




Intact prioritisation of unconscious face processing in schizophrenia

Nathan Caruana ^{a,b}, Timo Stein^c, Tamara Watson^d, Nikolas Williams^{a,b} and Kiley Seymour^{a,d}

^aARC Centre of Excellence in Cognition and Its Disorders, Sydney, Australia; ^bDepartment of Cognitive Science, Macquarie University, Sydney, Australia; ^cDepartment of Psychology, University of Amsterdam, Amsterdam, The Netherlands; ^dSchool of Social Sciences and Psychology, Western Sydney University, Sydney, Australia

ABSTRACT

Introduction: Faces provide a rich source of social information, crucial for the successful navigation of daily social interactions. People with schizophrenia suffer a wide range of social-cognitive deficits, including abnormalities in face perception. However, to date, studies of face perception in schizophrenia have primarily employed tasks that require patients to make judgements about the faces. It is, thus, unclear whether the reported deficits reflect an impairment in encoding visual face information, or biased social-cognitive evaluative processes.

Methods: We assess the integrity of early unconscious face processing in 21 out-patients diagnosed with Schizophrenia or Schizoaffective Disorder (15M/6F) and 21 healthy controls (14M/7F). In order to control for any direct influence of higher order cognitive processes, we use a behavioural paradigm known as breaking continuous flash suppression (b-CFS), where participants simply respond to the presence and location of a face. In healthy adults, this method has previously been used to show that upright faces gain rapid and privileged access to conscious awareness over inverted faces and other inanimate objects.

Results: Here, we report similar effects in patients, suggesting that the early unconscious stages of face processing are intact in schizophrenia.

Conclusion: Our data indicate that face processing deficits reported in the literature must manifest at a conscious stage of processing, where the influence of mentalizing or attribution biases might play a role.

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Schizophrenia is a complex psychiatric condition which affects multiple cognitive processes – including social and affective cognition – which can have severe and negative consequences for social functioning, quality of life and personal safety (Kee, Green, Mintz, & Brekke, 2003; Penn, Spaulding, Reed, & Sullivan, 1996). Importantly, social difficulties are reliably observed in schizophrenia, even when classical (positive) symptoms of the disorder (e.g., delusions and hallucinations) are controlled with medication (Brüne, 2005). Research on poor interpersonal functioning in schizophrenia has primarily focused on

impairments of emotion recognition and mental-state reasoning. For instance, deficits in social perception, emotion recognition, Theory of Mind (ToM), and mentalising processes (i.e., the ability to understand and infer the mental perspectives, thoughts, beliefs or intentions of others) have all been reported in the literature (see Billeke & Aboitiz, 2013 for review). However, little is known of more fundamental perceptual abilities needed to process a face. Indeed, it has been proposed that poor social cognition in schizophrenia may result from aberrant perception of socially relevant stimuli (e.g., Darke, Peterman, Park, Sundram, & Carter, 2013; Fletcher & Frith, 2009; Silverstein, 2016; Uhlhaas & Mishara, 2006). However, the empirical evidence to support this hypothesis is unclear.

Faces provide a rich source of social information (e.g., identity, gender, age, mental and emotional states), which if accurately perceived, enable us to effectively navigate our social interactions with others. A large body of literature has demonstrated that face perception is supported by specialised neural mechanisms, which have evolved to support the prioritised processing of conspecific face-bound information (e.g., Harries & Perrett, 1991; Haxby et al., 1999; Haxby, Hoffman, & Gobbini, 2002; Kanwisher, McDermott, & Chun, 1997; Perrett et al., 1985). Face perception and face recognition ability also critically depends on the holistic processing of face configuration (see Piepers & Robbins, 2012 for a review), whereby perceptually-invariant properties of faces, such as the shape and distance between facial features, are rapidly integrated (McKone & Yovel, 2009). Holistic processing is often examined using face inversion paradigms, in which participants are presented with upright and inverted faces. Studies consistently show an enhanced face discrimination for upright faces compared to inverted faces, suggesting a general sensitivity of the visual system to the canonical configuration of faces (Yin, 1969). Although there have been reports of holistic face processing impairments in schizophrenia (Baudouin, Vernet, & Franck, 2008; Joshua, 2010; Joshua & Rossell, 2009; Kim et al., 2010; Shin et al., 2007; Soria Bauser et al., 2012), the evidence is mixed (e.g., see Butler et al., 2008; Chambon, Baudouin, & Franck, 2006; Schwartz, Marvel, Drapalski, Rosse, & Deutsch, 2002).

