippot, & Bradley, 2004); depressed individuals exhibit sustained attention to dysphoric stimuli and diminished attentional maintenance to positive stimuli (Duque & Vázquez, 2015). Attentional biases are also implicated in vulnerability for various psychiatric disorders; either preconscious or conscious levels of attentional bias to negative stimuli (Fox, Cahill, & Zougkou, 2010; Pilgrim, Marin, & Lupien, 2010) predicted reactivity of the hypothalamic–pituitary–adrenal (HPA) axis system, which has been assumed to play important roles in the development and recurrence of psychosis, as well (Walker & Diforio, 1997). Therefore, whether ISZs exhibit a biased pattern of attention to specific types of emotional stimuli and, if so, when this bias emerges, are important questions.

Furthermore, previous studies have indicated that attentional processing of reward and threat will be especially relevant to understanding mechanisms underlying diverse symptoms of schizophrenia. To date, several affective biases have been identified to be related to positive and negative symptoms. For example, positive symptoms, such as persecutory delusions, have been linked with increased attention allocation to threat-related stimuli in studies using emotional Stroop tasks (Bentall & Kaney, 1989; Besnier et al., 2011). In another study using eye tracking, ISZs with delusions avoided rather than directed their attention to feature areas of fearful faces singly presented for 10 s (M. J. Green, Williams, & Davidson, 2003). Combining these results, it has been suggested that ISZs with delusions would exhibit "vigilance–avoidance" patterns of attention to threat (i.e., excessive threat scanning in the early period followed by active avoidance during later controlled processing stages) often observed in persons with anxiety disorders (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van IJzendoorn, 2007; M. J. Green & Phillips, 2004). Aberrant attentional processing of threatening information (hypervigilance) and safety behaviors have also been implicated in some forms of hallucinations (Coy & Hutton, 2013; Dudley et al., 2014). To date, the relationship between the vigilance–avoidance pattern of attention and positive symptoms has not been tested with a paradigm designed to elicit selective attention and evaluate continuous attention deployment. Last, diminished attention allocation to rewarding stimuli such as happy facial expressions may underlie anhedonia and apathy (Frewen, Dozois, Joanisse, & Neufeld, 2008). However, this association remains unexamined regarding negative symptoms of schizophrenia.

With these findings in mind, for the current study we investigated whether ISZs would exhibit early attentional capture by emotional salience indexed by direction of initial fixation and viewing time during the first 500 ms. We also examined continuous attentional engagement by dividing viewing time of 1,500 ms trials into three successive time intervals (0–500 ms, 500–1,000 ms, and 1,000–1,500 ms). Last, we investigated attentional biases to threat and reward with regard to positive, negative, and depressive symptoms and functioning of the ISZ group. By employing an eye-tracking method, we employed direct and online measures of overt attention, which are less likely to confound with verbal and motor processes in traditional reaction-time (RT)-based measures (Price et al., 2015). Building on earlier studies, we hypothesized that ISZs would show intact early attentional capture by emotional salience, similar to HCs. It was expected that positive symptoms would be related to vigilance–avoidance patterns to angry faces, whereas negative symptoms would be related to diminished attention to happy faces. Attentional bias related to depressive symptoms was explored, in addition.

Method

Participants

Twenty-three outpatients diagnosed with schizophrenia (n = 19) or schizoaffective disorder (n = 4) according to the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.;

DSM–IV–TR; APA, 2000), *DSM–IV–TR* and 19 age- and gender-matched healthy individuals between the ages of 19 and 55 years were initially recruited from community mental rehabilitation centers and online advertisements, respectively. Healthy individuals were required to have no current and past psychiatric diagnosis and both groups were required to have no history of substance abuse, neurological disease, or developmental/intellectual disorders. Psychiatric status of both groups was confirmed by the Mini International Neuropsychiatric Interview–Plus (Sheehan et al., 1998). Data from 22 ISZs and 19 HCs (21 ISZs and 18 HCs for the initial fixation analysis) were included in the final analysis (see the Eye-Tracking Data Analyses section for details). The two groups did not differ in age, gender composition, state or trait anxiety, or parental education but did differ in education level (see Table 1). All participants gave informed consent to participate in the study. The current study was approved by the local institutional review board of Korea University.

Measures

Positive and Negative Syndrome Scale (PANSS). The PANSS is a semistructured interview for measuring severity of various psychiatric symptoms, including positive, negative, and depressive symptoms (Kay, Fiszbein, & Opfer, 1987). Instead of the original scale, we used the PANSS five-factor model which was reliable, valid, and widely adopted in many studies (Wallwork, Fortgang, Hashimoto, Weinberger, & Dickinson, 2012). Three trained master-level interviewers whose interrater reliability was established (α = .91) evaluated the clinical symptoms of patients using a structured interview in the current study.

State–Trait Anxiety Inventory(STAI). The STAI (Spielberger, 2010) is a self-report measure of state and trait anxiety, that is, of currently experienced anxiety and anxiety level as a personal characteristic, respectively. It consists of 40 questions with a 4-point Likert scale; higher scores indicate higher anxiety. The STAI was used in this study to investigate potential group differences on anxiety levels that have been shown to relate to attentional bias toward threatening information (Mogg et al., 1997).

Beck Depression Inventory–II (BDI-II). The BDI-II (Beck, Steer, & Brown, 1996) is a widely used self-report inventory to measure the existence and severity of depression. It consists of 21 multiple-choice questions assessing cognitive, affective, motivational, and physiological symptoms of depression. Past studies indicated good psychometric properties of this scale including the Korean version. Depression has been related to biased attention to emotional stimuli and the BDI-II was included in the present study to ensure low levels of depression in healthy participants.

Quality of Life Scale (QLS). QLS is a semistructured interview for assessing ISZs' psychosocial functioning (Heinrichs, Hanlon, & Carpenter, 1984). It comprises 21 items with a 7-point Likert scale (0–6); higher scores indicate greater functioning. QLS assesses quality of interpersonal relationships, role functioning, intrapsychic foundation, and common objects and activities. The internal consistency of the Korean version of the QLS was α = .80 in the current study.

Task Stimuli and Paradigm

A visual dot-probe task similar to Gotlib et al. (2004) except for the orientation (top/down vs. left/right), durations (500, 1,500 ms vs. 1,000 ms), and the addition of 18 inverted facial cue trials was completed (see Figure 1). Faces were selected from the Korea University Facial Expression Collection (Lee, Lee, Lee, Choi, & Kim, 2006), a validated Korean population facial expression set. Both short (500 ms) and long (1,500 ms) duration of stimuli were included, as different durations may invoke distinct attentional processing patterns; the former is more likely to reflect early attentional allocation and the latter is sensitive to sustained attention (Mogg et al., 1997). Participants sitting approximately 56 cm from a monitor were initially required to look at the fixation cross for 500 ms; the cross disappeared at the onset of an emotional–neutral face pair (presented vertically—top and bottom—on the

Table 1
Demographic and Clinical Information

Variable	ISZs (n = 22)	HCs (n = 19)	Test statistics	p
Age	41.91 (8.09)	41.74 (8.03)	$t(39) = .07$	.95
Gender (male %)	63.60%	50%	$\chi^2 = .75$	.39
Years of education	12.86 (1.81)	14.63 (1.64)	$t(39) = -3.26$	.002
Parental education	10.32 (5.82)	12.21 (3.81)	$t(36.52) = -1.25$	.220
STAI-State	45.82 (11.31)	40.53 (8.34)	$t(39) = 1.68$	.101
STAI-Trait	51.50 (3.31)	50.42 (2.61)	$t(39) = 1.15$	.259
BDI-II	—	8.16 (6.53)	—	—
Age of onset	25.86 (6.42)	—	—	—
Duration of illness	16.05 (9.26)	—	—	—
Antipsychotic dosage (CPZ)[a]	473.53 (280.28)	—	—	—
PANSS				
Positive	2.67 (.95)	—	—	—
Negative	2.33 (.93)	—	—	—
Disorganized	1.92 (.73)	—	—	—
Excited	1.46 (.45)			
Depressed	2.20 (.85)	—	—	—
Total	61.55 (11.07)	—	—	—

Note. ISZ = individual with schizophrenia; HC = healthy control; STAI = State-Trait Anxiety Inventory; BDI-II = Beck Depression Inventory–II; PANSS = Positive and Negative Syndrome Scale.
[a] CPZ = chlorpromazine equivalent dose; 19 ISZs reported antipsychotic dosages.

