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Intact unconscious processing of eye contact in schizophrenia

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ABSTRACT

The perception of eye gaze is crucial for social interaction, providing essential information about another person's goals, intentions, and focus of attention. People with schizophrenia suffer a wide range of social cognitive deficits, including abnormalities in eye gaze perception. For instance, patients have shown an increased bias to misjudge averted gaze as being directed toward them. In this study we probed early unconscious mechanisms of gaze processing in schizophrenia using a technique known as continuous flash suppression. Previous research using this technique to render faces with direct and averted gaze initially invisible reveals that direct eye contact gains privileged access to conscious awareness in healthy adults. We found that patients, as with healthy control subjects, showed the same effect: faces with direct eye gaze became visible significantly faster than faces with averted gaze. This suggests that early unconscious processing of eye gaze is intact in schizophrenia and implies that any misjudgments of gaze direction must manifest at a later conscious stage of gaze processing where deficits and/or biases in attributing mental states to gaze and/or beliefs about being watched may play a role.

1. Introduction

The accurate perception of eye gaze is crucial for social interaction, providing essential information about another person's goals, intentions, and focus of attention (Baron-Cohen, 1995; Bayliss et al., 2011; Emery, 2000). Thus, a critical factor for healthy social functioning is the capacity to rapidly detect eye contact from other individuals (e.g., Loveland and Landry, 1986; Mundy and Crowson, 1997; Senju et al., 2005a; von Grunau and Anston, 1995). Humans have an innate mechanism for attending to eyes (Haith et al., 1977) and gaze direction (Farroni et al., 2002; Hood et al., 1998). Within the first days of life, babies show a bias toward looking at faces with direct eye contact compared to faces with closed eyes or averted gaze (Haith et al., 1977; Hood et al., 1998). This processing advantage for faces with direct eye gaze (the "eye contact effect") is maintained throughout life in healthy adults, with direct gaze being detected faster than averted gaze (Brothers, 1990; von Grunau and Anston, 1995), having a stronger influence on capturing attention (Conty et al., 2006; Driver et al., 1999; Senju and Hasegawa, 2005; von Grunau and Anston, 1995; Yokoyama et al., 2011), and being preferentially processed over averted gaze at a preconscious level to gain privileged access to conscious awareness (Stein et al., 2011).

People with schizophrenia suffer a wide range of social cognitive deficits (for reviews, see Green and Horan, 2010; Green and Leitman, 2008), including disturbances in the processing of eye gaze. For instance, patients spend less time spontaneously scanning eye regions of other people's faces compared to controls (Green and Phillips, 2004; Phillips and David, 1997) and have shown a bias to misjudge averted gaze as being direct (Hooker and Park, 2005; Rosse et al., 1994; Tso et al., 2012). Whether these abnormalities are a consequence of higher-order social–cognitive deficits, are driven by top-down beliefs about "being watched", or, instead, are caused by a more fundamental low-level perceptual impairment is currently unknown.

The literature to date on disturbances in gaze perception in schizophrenia suggests that the observed impairments may reflect a late stage of gaze processing, affecting the evaluation of eye gaze (Franck et al., 1998, 2002; Hooker and Park, 2005; Tso et al., 2012). For instance, the reported bias to misjudge averted gaze as direct appears task dependent. When patients are asked to make self-referential decisions about whether another person's gaze is directed towards them or not (e.g., are the eyes looking at **you** or away?), the direct gaze bias is reported (Hooker and Park, 2005; Rosse et al., 1994; Tso et al., 2012). However, when patients make simple direction judgments (e.g., are the eyes directed left or right?), the bias has not been reliably observed (Franck et al., 1998, 2002). These effects of task instruction raise questions about whether direct gaze bias in schizophrenia may result from either a self-referential decision bias or a higher-level impairment concerned with attributing intentional mental states to eye gaze (i.e., when asked is the person looking at you? – which is a probe about the other person's intention), rather than an early perceptual processing deficit per se.