Given the functional importance of accurately perceiving and evaluating social signals in faces, it has been suggested that aberrant face perception may explain why face-to-face interactions often lead to significant confusion, misinterpretation and distress in patients with schizophrenia (e.g., Doop & Park, 2009). Studies in patients have primarily reported difficulties associated with discriminating and recognising emotional expression from faces (e.g., Addington & Addington, 1998; Doop & Park, 2009; Kerr & Neale, 1993; Kohler, Walker, Martin, Healey, & Moberg, 2010; Marwick & Hall, 2008; Norton, McBain, Holt, Ongur, & Chen, 2009; Pinkham, Brelsinger, Kohler, Gur, & Gur, 2011; Whittaker, Deakin, & Tomenson, 2001). But, there are also findings of deficits in discriminating age (Delerue, Laprevote, Verfaillie, & Boucart, 2010; Gessler, Cutting, Frith, & Weinman, 1989; Kohler, Bilker, Hagendoorn, Gur, & Gur, 2000; Schneider, Gur, Gur, & Shtasel, 1995, 2006) gender (Bigelow et al., 2006; Hall et al., 2008), and identity (Addington & Addington, 1998; Evangelini & Broks, 2000; Hooker & Park, 2002; Kerr & Neale, 1993; Kim et al., 2010; Kucharska-Pietura, David, Masiak, & Phillips, 2005; Mueser et al., 1996; Penn et al., 2000; Salem, Kring, & Kerr, 1996; Shin et al., 2007; Soria Bauser et al., 2012; Whittaker et al., 2001) from faces in this group. It should be noted, however, that there are many inconsistent findings across the literature, which may reflect differences in illness *state* and symptom severity (Kucharska-Pietura et al., 2005; Ventura, Wood,

Jimenez, & Hellemann, 2013). Alternatively, it has been suggested that variation in higher-level cognitive demands of the tasks used to assess face perception may play a role (Bortolon et al., 2015). Indeed, some studies reveal that patients perform just as well as controls when given unlimited time to complete the task (e.g., Butler et al., 2008; Goghari, Macdonald, & Sponheim, 2011).

Thus, it is currently unclear whether the poor performance on face perception tasks reported in schizophrenia reflects a true *perceptual* aberration. For instance, a number of tasks designed to examine perceptual abnormalities in patients require intact working memory function, which is known to be impaired in schizophrenia (Chen, Norton, McBain, Ongur, & Heckers, 2009). Moreover, a majority of studies fail to dissociate a deficit in perception from a deficit in one's ability to socially *evaluate* the perceived stimulus. For instance, face perception tasks often require the synthesis of both perceptual and mentalizing abilities (e.g., Kohler et al., 2010). For example, when asking a participant to determine whether someone in a photograph is angry or sad, the task requires a perceptual discrimination but may also engage ToM processes. Thus, poor performance on face perception tasks might reflect higher-level disturbances or biases relating to how faces are consciously evaluated rather than a perceptual deficit *per se*. In support of this, face processing deficits are commonly reported with ToM impairments in schizophrenia (e.g., Irani et al., 2006). Moreover, task instruction has been shown to influence judgements of facial cues in schizophrenia (e.g., Franck et al., 2002; Seymour et al., 2017). Poor performance is also more consistently observed in emotion recognition and discrimination tasks that place greater demand on these higher-level mentalising processes compared to face identity tasks (Bortolon et al., 2015; Kohler et al., 2010).

In a recent review of social perception and cognition in schizophrenia, Billeke and Aboitiz (2013) identified a critical need to assess the integrity of early visual processing mechanisms underlying face perception. However, to date, most measures that examine perceptual sensitivity to faces in schizophrenia are confounded by the aforementioned influence of disruptions in higher-level cognitive processes. As such, no study has examined the more fundamental aspects of visual face processing with these confounding factors removed (also see Watson, 2013 for review). This is a pertinent focus of inquiry, with the field now recognising the need to develop clearer distinctions between impairments of social “perception” and “cognition” in schizophrenia, so that appropriate intervention targets can be identified (Green et al., 2008).

In the current study, we use a psychophysical technique known as continuous flash suppression (CFS; Tsuchiya & Koch, 2005) to probe the integrity of mechanisms underlying the earliest stages of face perception. The so-called “breaking CFS” (b-CFS) paradigm (Gayet, Van der Stigchel, & Paffen, 2014; Jiang, Costello, & He, 2007; Stein, Hebart, & Sterzer, 2011) can be used to assess face-specific processing and perception without requiring participants to make judgements that might otherwise engage higher-level cognitive deficits, biases or mentalising impairments. During the b-CFS experiment, stimuli presented to one eye are rendered invisible for several seconds by presenting high-contrast, contour-rich masks to the other eye. These masks initially dominate perception until the stimulus presented to the other eye overcomes suppression and breaks into awareness. The time it takes observers to detect the stimulus is a measure of its potency to gain access to conscious awareness (Gayet et al., 2014; Jiang et al., 2007; Stein et al., 2011). Recently, researchers have used b-CFS to examine face-specific processing at an unconscious level,