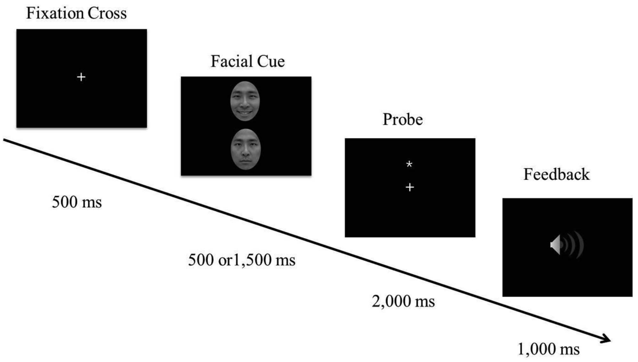

Figure 1. A trial sequence of the visual dot-probe task. A pair of emotional and neutral faces was presented randomly either for 500 ms or 1,500 ms after the fixation cross. A small asterisk replaced one face either on the top or bottom of the screen. Right after the participants' response or after 2 s if no response was made, a feedback page was presented for 1 s. On this page, participants were given auditory feedback when they made a wrong or no response.

screen), immediately followed by a probe (a small asterisk). During the facial image presentation, participants were free to visually explore the screen. Emotion type (happy, sad, angry), location (top, bottom), and presentation duration (500 ms, 1,500 ms) of emotional faces were counterbalanced within each block. Participants responded to the probe location as quickly as possible: "q" for the top or "p" for the bottom. They were not to press any key if the probe was preceded by a pair of two inverted neutral faces. This trial was included to maintain minimal task attention and thus incorporate facial processing of participants (Pollak & Tolley-Schell, 2003). If participants made a wrong response, a "beep" sounded for 150 ms as auditory feedback. Eye movements were recorded for each trial.

Stimuli were 48 gray-scaled, luminance- and arousal-matched, 8 × 9 cm (11.00° and 12.32° of visual angle, respectively) images consisting of happy, angry, and sad faces (16 faces for each emotion), and neutral faces from the same model of paired emotional faces. Two images of each face pair were located 1 cm (1.38°) apart from each other. These faces (from the Korea University Facial Expression Collection) were reviewed by experts trained in the Ekman Facial Emotion Scoring Technique (Ekman & Friesen, 2003). Hairs, scars, and blemishes were removed using Photoshop CS5. Half of the images were from female models.

Two blocks of 105 trials (a total of 210 trials), with 64 trials for each type of emotional–neutral face pair were performed. Eighteen trials with inverted facial cues were randomly presented for the abovementioned reason. Before the main trials, participants completed two blocks of practice trials: 60 trials of a simple probe-detection task and 60 trials of a dot-probe task with neutral–neutral facial cues different from those used in the main trials.

Procedure

First, diagnostic, demographic, and clinical evaluations were conducted. Then participants moved to the room designed for the eye-tracking study and sat in front of the computers with their heads placed on chin rests. Immediately before the start of the task, they rated state and trait anxiety levels and completed the calibration procedure. A 3-min break was given after the end of the first block and a calibration was conducted again before the start of the second block. At the end of the task, facial images of the task were presented and participants answered the question, "How positive/negative/aroused are you feeling toward this image?" by pressing the buttons corresponding to their feelings (1 = *not at all* to 6 = *very much*). To save time, half of emotional face images were presented for this rating.

Manual RT Data Analyses

The RT-based attentional bias score was calculated with a standard formula to provide additional information on attentional processing of emotional stimuli in the ISZ sample (MacLeod, Mathews, & Tata, 1986): Mean RT to the probe occurring at the location of the emotional face was subtracted from that to the probe occurring at the location of the neutral face. Positive scores indicate a faster response to emotional faces and attentional bias toward them, whereas negative scores reflect a slower response and attentional bias away from them (Mogg et al., 2004). As with previous studies (Price et al., 2015), bias scores were calculated after discarding trials with errors and rescaling outliers (Winsorizing), which were defined as RT values outside 1.5 interquartile ranges from the Tukey hinges (Erceg-Hurn & Mirosevich, 2008). The mean percentage of discarded trials due to errors was 3.13% and 0.55% for ISZ and HC groups, respectively, with significant group differences observed, $t(22.76) = -2.82$, $p = .01$, $d = -0.88$. The mean number of rescaled outliers was 7.55 and 7.05 for ISZ and HC groups, respectively, with no significant group differences observed ($p > .05$, $d = 0.15$).

Eye-Tracking Data Analyses

The observer's left eye movement was recorded using an Eyelink 1000 (SR Research, Mississauga, ON, Canada). Controlled by the Eyelink toolbox for MATLAB (Cornelissen, Peters, & Palmer, 2002), eye-movement data were sampled at a rate of 1,000 Hz and pupil dilation was tracked using ellipse fitting. The eye tracker was calibrated with the conventional 5-point procedure. Saccades and fixations were marked with software saccade sensitivity set to the normal mode, suitable for cognitive tasks (velocity threshold 30 deg/s, acceleration threshold 8,000 deg/s, and displacement thresholds 0.1°; (Meijering, Van Rijn, Taatgen, & Verbrugge, 2012). Eye fixations were analyzed offline using MATLAB R2011a.

Initial fixations on facial displays of 500 ms and 1,500 ms were collected to index initial orientation to emotional faces. Those not fixated on the central cross just before the saccadic movement to the faces and occurring within 100 ms after the face onset were removed, as they are not considered gaze responses to facial presentation (B. P. Bradley, Mogg, & Millar, 2000). Three observers (2 ISZs, 1 HC), and were excluded from this analysis due to excessive data loss after applying these criteria (remaining trials fewer than 15% of total trials; (Mogg, Bradley, Field, & De Houwer, 2003). Initial fixation was considered "on the emotional face" when its *x,y* coordinates were within the boundary of an emotional face picture.

Viewing time was calculated for facial presentations of 1,500 ms, divided into three successive time intervals (0–500, 500–1,000, 1,000–1,500 ms), consistent with previous eye-tracking studies (Calvo & Lang, 2004; Nummenmaa, Hyönä, & Calvo, 2006). The viewing time during the first 500 ms was assumed to reflect early attentional engagement along with the initial fixation placement, whereas subsequent intervals measured relatively late engagement. Viewing time was calculated by summing the duration of fixations classified into one of three intervals, depending on their onset time (Wieser, Pauli, Weyers, Alpers, & Mühlberger, 2009). The data of one ISZ were discarded in the viewing-time analysis owing to the extremely low number of fixations ($n = 17$), resulting in the data of 22 ISZs and 19 HCs being included in this analysis.

Results

Valence and Arousal Ratings

Mixed repeated-measures analyses of variance (RM-ANOVAs) with emotion type (happy, sad, angry) as a within-subject variable and group (ISZ, HC) as a between-subjects variable were conducted separately on positive and negative valences and arousal ratings. For positive valence, a significant main effect of emotion type, $F(2, 38) = 50.68$, $p < .001$, $\eta_p^2 = .73$, indicated that participants reported higher positive feelings to happy faces than sad or angry faces. There was also a significant interaction between emotion type and group, $F(2, 38) = 9.94$, $p < .001$, $\eta_p^2 = .34$. ISZs reported relatively less positive feelings toward happy faces ($p = .001$, $d = -1.11$) and more positive feelings toward angry faces ($p < .05$, $d = 0.74$) than HCs. For negative valence, a significant main effect of emotion type, $F(2, 78) = 35.31$, $p < .001$, $\eta_p^2 = .48$, indicated that participants reported less negative feelings toward happy faces than sad and angry faces. Additionally, a significant between-groups effect, $F(1, 39) = 4.24$, $p < .05$, $\eta_p^2 = .10$, indicated that ISZs reported higher negative feelings toward overall emotional faces than HCs ($p < .05$, $d = 0.65$). For arousal, there was a significant interaction of emotion type and group, $F(2, 78) = 4.74$, $p < .05$, $\eta_p^2 = .11$. ISZs reported higher arousal toward happy faces than HCs ($p < .05$, $d = 0.72$; see online supplemental material 1).

Manual RT Data

The two groups significantly differed in terms of RT, $t(28.16) = 2.41$, $p < .05$, $d = 0.75$, and accuracy, $t(22.76) = -2.82$, $p = .01$, $d = -0.88$. The ISZ group was slower (688.91 ms vs. 587.63 ms) and less accurate (97.25% vs. 99.45%) than the HC group.