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However, the data are far from conclusive with regard to ruling out an early impairment concerned with the encoding of gaze direction in schizophrenia. For instance, although Franck et al. (1998, 2002) found no evidence of direct gaze bias using a left/right judgment task that appeared to eliminate mental state attributions and self-referential processing, their studies also failed to detect any bias using the standard self-referential categorization task (Franck et al., 2002), suggesting that the results may be dependent on sample characteristics rather than task instructions. Also, Hooker and Park (2005) convincingly ruled out a generalized low-level perceptual deficit accounting for gaze disturbance in schizophrenia, but their study did not directly assess perceptual mechanisms specific to gaze perception (in the absence of self-referential judgments), which might be impaired in this group. Given that direct eye gaze can also signal threat (Emery, 2000) and patients with schizophrenia show a hypersensitivity to threat signals (Bentall and Kaney, 1989; Blackwood et al., 2001; Fear et al., 1996), there is theoretical impetus to comprehensively investigate early detection of direct gaze signals in schizophrenia.

Research to date using task instructions that require either self-referential decisions or left/right gaze discrimination judgments has only considered one aspect of gaze perception; the ability to consciously differentiate gaze deviations. Thus, it remains unknown whether or not patients show abnormalities in the simple detection of eye gaze direction. In particular, do they show evidence of the rapid preferential detection of direct eye contact (Brothers, 1990; Conty et al., 2006; Driver et al., 1999; Senju & Hasegawa, 2005; Stein et al., 2011; von Grunau and Anston, 1995; Yokoyama et al., 2011)? This is a question that cannot be addressed measuring gaze discrimination thresholds.

To directly test whether disturbances in gaze processing in schizophrenia originate at an early detection stage of gaze processing, it is necessary to employ methods that (a) do not require a discriminative judgment about gaze direction and (b) tap preconscious stages of gaze processing where eye contact is first registered in the visual system. Thus, in this study we use a technique known as continuous flash suppression (CFS; Tsuchiya and Koch, 2005) to probe unconscious mechanisms leading to rapid detection of eye-contact. The CFS paradigm involves suppressing a target stimulus from conscious awareness for an extended period of time. Potency of the target to break into awareness, as measured with simple detection response times, is considered an index of unconscious processing (Tsuchiya et al., 2009). It has been shown in healthy individuals that target faces with direct eye gaze break into awareness earlier (and are thus detected earlier) than target faces with averted gaze (Stein et al., 2011; Yokoyama et al., 2013), indicating preferential and distinct processing of direct eye contact that is early, is automatic, and occurs in the absence of conscious awareness.

We hypothesized that if disturbances in gaze processing in schizophrenia reflect imprecision in the initial preconscious representation of eye gaze directions, we would see reduced differences in suppression times between direct and averted gaze compared to control participants (as averted gaze will sometimes be mistakenly encoded as direct). Alternatively, if distorted perception of eye gaze has a higher-level cognitive origin, patients with schizophrenia should show a similar advantage of direct over averted gaze in suppression times as healthy controls.

2. Method

2.1. Participants

The study consisted of 24 Caucasian clinical participants (18 M/6 F) and 24 healthy controls (18 M/6 F). Patients were recruited from the Volunteer Schizophrenia Research Register of the Australian Schizophrenia Research Bank (Loughland et al., 2010) and Macquarie Belief Formation Volunteer Register. Diagnosis of schizophrenia was confirmed using the Diagnostic Interview for Psychosis (Castle et al., 2006). Exclusion criteria for both groups included current or past central nervous system disease or history of head injury, current substance abuse (as per DSM-V), previous persistent substance abuse (met DSM-V criteria > 2/past 5years), and less than 8years of formal education. All patients were on stable doses of antipsychotic medication and each participant had normal or corrected vision. Participants gave written informed consent, which was approved by Macquarie University's Ethics Committee.

2.2. Apparatus and stimuli

We closely followed the method of Stein et al (2011). Participants viewed dichoptic displays on a CRT monitor (resolution: 1024 × 768, 60 Hz) through a stereoscope. They were seated 57 cm from the screen with their head stabilized in a chin rest. Two red frames (10.6° × 10.6°) were displayed side-by-side on the screen, such that only one frame was visible to each eye. To further support binocular alignment of these images, fusion contours (width 0.8°) consisting of random noise pixels were presented within the red frames. In the center of each frame, a red fixation dot was also presented. We used face stimuli created by Senju and Hasegawa (2006). These were grayscale digital photographs of four adult Asian females with neutral facial expressions with their eyes either gazing left, right or direct. Half of the faces were oriented to the left and half to the right. This offered control over potential confounding influences of local contrast differences and greater eye symmetry present in faces with direct gaze and straight head direction (Langton et al., 2004). All stimuli were equated in contrast and luminance and presented within an oval aperture (3.3 × 4.6). Edges of the aperture were blurred to assist suppression of the face during CFS masking.