An RM-ANOVA of attentional bias scores was conducted with emotion type (happy, sad, angry) and duration (500 ms, 1,500 ms) as within-subjects variables and group (ISZ, HC) as the between-subjects variable. A significant interaction between time and group, $F(1, 39) = 4.24$, $p < .05$, $\eta_p^2 = 0.10$, was found. A follow-up t test indicated that HCs exhibited higher positive bias scores toward emotional faces (happy, sad, and angry faces aggregated) presented for 1,500 ms compared with ISZs, $t(39) = 2.52$, $p < .05$, $d = 0.79$. These bias scores were tested against an absolute value of zero in each group to infer the direction of the bias other than relative group differences (B. P. Bradley, Mogg, Falla, & Hamilton, 1998). It was found that the bias score was significantly different from zero in the HC group, $t(18) = 2.17$, $p < .05$, $d = 0.50$, but not in the ISZ group, $t(21) = -1.44$, $p > .05$, $d = -0.31$, indicating that the HC group allocated more attentional resources to emotional than neutral faces when they were presented for 1,500 ms, which was not the case in the ISZ group. There were no other main effects or interactions (see Table 2). Regarding relationships with symptoms and functioning. No RT-based attention indices were significantly correlated with PANSS symptoms or QLS functioning (all ps $> .05$).

Eye-Tracking Data

Overall number of fixations. Before progressing to main analyses of initial fixation and viewing time, we confirmed whether the two groups exhibited comparable numbers of fixations so that subsequent analyses were based on reasonable and comparable amounts of fixation data. No group differences were observed in the number of trials where initial fixations met the inclusion criteria ($p > .05$). Specifically, they were collected in more than 50% of the entire trial for both groups ($M = 62.25\%$, $SD = 22.82$; range = 23.33–98.20). With regard to total fixation numbers on facial pairs, the two groups were comparable during all three intervals of the 1,500 ms facial presentation ($p > .05$; see online supplemental material 2).

Initial orienting. A mixed RM-ANOVA on the number of initial fixations with emotion type (happy, sad, angry), presentation duration (500, 1,500 ms), and cue location (emotional, neutral) as within-subject variables and group (ISZ, HC) as the between-subjects variable yielded significant main effects of cue location, $F(1, 37) = 17.66$, $p < .001$, $\eta_p^2 = .32$, and presentation duration, $F(1, 37) = 5.93$, $p < .05$, $\eta_p^2 = .138$. Follow-up t tests indicated that more initial fixations were made toward emotional than neutral faces, $p < .001$, and during the longer face presentation (1,500 ms) than during the shorter presentation (500 ms), $p < .05$. There were no significant interaction effects.

To further test whether the two groups exhibited attentional capture for emotional faces in their initial orienting response, the percentages of initial fixations being directed toward emotional faces were calculated (i.e., the number of trials in which initial fixation was directed toward emotional faces divided by the number of trials in which initial fixation was directed toward emotional or neutral faces), then tested against the 50% chance likelihood using separate one-sample t tests for each group. The results showed that the percentages were significantly different from 50% in both groups, $t(20) = 3.55$, $p < .01$, $d = 0.77$ for ISZs, $t(17) =$

Table 2
RT-Based Attentional Bias Scores (Ms) in ISZ and HC Groups (Mean, SD)

RT	ISZ ($n = 22$)	HC ($n = 19$)
Happy		
500 ms	−6.57 (62.34)	−5.00 (25.64)
1,500 ms	−10.15 (63.95)	17.21 (34.58)
Sad		
500 ms	17.94 (82.95)	.03 (32.03)
1,500 ms	−5.25 (51.46)	6.33 (35.23)
Angry		
500 ms	6.58 (45.85)	−5.52 (26.71)
1,500 ms	−5.28 (62.83)	6.53 (24.20)

Note. ISZ = individual with schizophrenia; HC = healthy control.

2.69, $p < .05$, $d = 0.63$ for HCs, indicating that both ISZs and HCs were more likely to direct their initial fixation toward emotional than neutral faces. Further, the percentages of the two groups did not significantly differ, $t(37) = 0.59$, $p > .05$, $d = 0.19$.

Attentional engagement over time. A mixed RM-ANOVA on viewing time with emotion type (happy, sad, angry), time interval (0–500, 500–1,000, 1,000–1,500 ms), and cue location (emotional face, neutral face) as within-subjects variables and a group (ISZ, HC) as a between-subjects variable yielded significant main effects of time interval, $F(2, 78) = 26.81$, $p < .001$, $\eta_p^2 = .57$, and cue location, $F(1, 39) = 8.20$, $p < .01$, $\eta_p^2 = .17$. These main effects were qualified by a significant interaction among them, $F(2, 38) = 4.64$, $p < .05$, $\eta_p^2 = .20$,; participants spent greater time viewing emotional than neutral faces during 0–500 and 1,000–1,500 ms ($p < .01$, $d = 0.48$ and 0.44, respectively), but not during 500–1,000 ms ($p > .05$, $d = -0.24$) intervals. We also found a significant interaction between emotion type and cue location, $F(2, 78) = 3.35$, $p < .05$, $\eta_p^2 = .08$. Compared with neutral faces, participants exhibited longer viewing time to angry ($p < .05$, $d = 0.39$) and happy ($p < .01$, $d = 0.43$) but not to sad faces ($p > .05$, $d = -0.13$).

Last, a significant interaction of emotion type, time intervals, and group emerged, $F(4, 36) = 2.82$, $p < .05$, $\eta_p^2 = .24$. That is, ISZs spent significantly less time viewing angry-neutral and sad-neutral facial pairs than HCs during the last interval (1,000–1,500 ms; $t(32.63) = -2.89$, $p < .01$, $d = 0.89$ and $t(39) = -2.21$, $p < .05$, $d = 0.70$, respectively). To test whether this group difference was driven by either the HC group's increased and/or the group's decreased viewing of negative, compared with positive, facial pairs, we conducted within-group comparisons of viewing time during the last interval across different emotions (positive vs. negative). The results showed that during the last interval, the viewing time for negative facial pairs (sad and angry combined) was shorter than that for positive ones in the ISZ group, $t(21) = 2.10$, $p < .05$, $d = 0.45$), whereas it was longer in the HC group, $t(18) = -2.36$, $p < .05$, $d = -0.54$, (see Table 3 and Figure 2).

Relationships with symptoms. We used the PANSS Positive and Negative factors (Wallwork, 2012) to assess whether biased attention to angry and happy faces was associated with Positive and Negative symptoms of schizophrenia, respectively. Negative symptoms were subdivided into expressive and motivational subdomains to reflect the current conceptualization of these symptoms, which includes emotional withdrawal, apathetic social withdrawal, and active social avoidance (Fervaha, Foussias, Agid, & Remington, 2014; Jang et al., 2016). We also explored how depression severity is related to biased attention to emotional faces. For these purposes, the following bias indices were calculated based on the previous literature (Armstrong & Olatunji, 2012; Wieser et al., 2009; see Table 4): the probability of initial fixation directed to angry faces and the emotional face-viewing time (as measures of orienting to threat) divided by viewing time of both emotional and neutral faces during three successive time intervals for each emotion as attention biases in subsequent attentional engagement stages. Due to multiple comparisons, Bonferroni correction was applied ($p < .0026$).

This resulted in three significant correlations; PANSS (Wallwork, 2012) Positive symptoms were negatively correlated with the probability of initial fixations being directed to angry faces presented for 1,500 ms, $r = -.74$, $p < .001$. The social amotivation subdomain of PANSS Negative symptoms was significantly associated with decreased viewing time of happy faces relative to neutral faces during 500–1,000 ms, $r = -.66$, $p = .001$. Last, PANSS depressed symptoms were correlated with decreased viewing time of angry faces relative to neutral faces during 1,000–1,500 ms, $r = -.62$, $p = .002$. There were no other significant correlations.

Relationships with functioning. Correlations were calculated between the above-defined bias indices and four QLS (Heinrichs et al., 1984) subdomains with Bonferroni corrections ($p < .0011$). Only greater QLS interpersonal functioning was positively correlated with time viewing happy faces relative to neutral faces during 500–1,000 ms, $r = .65$, $p = .001$.