2.3. Procedure

Fig. 1 below illustrates the task and stimuli. Participants maintained fixation throughout the experiment. Each trial began with a 1 s presentation of the red frames, fusion contours, and fixation dots on a uniform black background. Next, high-contrast colored Mondrian-like masks (9.0 × 9.0) flashed at a frequency of 10 Hz to one randomly selected eye. In the opposite eye, a face stimulus was gradually introduced by linearly ramping up stimulus contrast from 0% to 100% within a period of one second from the beginning of the trial. Following this, the contrast of the masks was linearly decreased to 0% over a period of 7 s. Face stimuli were presented to either the left or right of the fixation dot (horizontal center-to-center distance 2.7°) at a random vertical position relative to the fixation dot (maximum vertical center-to-center distance 2.1°). Participants were required to press the left or right arrow key to indicate on which side of fixation the face appeared. They were instructed to respond as fast and as accurately as possible when any part of the face became visible. Note the variable of interest was suppression time — the participants' task was simply to detect a face and that no specific response to gaze direction was required. This allowed us to assess early gaze processing mechanisms whilst eliminating the influence of high-level cognitive factors that might influence measurements of gaze perception (Franck et al., 2002; Hooker and Park, 2005; Teufel et al., 2009). Participants completed 80 trials divided into two blocks. Each combination of four facial identities, two gaze directions (direct, averted), and two head orientations (left, right) occurred equally often within each block. We calculated mean response times (RTs) needed to localize faces with direct versus averted gaze based on trials with correct responses only.

2.4. Clinical measures

Clinical demographics were recorded and symptom severity was assessed using the Scales for Assessment of Positive and Negative Symptoms (SAPS & SANS; Andreasen, 1983, 1984). To test for any

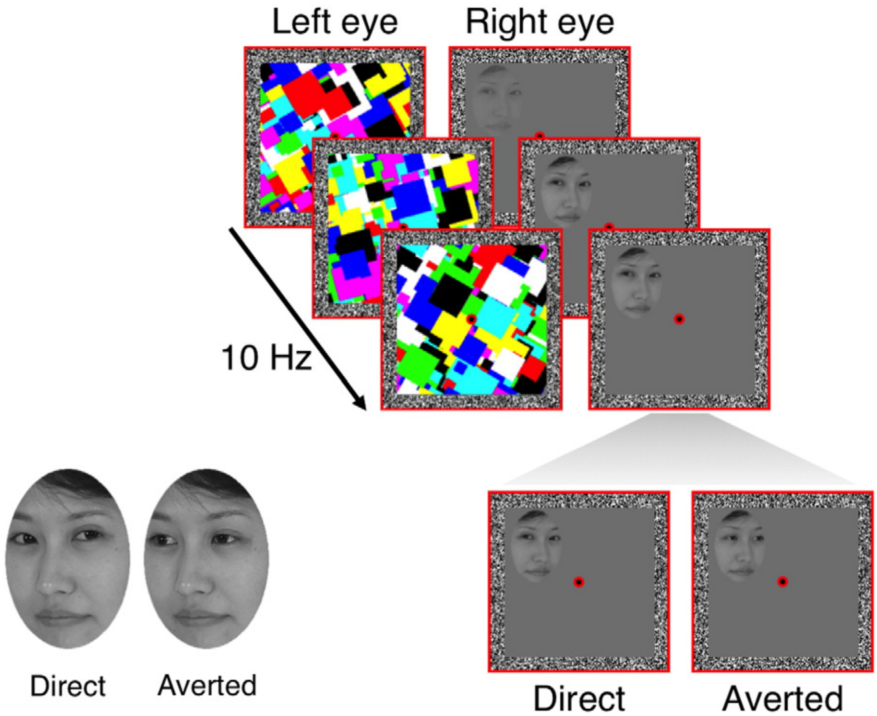

Fig. 1. Face stimuli and a schematic of an example trial. Participants were presented with masks to one eye, while a face (with direct or averted gaze) was presented to the other eye. This resulted in the temporary suppression of the face stimulus from conscious awareness. Participants were required to indicate on which side of fixation the face broke suppression (became visible).

relationship with clinical demographics, we conducted correlation analyses on the magnitude of the eye-contact effect (i.e., the difference score) against illness duration, age of onset, mean SAPS, and mean SANS global scores. We also conducted similar analyses on suppression times for direct gaze and averted gaze.