Discussion

This study was an investigation of attentional processing of emotional stimuli over time in people with schizophrenia. Specifically, we sought to test whether emotional salience would initially capture the overt attention of ISZs. We also examined continuous attention allocation to emotional facial pairs, which extends to a period lasting longer than 1000 ms, and the specific relationships among motivated attention, symptoms, and functioning. Three

Table 3
Initial Fixation Positions (Number of Trials) and Viewing Times (Ms) in ISZ (n = 22) and HC (n = 19) Groups (Mean, SD)

Variable	Happy	Neutral	Sad	Neutral	Angry	Neutral
	ISZ group (*n* = 21)					
IF	19.71 (8.71)	16.00 (7.43)	19.86 (8.74)	15.95 (6.97)	20.38 (9.57)	16.81 (7.69)
VT (0–500)	4884.41 (2465.20)	3681.05 (1650.09)	4412.00 (1953.54)	3903.41 (2735.22)	5663.23 (2307.69)	4021.50 (1978.08)
VT (500–1,000)	5820.05 (1977.48)	5932.23 (2527.76)	5379.00 (1760.30)	6190.64 (2359.56)	5909.41 (2286.89)	5845.91 (2192.77)
VT (1,000–1,500)	4521.27 (1678.12)	3992.45 (1611.82)	4019.86 (1758.47)	3826.59 (1689.28)	3966.68 (1848.46)	3600.91 (1778.52)
	HC group (*n* = 18)					
IF	17.06 (8.58)	15.61 (6.56)	17.33 (6.84)	15.17 (6.51)	18.33 (6.23)	15.78 (5.61)
VT (0–500)	4333.47 (1830.00)	3852.42 (1543.07)	4267.84 (1792.41)	4188.68 (2450.31)	4348.26 (1677.18)	4074.21 (1617.42)
VT (500–1,000)	6211.21 (2618.48)	6053.84 (1996.02)	5492.26 (1519.36)	6479.79 (1739.63)	6192.21 (1575.38)	6235.47 (2463.66)
VT (1,000–1,500)	4959.16 (1333.43)	3884.42 (1803.93)	4773.84 (1579.38)	4929.89 (1759.91)	5268.05 (1323.85)	4506.58 (1386.63)

Note. IF = initial fixation; VT = viewing time.

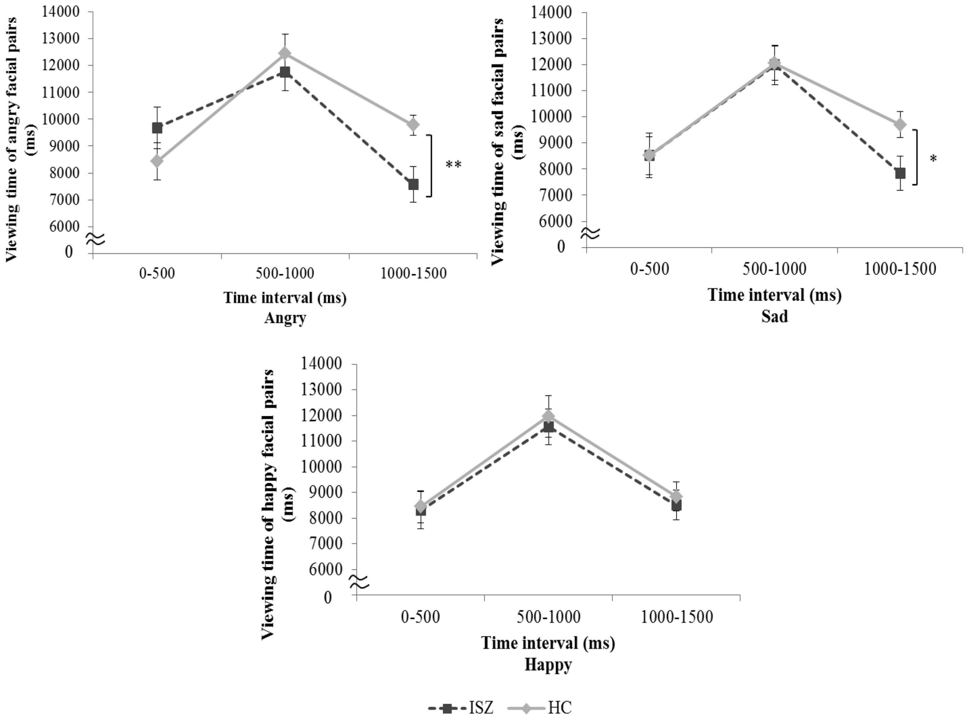

Figure 2. Time course of attentional engagement for angry (top left), sad (top right), and happy (bottom) face pairs (Mean, *SE*). $^{*}p < .05$. $^{**}p < .01$.

major findings emerged. First, in the initial fixation analysis, the ISZ group exhibited enhanced initial orienting toward emotional stimuli relative to neutral stimuli counterparts, which is similar to the result for the HC group. In the viewing-time analysis, participants also exhibited a longer viewing time in relation to emotional, versus neutral, faces during the early and late periods (0–500 ms and 500–1,500 ms), although subtle group differences may have been obscured due to low power. Second, despite early attentional capture by emotion, ISZs withdrew their attention from faces later when one of the facial pairs displayed negative emotions (angry and sad). Last, symptoms and functioning were closely associated with distinct attentional processes: high positive and depressive symptoms were related with initial and late avoidance of angry faces, respectively, and greater negative symptoms and poorer interpersonal functioning with diminished attention to happy faces during 500–1,000 ms.

Valence and Arousal Ratings

We found that both ISZs and HCs rated happy faces more positively than sad and angry faces. They also rated sad and angry faces more negatively than happy faces, supporting the validity of the stimuli set. The finding that arousal ratings did not differ across emotions in both groups also demonstrates that the stimuli selection procedure that matched the arousal level of emotional faces achieved its purpose. Subtle group differences in valence ratings, such as more negative valence ratings of overall emotional faces and more positive valence ratings to angry faces compared with

Table 4
Eye Movement Bias Indices in ISZ (n = 22) and HC (n = 19) Groups (Mean, SD, %)

	Happy		Sad		Angry	
Eye-movement indices	ISZ	HC	ISZ	HC	ISZ	HC
IF direction[a] (500 ms)	53.19 (10.41)	56.02 (19.09)	57.85 (14.28)	54.56 (14.80)	50.53 (11.53)	53.94 (11.39)
IF direction (1,500 ms)	56.85 (12.59)	49.26 (12.56)	54.13 (15.26)	54.10 (17.15)	56.56 (13.27)	54.32 (14.16)
RVT (0–500 ms)	56.07 (14.50)	52.62 (14.26)	54.98 (16.80)	51.13 (10.32)	59.47 (13.44)	51.46 (10.47)
RVT (500–1,000 ms)	50.46 (11.92)	49.35 (14.61)	46.92 (8.72)	45.77 (7.62)	50.19 (13.43)	51.36 (11.59)
RVT (1,000–1,500 ms)	53.05 (11.77)	57.71 (13.60)	51.28 (12.97)	49.84 (14.80)	51.81 (13.00)	53.95 (11.02)

Note. IF direction = probability of initial fixations being directed to each emotional face (happy, sad, angry) presented for 500 ms or 1,500 ms relative to its neutral counterpart. RVT = proportion of time viewing emotional faces (viewing time of the emotional face divided by the total viewing time of the emotional and the neutral face) during three time intervals (0–500, 500–1,000, 1,000–1,500 ms) for each emotion.
[a] For IF direction, *n*s = 21 and 18 for ISZs and HCs, respectively.

HCs were reported by ISZs, which is largely consistent with the literature documenting heightened negative affect and ambivalence in emotional responding in schizophrenia (Trémeau et al., 2009). Unlike studies that found no differences in pleasantness ratings of positive stimuli between ISZs and HCs (Cohen et al., 2011), we found diminished positive feelings toward happy faces in ISZs. However, although small in number, some past studies have reported reduced pleasant feelings toward positive stimuli, including happy faces in schizophrenia (Reske et al., 2007).

Manual RT Data

In the analysis of RT-based attentional bias indices, it was found that whereas HCs selectively attended to emotional faces, ISZs did not, when faces were presented for 1,500 ms. The group difference was not observed to faces presented for 500 ms. Some previous studies employing the visual dot-probe task with a healthy control population found that, compared with neutral faces, participants selectively attended more to emotional faces, for example, happy ones presented for 1,500 ms (Isaacowitz, Wadlinger, Goren, & Wilson, 2006; Joormann, Talbot, & Gotlib, 2007) and angry ones presented for 1,000 ms (Tomaszczyk & Fernandes, 2014), although there were large variations in terms of attentional preferences depending on one's developmental stage, gender, and temperament (Shechner et al., 2012). The fact that the group difference observed in this study only within the longest facial presentation duration (1,500 ms) indicates that ISZs may have been less prone to attend to emotional stimuli than HCs were, when stimuli were presented for a sufficiently long duration, long enough to offer enough leverage to voluntarily control one's attention (Cisler & Koster, 2010). In line with this idea, it has been shown that attention can be not only reflexively captured, but also endogenously guided by emotional stimuli (Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). Taken together, ISZs and HCs exhibited differences in attentional processing of emotional stimuli in the late stage, which was predominated by voluntary attentional control.

Although potentially informative, RT-based attentional indices assess "snapshots" of attention, thus, using them to discern a precise time course that includes initial orienting and continuous allocation of attention is considered difficult (Armstrong & Olatunji, 2012; Weierich, Treat, & Hollingworth, 2008). Therefore, we moved on to the discussion of eye-tracking data to address the specific research questions raised above, which encompass the initial orienting and temporal dynamics of the attention people with schizophrenia pay to emotional faces.

Eye-Tracking Data: Initial Orienting and Attentional Engagement Over Time

We first examined whether ISZs would exhibit early attentional capture to emotional faces. Past studies of motivated attention in healthy population reported that the probability of initial fixation placement and viewing time during the first 500 ms were greater for both pleasant and unpleasant pictures than for neutral pictures (Calvo & Lang, 2004; Nummenmaa et al., 2006). Similar to these findings, we found that both ISZ and HC groups directed their initial fixations toward emotional faces significantly more often than they did toward neutral faces. In addition, we did not find group interaction in viewing time during the early period (0–500 ms) such that, overall, participants exhibited a longer viewing time toward emotional, compared with neutral, faces in this period. Taken together, these results suggest that early attentional capture by emotionally salient stimuli is likely to be preserved in ISZs, supporting previous ERP findings (Horan et al., 2012; Horan et al., 2010) and extending them to gaze behaviors with facial stimuli.

Participants also looked at emotional faces longer than neutral faces during the last interval (1,000–1,500 ms) with no significant group interaction being observed in the current study. This suggests that emotional faces tended to regain overt attention after a brief period of attentional shift to neutral faces. Besides, when aggregated across three intervals, viewing time was longer to angry and happy faces, but not sad faces, relative to their neutral counterparts. Sad faces may have not elicited longer viewing time in total than their simultaneously presented neutral faces, possibly due to their less pronounced reward or threat values than happy and angry faces. However, it should be noted that initial fixation placement showed preferences for overall emotional faces including the sad one.

Despite their early attentional capture by emotional faces, the ISZ group exhibited a shorter viewing time toward angry and sad face pairs than the HC group did during the late stage (1,000–1,500 ms). This group difference was driven by both the HC group's increased and the ISZ group's decreased viewing time for negative facial pairs relative to happy ones during this interval. The HC group's longer viewing time for negative, compared with positive, pairs in the late stage can be seen as being in line with a past study reporting that attention paid to unpleasant stimuli persisted longer than that for positive stimuli (Hajcak & Olvet, 2008). This sustained attention paid to unpleasant stimuli is thought to reflect a negativity bias in human cognition (Ito, Larsen, Smith, & Cacioppo, 1998), and pose an evolutionary advantage (Lang, Davis, & Öhman, 2000).

In contrast, the ISZ group exhibited a shorter viewing time for negative facial pairs compared with happy ones during the last interval, suggesting diminished processing of negative stimuli in the late stage. Of note, the current findings closely parallel the results from a recent ERP study that investigated late positive potential (LPP) responses to emotional stimuli in people with schizophrenia, people with bipolar disorder, and healthy controls (Horan, Wynn, Hajcak, Altshuler, & Green, 2016). In a motivational gradient paradigm, the schizophrenia group was found to show elevated LPPs for appetitive and aversive cues in the initial stage but hypoactivation for aversive cues in the last (imminent) stage. The current study results, therefore, may indicate that aberrant late attentional processing of negative stimuli in people with schizophrenia converges between different measures of attention, that is, ERP and eye-tracking data.

One possible way to interpret current finding is that ISZs may have avoided paying attention to negative stimuli in the late stage. Attentional avoidance of negative or pathology-congruent stimuli in relatively late period was often observed in individuals with affective disorder, related to dysfunctional stimuli elaboration processes and/or a strategic attentional control to minimize experiences of unpleasant emotions (Bar-Haim et al., 2007; Giel et al., 2011). It should be noted that decreased attention was not only observed toward negative faces themselves but also toward their paired neutral faces in ISZs, indicating reduced processing of external stimuli in response to a negative valence. Whether this reflects an identical process with selective avoidance, which is often seen in affective disorders, awaits further empirical studies.

We speculate that atypical late attentional processes of negative facial expressions observed in this study may relate to affective vulnerabilities in schizophrenia. For example, previous studies have demonstrated that ISZs tend to experience negative emotions more often and intensely than healthy individuals both in daily life and in response to evocative stimuli in laboratory (Cohen et al., 2011; Myin-Germeys, Delespaul, & DeVries, 2000). Negative affectivity is often assumed to play a role in vulnerability to schizophrenia-related disorders, and believed to reflect a compromised ability to deal with daily life stress (Horan, Blanchard, Clark, & Green, 2008). In this respect, a study of emotional attention processing can help to illuminate how affective traits manifest in relation to cognition and, thus, contribute to understanding risks and developmental processes of schizophrenia and related disorders.

Integration of Eye-Tracking and RT Data

Both RT and eye-tracking results suggest the ISZ group paid less attention to emotional faces compared with HCs during the late stage. However, whereas reduced attention was observed toward overall emotional stimuli in the RT data, this was specific to negative valences for the eye-tracking data. The divergence of results from the two measurement modalities appears to be in line with recent studies demonstrating that eye-tracking and RT indices were not strongly related (Isaacowitz et al., 2006; Marks, Pike, Stoops, & Rush, 2014; Woody, Owens, Burkhouse, & Gibb, 2016), and may stem from the distinct nature of these two methodologies (Armstrong & Olatunji, 2012). For example, although eye movements and covert attention shifts are closely linked functionally and anatomically, the latter can be shifted without an overt gaze change (Weierich et al., 2008). In this regard, RT-based bias indices may be able to be used to detect attentional patterns that are not evident from eye movement measures.

Alternatively, it has been pointed out that the “snapshot” nature of an RT-based bias index, which assesses spatial attention sampled at a single point of time, could reduce the sensitivity of measures (Caseras, Garner, Bradley, & Mogg, 2007). For example, a previous study found that while the proportion of gaze duration toward angry faces predicted major depressive disorder recurrence in women, RT bias scores did not (Woody et al., 2016). The sensitivity issue may be especially relevant in the study of schizophrenia, which has been consistently found to be related to high intraindividual RT variability (Kaiser et al., 2008). The lack of correlation between RT-based attention indices and symptoms and functioning observed in this study may also point toward lower sensitivity of the RT measures. Last, it should be noted that a simultaneous decrease in visual scanning time for both negative faces and their paired neutral faces as shown by eye tracking may have not been reflected in RT-based bias scores, which index relative attentional preference for either emotional or neutral stimuli.

Eye-Tracking Data: Relationships With Symptoms and Functioning

We found positive symptoms were closely associated with the avoidance of initial fixations from angry faces presented for 1,500 ms. This is interesting in that to move initial fixation away from the angry face, scanning threats at least partly via parafoveal processing may have been required, because only the initial fixations placed on the central cross just before the saccadic movement were analyzed. This implies that ISZs with high positive symptoms may be characterized by both hypervigilance, that is, the tendency to persistently monitor for threat, and avoidance, supporting the vigilance-avoidance hypothesis. Previous studies also reported close associations between positive symptoms and atypical attentional pattern to threat-related stimuli (Savulich, Shergill, & Yiend, 2012). For example, M. J. Green et al. (2003) found that ISZs with delusions showed fewer fixations to fearful faces than HCs and ISZs without delusions, but comparable number of fixations to happy faces. Current study adds information regarding temporal characteristics of aberrant attention to threat-related stimuli and also indicates positive symptoms of schizophrenia are highly related to automatic avoidance of social threat which may involve atypical sustained threat systems (Schlund, Hudgins, Magee, & Dymond, 2013). This defensive deployment of attention to threatening stimuli may paradoxically contribute to maintaining positive symptoms via inability to reappraise and habituate to threats (Savulich et al., 2012). The finding may be consistent with a theoretical model postulating that positive symptoms are closely associated with negative evaluative beliefs, such as perceiving the self as vulnerable and others as threatening, along with a hyperactive threat system involving exaggerated threat anticipation (Garety, Kuipers, Fowler, Freeman, & Bebbington, 2001; Salvatore et al., 2012). The precise role of this cognitive bias in the emergence and/or maintenance of positive symptoms would be a fruitful subject to focus on in future studies.

Depression severity was related to late avoidance of angry faces measured by viewing time. Therefore, threat avoidance appears to be related with not only positive symptoms but also depression in schizophrenia albeit in a different information processing stage and presumably with distinct mechanisms. Interestingly, it has been recently found that individuals with high paranoia showed defensive cognitive responses, that is, biasing gaze away from threat-related stimuli, when they were activated with depressive schema (Provencio, Vázquez, Valiente, & Hervas, 2012). Taken together, these results indicate that depression seems to involve an atypical threat elaboration process in clinical and nonclinical samples of people with schizophrenia. Given a recent study linking threat avoidance to depression risk (Price et al., 2016), aberrant late threat processing may be implicated in depression across diagnostic boundaries. However, as the PANSS depression variable includes one item for anxiety and because the current sample showed a relatively low level of depression, this finding should be replicated in future studies by employing more comprehensive measures of depression and including more patients with a high depression level.