3. Results

Groups did not differ significantly on age (Clinical M = 47.23, SD = 10.09; Control M = 43.5, SD = 1.14; t(23) = 0.26 p = 0.26). Patients were a high functioning chronic sample with mean illness duration of 23.31 years (SD = 10.09) and mild symptomatology: mean SAPS global score of 1.27 (SD = 1.05); mean SANS global score of 1.86 (SD = 0.96).

We calculated the mean response time (RT) needed to localize faces with direct and averted gaze. This calculation was based on trials with correct responses only. The number of no responses and incorrect responses did not differ between groups or conditions (all *ts* < 1, *ps* > .05). Mean RTs were compared using a two-way mixed analysis of variance (ANOVA) with group (patients or controls) as the between-group factor and gaze direction (direct or averted) as the within group factor.

We found a significant main effect of gaze direction ($F(1,48) = 50.03$, $p = 0.0004$, $\eta_p^2 = 0.51$); faces with direct gaze were detected faster than faces with averted gaze (Fig. 2). No main effect of group ($F(1,48) = 0.12$, $p = 0.73$, $\eta_p^2 = 0.17$) or significant Group × Gaze Direction interaction was observed ($F(1, 48) = 1.06$, $p = 0.31$, $\eta_p^2 = 0.02$). Paired t-tests comparing direct and averted gaze RTs confirmed that patients responded significantly faster to direct gaze faces ($t(23) = 5.19$, $p = 0.0002$, $d = 2.16$), as did controls ($t(23) = 4.89$, $p = 0.0006$, $d = 2.04$). Bayesian statistics on the difference scores revealed that on average patients had a direct gaze advantage that was actually 127 ms faster than that of controls, but 95% credible intervals ranged from −137 ms to 385 ms, meaning the magnitude of this "eye contact effect" did not differ significantly between groups.

We found no relationships between the magnitude of the "eye contact effect" and clinical variables. Nor were there any significant correlations between response times for direct or averted gaze with clinical measures.

4. Discussion

Using a technique known as CFS, we investigated early unconscious processing of direct and averted eye gaze in patients with

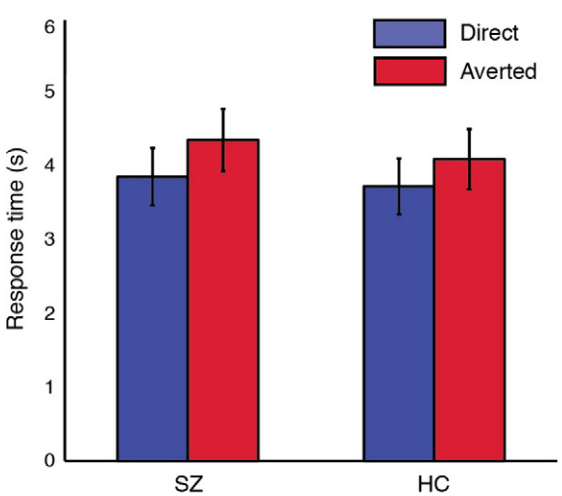

Fig. 2. The bar graphs represent mean response times in each group to faces breaking suppression with direct and averted gaze. Error bars denote standard error. SZ, Schizophrenic patients; HC, healthy controls.

schizophrenia. We compared suppression durations for faces with direct eye gaze to those with averted gaze. We found that faces with direct gaze overcame suppression significantly faster than faces with averted gaze in both patients and control participants. No significant difference in the magnitude of this "eye contact effect" was observed between groups. Thus, while there are reports that patients with schizophrenia make errors when consciously judging direction of another person's gaze (Hooker and Park, 2005; Rosse et al., 1994; Tso et al., 2012), our data suggest that unconscious processing of gaze is intact in schizophrenia.