It was found that the PANSS (Wallwork et al., 2012) social amotivation subdomain of Negative symptoms and interpersonal functioning measured by the QLS (Heinrichs et al., 1984) were significantly related to diminished attentional engagement to happy faces during 500–1,000 ms. This is consistent with previous studies reporting that ISZs with high negative symptoms showed a lack of positive attentional bias in the emotional Stroop task (Strauss, Allen, Duke, Ross, & Schwartz, 2008) and linking negative symptoms with failure to signal the salience of positive events (Dowd & Barch, 2010; Nelson, Bjorkquist, Olsen, & Herbener, 2015). It seems that deficient allocation of attentional resources to rewarding stimuli, that is, happy faces, is closely associated with amotivation and low interpersonal functioning in schizophrenia (Frewen et al., 2008). Given that this relationship was found in the 500–1,000-ms interval, along with a relatively intact initial orienting toward emotional salience in the whole ISZ group, aberrancy in initiating and sustaining attentional control toward positive stimuli rather than salience detection itself may be implicated in social amotivation for people with schizophrenia, which needs to be tested using a suitable task in the future.

Overall Limitations

Several limitations should be acknowledged. First, the sample size was small and, thus, likely to be underpowered to detect small or medium-sized effects. This might have resulted in our failing to find potential group differences for some attentional components and also differences across emotion types. Future studies with larger sample sizes are needed to replicate and extend the current findings. Second, our sample was relatively asymptomatic, with an average total PANSS (Wallwork et al., 2012) score of 61.55; thus, replicating the current findings using a sample with a wider range of symptoms is warranted. Third, we did not examine visual gaze to specific areas within a face. Previous studies have reported aberrant visual scan paths in ISZs, such as a smaller number of fixations to facial feature areas than nonfeature areas and short scan-path length (Williams, Loughland, Gordon, & Davidson, 1999). However, our focus lay on the selection of whole faces by emotional valences. Future researchers may want to examine temporal dynamics of overt attention to specific emotional facial areas. Last, this study is cross-sectional and further research is needed to investigate temporal stability and predictive utility of overt attention measures on the course of symptoms and functioning in schizophrenia and its related disorders.

Despite limitations, this is the first study to examine temporal dynamics of attentional processing of emotional faces in the context of selective attention using online and ecological measures of overt attention in schizophrenia. We found that ISZs showed relatively intact early attentional capture by emotional salience but exhibited generalized face avoidance in response to negative facial expressions in later elaborative stimuli processes. This gives clues to the nature of emotional deficits in schizophrenia and is consistent with recent postulation of social cognition deficits in this disorder, that is, relatively intact reflexive processes, but impaired reflective processes (M. F. Green, Horan, & Lee, 2015). Future studies need to examine whether late generalized attentional avoidance is also observed in negative stimuli other than faces. Close relationships between distinct affective biases and symptoms also offer insights into cognitive and emotional mechanisms underlying symptoms. Of particular note, the current study findings demonstrate a complicated manifestation of affective bias in schizophrenia, which necessitates careful consideration of the clinical presentation of the sample and also the temporal characteristics of attentional processes in future studies of attention–emotion interaction in relation to this disorder. Last, the present study has functional and potential therapeutic implications. Diminished visual attention to social rewards was closely related to social amotivation and low interpersonal functioning in this population and thus may serve as a candidate treatment target.

References

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text rev.). Washington, DC: Author.

Armstrong, T., & Olatunji, B. O. (2012). Eye tracking of attention in the affective disorders: A meta-analytic review and synthesis. *Clinical Psychology Review, 32,* 704–723. http://dx.doi.org/10.1016/j.cpr.2012.09.004

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin, 133,* 1–24. http://dx.doi.org/10.1037/0033-2909.133.1.1

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Beck Depression Inventory–II.* San Antonio, TX: Psychological Corporation.

Bentall, R. P., & Kaney, S. (1989). Content specific information processing and persecutory delusions: An investigation using the emotional Stroop test. *British Journal of Medical Psychology, 62,* 355–364. http://dx.doi.org/10.1111/j.2044-8341.1989.tb02845.x

Besnier, N., Kaladjian, A., Mazzola-Pomietto, P., Adida, M., Fakra, E., Jeanningros, R., & Azorin, J.-M. (2011). Differential responses to emotional interference in paranoid schizophrenia and bipolar mania. *Psychopathology, 44,* 1–11. http://dx.doi.org/10.1159/000322097

Bora, E., & Pantelis, C. (2013). Theory of mind impairments in first-episode psychosis, individuals at ultra-high risk for psychosis and in first-degree relatives of schizophrenia: Systematic review and meta-analysis. *Schizophrenia Research, 144,* 31–36. http://dx.doi.org/10.1016/j.schres.2012.12.013

Bradley, B. P., Mogg, K., Falla, S. J., & Hamilton, L. R. (1998). Attentional bias for threatening facial expressions in anxiety: Manipulation of stimulus duration. *Cognition and Emotion, 12,* 737–753. http://dx.doi.org/10.1080/026999398379411

Bradley, B. P., Mogg, K., & Millar, N. H. (2000). Covert and overt orienting of attention to emotional faces in anxiety. *Cognition & Emotion, 14,* 789–808. http://dx.doi.org/10.1080/02699930050156636

Bradley, M. M., Sabatinelli, D., Lang, P. J., Fitzsimmons, J. R., King, W., & Desai, P. (2003). Activation of the visual cortex in motivated attention. *Behavioral Neuroscience, 117,* 369–380. http://dx.doi.org/10.1037/0735-7044.117.2.369

Calvo, M. G., & Lang, P. J. (2004). Gaze patterns when looking at emotional pictures: Motivationally biased attention. *Motivation and Emotion, 28,* 221–243. http://dx.doi.org/10.1023/B:MOEM.0000040153.26156.ed

Caseras, X., Garner, M., Bradley, B. P., & Mogg, K. (2007). Biases in visual orienting to negative and positive scenes in dysphoria: An eye movement study. *Journal of Abnormal Psychology, 116,* 491–497. http://dx.doi.org/10.1037/0021-843X.116.3.491

Cisler, J. M., & Koster, E. H. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical*

Psychology Review, 30, 203–216. http://dx.doi.org/10.1016/j.cpr.2009.11.003

Cohen, A. S., Najolia, G. M., Brown, L. A., & Minor, K. S. (2011). The state–trait disjunction of anhedonia in schizophrenia: Potential affective, cognitive and social-based mechanisms. *Clinical Psychology Review, 31,* 440–448. http://dx.doi.org/10.1016/j.cpr.2010.11.001

Cornelissen, F. W., Peters, E. M., & Palmer, J. (2002). The Eyelink Toolbox: Eye tracking with MATLAB and the Psychophysics Toolbox. *Behavior Research Methods, Instruments & Computers, 34,* 613–617. http://dx.doi.org/10.3758/BF03195489

Couture, S. M., Penn, D. L., & Roberts, D. L. (2006). The functional significance of social cognition in schizophrenia: A review. *Schizophrenia Bulletin, 32,* S44–S63. http://dx.doi.org/10.1093/schbul/sbl029

Coy, A. L., & Hutton, S. B. (2013). The influence of hallucination proneness and social threat on time perception. *Cognitive Neuropsychiatry, 18,* 463–476. http://dx.doi.org/10.1080/13546805.2012.730994

Dichter, G. S., Bellion, C., Casp, M., & Belger, A. (2010). Impaired modulation of attention and emotion in schizophrenia. *Schizophrenia Bulletin, 36,* 595–606. http://dx.doi.org/10.1093/schbul/sbn118

Dowd, E. C., & Barch, D. M. (2010). Anhedonia and emotional experience in schizophrenia: Neural and behavioral indicators. *Biological Psychiatry, 67,* 902–911. http://dx.doi.org/10.1016/j.biopsych.2009.10.020

Dudley, R., Dodgson, G., Sarll, G., Halhead, R., Bolas, H., & McCarthy-Jones, S. (2014). The effect of arousal on auditory threat detection and the relationship to auditory hallucinations. *Journal of Behavior Therapy and Experimental Psychiatry, 45,* 311–318. http://dx.doi.org/10.1016/j.jbtep.2014.02.002

Duque, A., & Vázquez, C. (2015). Double attention bias for positive and negative emotional faces in clinical depression: Evidence from an eye-tracking study. *Journal of Behavior Therapy and Experimental Psychiatry, 46,* 107–114. http://dx.doi.org/10.1016/j.jbtep.2014.09.005

Ekman, P., & Friesen, W. V. (2003). *Unmasking the face: A guide to recognizing emotions from facial clues*. Los Altos, CA: Institute for the Study of Human Knowledge.

Erceg-Hurn, D. M., & Mirosevich, V. M. (2008). Modern robust statistical methods: An easy way to maximize the accuracy and power of your research. *American Psychologist, 63,* 591–601. http://dx.doi.org/10.1037/0003-066X.63.7.591

Fani, N., Tone, E. B., Phifer, J., Norrholm, S. D., Bradley, B., Ressler, K. J., . . . Jovanovic, T. (2012). Attention bias toward threat is associated with exaggerated fear expression and impaired extinction in PTSD. *Psychological Medicine, 42,* 533–543. http://dx.doi.org/10.1017/S0033291711001565

Fervaha, G., Foussias, G., Agid, O., & Remington, G. (2014). Motivational and neurocognitive deficits are central to the prediction of longitudinal functional outcome in schizophrenia. *Acta Psychiatrica Scandinavica, 130,* 290–299. http://dx.doi.org/10.1111/acps.12289

Fox, E., Cahill, S., & Zougkou, K. (2010). Preconscious processing biases predict emotional reactivity to stress. *Biological Psychiatry, 67,* 371–377. http://dx.doi.org/10.1016/j.biopsych.2009.11.018

Frewen, P. A., Dozois, D. J., Joanisse, M. F., & Neufeld, R. W. (2008). Selective attention to threat versus reward: Meta-analysis and neural-network modeling of the dot-probe task. *Clinical Psychology Review, 28,* 307–337. http://dx.doi.org/10.1016/j.cpr.2007.05.006

Garety, P. A., Kuipers, E., Fowler, D., Freeman, D., & Bebbington, P. E. (2001). A cognitive model of the positive symptoms of psychosis. *Psychological Medicine, 31,* 189–195. http://dx.doi.org/10.1017/S0033291701003312

Giel, K. E., Friederich, H.-C., Teufel, M., Hautzinger, M., Enck, P., & Zipfel, S. (2011). Attentional processing of food pictures in individuals with anorexia nervosa: An eye-tracking study. *Biological Psychiatry, 69,* 661–667. http://dx.doi.org/10.1016/j.biopsych.2010.09.047

Gotlib, I. H., Kasch, K. L., Traill, S., Joormann, J., Arnow, B. A., & Johnson, S. L. (2004). Coherence and specificity of information-processing biases in depression and social phobia. *Journal of Abnormal Psychology, 113,* 386–398. http://dx.doi.org/10.1037/0021-843X.113.3.386

Green, M. F., Horan, W. P., & Lee, J. (2015). Social cognition in schizophrenia. *Nature Reviews Neuroscience, 16,* 620–631. http://dx.doi.org/10.1038/nrn4005

Green, M. J., & Phillips, M. L. (2004). Social threat perception and the evolution of paranoia. *Neuroscience and Biobehavioral Reviews, 28,* 333–342. http://dx.doi.org/10.1016/j.neubiorev.2004.03.006

Green, M. J., Williams, L. M., & Davidson, D. (2003). Visual scanpaths to threat-related faces in deluded schizophrenia. *Psychiatry Research, 119,* 271–285. http://dx.doi.org/10.1016/S0165-1781(03)00129-X

Hajcak, G., Dunning, J. P., & Foti, D. (2009). Motivated and controlled attention to emotion: Time course of the late positive potential. *Clinical Neurophysiology, 120,* 505–510. http://dx.doi.org/10.1016/j.clinph.2008.11.028

Hajcak, G., & Olvet, D. M. (2008). The persistence of attention to emotion: Brain potentials during and after picture presentation. *Emotion, 8,* 250–255. http://dx.doi.org/10.1037/1528-3542.8.2.250

Heinrichs, D. W., Hanlon, T. E., & Carpenter, W. T., Jr. (1984). The Quality of Life Scale: An instrument for rating the schizophrenic deficit syndrome. *Schizophrenia Bulletin, 10,* 388–398. http://dx.doi.org/10.1093/schbul/10.3.388

Horan, W. P., Blanchard, J. J., Clark, L. A., & Green, M. F. (2008). Affective traits in schizophrenia and schizotypy. *Schizophrenia Bulletin, 34,* 856–874. http://dx.doi.org/10.1093/schbul/sbn083

Horan, W. P., Foti, D., Hajcak, G., Wynn, J. K., & Green, M. F. (2012). Intact motivated attention in schizophrenia: Evidence from event-related potentials. *Schizophrenia Research, 135,* 95–99. http://dx.doi.org/10.1016/j.schres.2011.11.005

Horan, W. P., Wynn, J. K., Hajcak, G., Altshuler, L., & Green, M. F. (2016). Distinct patterns of dysfunctional appetitive and aversive motivation in bipolar disorder versus schizophrenia: An event-related potential study. *Journal of Abnormal Psychology, 125,* 576–587. http://dx.doi.org/10.1037/abn0000142

Horan, W. P., Wynn, J. K., Kring, A. M., Simons, R. F., & Green, M. F. (2010). Electrophysiological correlates of emotional responding in schizophrenia. *Journal of Abnormal Psychology, 119,* 18–30. http://dx.doi.org/10.1037/a0017510

Isaacowitz, D. M., Wadlinger, H. A., Goren, D., & Wilson, H. R. (2006). Is there an age-related positivity effect in visual attention? A comparison of two methodologies. *Emotion, 6,* 511–516. http://dx.doi.org/10.1037/1528-3542.6.3.511

Ito, T. A., Larsen, J. T., Smith, N. K., & Cacioppo, J. T. (1998). Negative information weighs more heavily on the brain: The negativity bias in evaluative categorizations. *Journal of Personality and Social Psychology, 75,* 887–900. http://dx.doi.org/10.1037/0022-3514.75.4.887

Jang, S. K., Choi, H. I., Park, S., Jaekal, E., Lee, G. Y., Cho, Y. I., & Choi, K.-H. (2016). A two-factor model better explains heterogeneity in negative symptoms: Evidence from the Positive and Negative Syndrome Scale. *Frontiers in Psychology, 7,* 707. http://dx.doi.org/10.3389/fpsyg.2016.00707

Joormann, J., Talbot, L., & Gotlib, I. H. (2007). Biased processing of emotional information in girls at risk for depression. *Journal of Abnormal Psychology, 116,* 135–143. http://dx.doi.org/10.1037/0021-843X.116.1.135

Kaiser, S., Roth, A., Rentrop, M., Friederich, H.-C., Bender, S., & Weisbrod, M. (2008). Intra-individual reaction time variability in schizophrenia, depression and borderline personality disorder. *Brain and Cognition, 66,* 73–82. http://dx.doi.org/10.1016/j.bandc.2007.05.007

Kay, S. R., Flszbein, A., & Opfer, L. A. (1987). The Positive and Negative Syndrome Scale (PANSS) for schizophrenia. *Schizophrenia Bulletin, 13,* 261–276. http://dx.doi.org/10.1093/schbul/13.2.261

Lang, P. J., & Bradley, M. M. (2010). Emotion and the motivational brain. *Biological Psychology, 84,* 437–450. http://dx.doi.org/10.1016/j.biopsycho.2009.10.007

Lang, P. J., Davis, M., & Öhman, A. (2000). Fear and anxiety: Animal models and human cognitive psychophysiology. *Journal of Affective Disorders, 61,* 137–159. http://dx.doi.org/10.1016/S0165-0327(00)00343-8

Lee, T. H., Lee, K., Lee, K. Y., Choi, J. S., & Kim, H. T. (2006). *The Korea University facial expression collection: KUFEC*. Lab. Seoul, Korea: Lab. of Behavioral Neuroscience, Dept. of Psychology.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology, 95,* 15–20. http://dx.doi.org/10.1037/0021-843X.95.1.15

Marks, K. R., Pike, E., Stoops, W. W., & Rush, C. R. (2014). Test-retest reliability of eye tracking during the visual probe task in cocaine-using adults. *Drug and Alcohol Dependence, 145,* 235–237.