Previous research on gaze processing in schizophrenia has reported disturbances in the conscious perception of eye gaze (Hooker and Park, 2005; Rosse et al., 1994; Tso et al., 2012). However, no study has assessed the integrity of preconscious mechanisms underlying gaze perception, such as those contributing to the rapid detection of eye contact. By employing CFS as a means to probe unconscious gaze mechanisms, we were able to examine the earliest stages of gaze processing in schizophrenia, removing any influence of a higher-level deficit that might affect conscious perceptual judgments. Thus, our findings of unimpaired unconscious processing of eye gaze in schizophrenia (as indicated by CFS suppression times being comparable to controls in both the averted and direct gaze conditions) provide support for abnormalities in gaze processing being confined to a higher order impairment affecting the interpretation of another's gaze (Franck et al., 2002; Teufel et al., 2009), rather than a perturbation related to the preconscious encoding of eye gaze direction within the visual system. Also, our data reveal no evidence for any preconscious hypersensitivity to direct eye contact as a threat signal in schizophrenia (Bentall and Kaney, 1989; Blackwood et al., 2001).

Much research on social cognition in schizophrenia is consistent with a high-level account of gaze disturbances in these patients. For instance, deficits in inferring intentional mental states or "Theory of Mind" (Kington et al., 2000; Russell et al., 2000) may lead to errors in judging another person's eye gaze when patients are asked whether another person is looking at them. It has been shown in healthy subjects that attributing mental states to gaze can influence judgments of gaze direction (Teufel et al., 2009). Thus, a reduced ability to accurately attribute other people's mental states to their eye gaze signals, as seen in schizophrenia (Kington et al., 2000; Russell et al., 2000), could result in a self-referential direct eye gaze bias in these patients (Hooker and Park, 2005; Rosse et al., 1994; Tso et al., 2012). In support of this, Franck et al. (2002) showed that patients displayed relative difficulty (i.e., reaction times) judging if a person's gaze was directed towards them or not (a task instruction that prompts mental state attributions) compared to when making simple direction judgements from the same stimuli, whereas controls showed no such response time differences.

It is also possible that the top-down effects of delusional beliefs about "being watched" could lead to errors in consciously judging gaze direction in schizophrenia when instructions are self-referential. This accords with Bayesian models of perception that predict abnormalities in one's beliefs lead to abnormalities in one's perception, and vice versa (Fletcher and Frith, 2009; Schmack et al., 2013; Sterzer et al., 2008). Recent studies in healthy subjects show that humans exhibit a prior expectation (bias) to perceive gaze as direct when stimulus ambiguity is high (Mareschal et al., 2013). This may suggest, that despite receiving intact sensory evidence, patients with schizophrenia rely more on this inherent bias to guide perception. In line with this view, research shows that patients exhibit a tendency to discount new sensory evidence in favor of their delusional beliefs (Freeman et al., 2004; Langdon and Coltheart, 2000). Studies also report that the tendency to endorse averted gaze as direct is amplified under high levels of stimulus ambiguity (Hooker and Park, 2005; Rosse et al., 1994; Tso et al., 2012). This suggests that the threshold at which prior expectations for direct gaze are weighted over incoming sensory evidence might be lower in individuals with schizophrenia. However, whether this is likely to reflect a deficit in Bayesian inference (Fletcher and Frith, 2009) or greater noise within gaze processing channels beyond initial preconscious encoding stages (Baron-Cohen, 1995), requires further examination.

In conclusion, the rapid detection of eye gaze is pivotal for healthy social interactions as it provides essential information about another person's goals, intentions, and focus of attention. Although there are reports that patients with schizophrenia exhibit impairments in consciously judging gaze direction, our data suggest a preservation of early preconscious mechanisms that facilitate rapid detection of direct eye contact. While we have presented some possible social contextual and belief-driven factors that may account for errors in conscious judgments of gaze direction in schizophrenia, it is clear that more research concerning the interplay between aberrant gaze processing, social–cognitive deficits and top-down belief-driven effects is needed (Senju et al., 2005b).

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Conflict of interest

The authors declare no conflict of interest.

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