Meijering, B., van Rijn, H., Taatgen, N. A., & Verbrugge, R. (2012). What eye movements can tell about theory of mind in a strategic game. *PLoS ONE, 7,* e45961. http://dx.doi.org/10.1371/journal.pone.0045961

Mogg, K., Bradley, B. P., de Bono, J., & Painter, M. (1997). Time course of attentional bias for threat information in non-clinical anxiety. *Behaviour Research and Therapy, 35,* 297–303. http://dx.doi.org/10.1016/S0005-7967(96)00109-X

Mogg, K., Bradley, B. P., Field, M., & De Houwer, J. (2003). Eye movements to smoking-related pictures in smokers: Relationship between attentional biases and implicit and explicit measures of stimulus valence. *Addiction, 98,* 825–836. http://dx.doi.org/10.1046/j.1360-0443.2003.00392.x

Mogg, K., Philippot, P., & Bradley, B. P. (2004). Selective attention to angry faces in clinical social phobia. *Journal of Abnormal Psychology, 113,* 160–165. http://dx.doi.org/10.1037/0021-843X.113.1.160

Myin-Germeys, I., Delespaul, P. A. E. G., & deVries, M. W. (2000). Schizophrenia patients are more emotionally active than is assumed based on their behavior. *Schizophrenia Bulletin, 26,* 847–854. http://dx.doi.org/10.1093/oxfordjournals.schbul.a033499

Nelson, B. D., Bjorkquist, O. A., Olsen, E. K., & Herbener, E. S. (2015). Schizophrenia symptom and functional correlates of anterior cingulate cortex activation to emotion stimuli: An fMRI investigation. *Psychiatry Research: Neuroimaging, 234,* 285–291. http://dx.doi.org/10.1016/j.pscychresns.2015.11.001

Nummenmaa, L., Hyönä, J., & Calvo, M. G. (2006). Eye movement assessment of selective attentional capture by emotional pictures. *Emotion, 6,* 257–268. http://dx.doi.org/10.1037/1528-3542.6.2.257

Penn, D. L., Sanna, L. J., & Roberts, D. L. (2008). Social cognition in schizophrenia: An overview. *Schizophrenia Bulletin, 34,* 408–411. http://dx.doi.org/10.1093/schbul/sbn014

Pessoa, L., McKenna, M., Gutierrez, E., & Ungerleider, L. G. (2002). Neural processing of emotional faces requires attention. *Proceedings of the National Academy of Sciences of the United States of America, 99,* 11458–11463. http://dx.doi.org/10.1073/pnas.172403899

Pilgrim, K., Marin, M.-F., & Lupien, S. J. (2010). Attentional orienting toward social stress stimuli predicts increased cortisol responsivity to psychosocial stress irrespective of the early socioeconomic status. *Psychoneuroendocrinology, 35,* 588–595. http://dx.doi.org/10.1016/j.psyneuen.2009.09.015

Pollak, S. D., & Tolley-Schell, S. A. (2003). Selective attention to facial emotion in physically abused children. *Journal of Abnormal Psychology, 112,* 323–338. http://dx.doi.org/10.1037/0021-843X.112.3.323

Price, R. B., Kuckertz, J. M., Siegle, G. J., Ladouceur, C. D., Silk, J. S., Ryan, N. D., . . . Amir, N. (2015). Empirical recommendations for improving the stability of the dot-probe task in clinical research. *Psychological Assessment, 27,* 365–376. http://dx.doi.org/10.1037/pas0000036

Price, R. B., Rosen, D., Siegle, G. J., Ladouceur, C. D., Tang, K., Allen, K. B., . . . Silk, J. S. (2016). From anxious youth to depressed adolescents: Prospective prediction of 2-year depression symptoms via attentional bias measures. *Journal of Abnormal Psychology, 125,* 267–278. http://dx.doi.org/10.1037/abn0000127

Provencio, M., Vázquez, C., Valiente, C., & Hervas, G. (2012). Depressive primes stimulate initial avoidance of angry faces: An eye-tracking study of paranoid ideation. *Cognitive Therapy and Research, 36,* 483–492. http://dx.doi.org/10.1007/s10608-011-9388-5

Reske, M., Kellermann, T., Habel, U., Jon Shah, N., Backes, V., von Wilmsdorff, M., . . . Schneider, F. (2007). Stability of emotional dysfunctions? A long-term fMRI study in first-episode schizophrenia. *Journal of Psychiatric Research, 41,* 918–927. http://dx.doi.org/10.1016/j.jpsychires.2007.02.009

Sagliano, L., Trojano, L., Amoriello, K., Migliozzi, M., & D'Olimpio, F. (2014). Attentional biases toward threat: The concomitant presence of difficulty of disengagement and attentional avoidance in low trait anxious individuals. *Frontiers in Psychology, 5,* Article No. 685. http://dx.doi.org/10.3389/fpsyg.2014.00685

Salvatore, G., Lysaker, P. H., Popolo, R., Procacci, M., Carcione, A., & Dimaggio, G. (2012). Vulnerable self, poor understanding of others' minds, threat anticipation and cognitive biases as triggers for delusional experience in schizophrenia: A theoretical model. *Clinical Psychology & Psychotherapy, 19,* 247–259. http://dx.doi.org/10.1002/cpp.746

Savulich, G., Shergill, S., & Yiend, J. (2012). Biased cognition in psychosis. *Journal of Experimental Psychopathology, 3,* 514–536.

Schlund, M. W., Hudgins, C. D., Magee, S., & Dymond, S. (2013). Neuroimaging the temporal dynamics of human avoidance to sustained threat. *Behavioural Brain Research, 257,* 148–155. http://dx.doi.org/10.1016/j.bbr.2013.09.042

Shechner, T., Britton, J. C., Pérez-Edgar, K., Bar-Haim, Y., Ernst, M., Fox, N. A., . . . Pine, D. S. (2012). Attention biases, anxiety, and development: Toward or away from threats or rewards? *Depression and Anxiety, 29,* 282–294. http://dx.doi.org/10.1002/da.20914

Sheehan, D. V., Lecrubier, Y., Sheehan, K. H., Amorim, P., Janavs, J., Weiller, E., . . . Dunbar, G. C. (1998). The Mini-International Neuropsychiatric Interview (M.I.N.I.): The development and validation of a structured diagnostic psychiatric interview for *DSM–IV* and ICD-10. *Journal of Clinical Psychiatry, 59,* 22–33.

Spielberger, C. D. (2010). *State–Trait Anxiety Inventory*. Hoboken, NJ: Wiley.

Strauss, G. P., Allen, D. N., Duke, L. A., Ross, S. A., & Schwartz, J. (2008). Automatic affective processing impairments in patients with deficit-syndrome schizophrenia. *Schizophrenia Research, 102,* 76–87. http://dx.doi.org/10.1016/j.schres.2008.01.014

Tomaszczyk, J. C., & Fernandes, M. A. (2014). Age-related differences in attentional bias for emotional faces. *Aging, Neuropsychology, and Cognition: A Journal on Normal and Dysfunctional Development, 21,* 544–559. http://dx.doi.org/10.1080/13825585.2013.838201

Trémeau, F., Antonius, D., Cacioppo, J. T., Ziwich, R., Jalbrzikowski, M., Saccente, E., . . . Javitt, D. (2009). In support of Bleuler: Objective evidence for increased affective ambivalence in schizophrenia based upon evocative testing. *Schizophrenia Research, 107,* 223–231. http://dx.doi.org/10.1016/j.schres.2008.09.020

Walker, E. F., & Diforio, D. (1997). Schizophrenia: A neural diathesis-stress model. *Psychological Review, 104,* 667–685. http://dx.doi.org/10.1037/0033-295X.104.4.667

Wallwork, R. S., Fortgang, R., Hashimoto, R., Weinberger, D. R., & Dickinson, D. (2012). Searching for a consensus five-factor model of the Positive and Negative Syndrome Scale for schizophrenia. *Schizophrenia Research, 137,* 246–250. http://dx.doi.org/10.1016/j.schres.2012.01.031

Weierich, M. R., Treat, T. A., & Hollingworth, A. (2008). Theories and measurement of visual attentional processing in anxiety. *Cognition and Emotion, 22,* 985–1018. http://dx.doi.org/10.1080/02699930701597601

Wieser, M. J., Pauli, P., Weyers, P., Alpers, G. W., & Mühlberger, A. (2009). Fear of negative evaluation and the hypervigilance-avoidance hypothesis: An eye-tracking study. *Journal of Neural Transmission, 116,* 717–723. http://dx.doi.org/10.1007/s00702-008-0101-0

Williams, L. M., Loughland, C. M., Gordon, E., & Davidson, D. (1999). Visual scanpaths in schizophrenia: Is there a deficit in face recognition? *Schizophrenia Research, 40,* 189–199. http://dx.doi.org/10.1016/S0920-9964(99)00056-0

Woody, M. L., Owens, M., Burkhouse, K. L., & Gibb, B. E. (2016). Selective attention toward angry faces and risk for major depressive disorder in women: Converging evidence from retrospective and prospective analyses. *Clinical Psychological Science, 4,* 206–215. http://dx.doi.org/10.1177/2167702615581580

Received February 18, 2016
Revision received June 1, 2016
Accepted July 20, 2016 ■