demonstrating a unique potency of upright faces to gain privileged access to conscious awareness over inverted faces and non-face stimuli (e.g., Stein, Reeder, & Peelen, 2015; Stein, Sterzer, & Peelen, 2012; Zhou, Zhang, Liu, Yang, & Qu, 2010). Specifically, they showed that upright faces broke suppression faster than inverted faces, and this inversion effect was larger than for non-face objects. This face-specific inversion effect in breaking CFS has been considered a hallmark of face-specific (holistic) processing at early stages of visual encoding (Stein et al., 2012). Here, we adapt this method to examine whether face processing impairments previously reported in schizophrenia arise from a fundamental deficit at the earliest stages of face encoding, prior to the recruitment of higher-level evaluative processes. In such a case, we would expect to see a reduced (or absent) prioritisation of upright faces, as evidenced by smaller inversion effects (i.e., smaller difference in suppression times between upright and inverted stimuli) for faces but not for non-face stimuli (i.e., chairs).

Method

Participants

The study consisted of 21 out-patients diagnosed with Schizophrenia or Schizoaffective Disorder (15M/6F) and 21 healthy controls (14M/7F). Groups did not differ significantly on age (Patients $M = 50.14$, $SD = 7.95$; Control $M = 46.68$, $SD = 8.68$; $t(40) = -1.35$, $p = 0.184$, $BF_{10} = 0.627$). Exclusion criteria for both groups included current or past central nervous system disease or history of head injury (unconscious >1 h), current substance abuse (as per DSM-V), previous persistent substance abuse (as per DSM-V criteria), and less than eight years of formal education. Prior to testing participants gave written informed consent, which was approved by Macquarie University's Ethics Committee.

Patients were recruited from the Volunteer Schizophrenia Research Register of the Australian Schizophrenia Research Bank (Loughland et al., 2010) and the Macquarie Belief Formation Volunteer Register. All patients had been formally diagnosed by a clinical psychologist or psychiatrist but were additionally assessed against current DSM-V criteria using the Diagnostic Interview for Psychosis (Castle et al., 2006). Clinical demographics were recorded, and symptom severity was assessed using the Scales for Assessment of Positive and Negative Symptoms (SAPS & SANS; Andreasen, 1983, 1984). Our patients were considered stable with mild symptomology; hallucinations ($M = 0.50$, $SD = 1.05$, *Scale range* = 0–5), delusions ($M = 1.55$, $SD = 1.15$, *Scale range* = 0–5), bizarre behaviour ($M = 0.75$, $SD = 1.07$, *Scale range* = 0–3), positive thought disorder ($M = 1.20$, $SD = 1.44$, *Scale range* = 0–4) and negative symptoms ($M = 2.09$, $SD = 0.28$, *Scale range* = 0–4). Valid clinical rating data could not be collected from one patient at the time of testing. All patients were on stable doses of antipsychotic medication and each participant had normal or corrected vision.

Healthy controls were screened using a structured interview based on the affective, psychotic and substance abuse screening modules from the Structural Clinical Interview for Axis I Disorders previously outlined under DSM-IV (SCID-1; First, Spitzer, Gibbon, & Williams, 2002). Control participants also completed the brief version of the Schizotypal Personality Questionnaire (SPQ-B; Raine & Benishay, 1995). The range of scores obtained ($M = 5.81$, $SD = 4.70$) were consistent with previous studies involving non-clinical community samples (e.g., Compton, Chien, & Bollini, 2007).

Assessment of higher-level cognitive function

Participants completed the National Adult Reading Test (NART; Nelson & Willison, 1991) as a measure of premorbid intelligence. There were no significant differences between groups on the full-scale NART IQ estimate (Patients $M = 107.76$, $SD = 10.36$; Control $M = 108.43$, $SD = 9.75$; $t(40) = 0.22$, $p = 0.831$, $BF_{10} = 0.309$). Given the aims of our study, we also assessed participants on social cognitive function, namely their ToM ability. Participants read four short stories; two assessing first-order ToM and two assessing second-order ToM (see Langdon, Connors, & Connaughton, 2014). We verified the previous reports of a ToM deficit in schizophrenia. This was demonstrated by a significant main effect of group ($F(1,40) = 11.84$, $p = 0.001$, $\eta^2 = 0.228$) and a question type*group interaction ($F(1,40) = 13.81$, $p < 0.001$, $\eta^2 = 0.055$), in which poorer performance by patients compared to controls trended towards significance on first-order ToM questions, ($t(28.91) = 2.05$, $p = 0.050$, $d = 0.632$, $BF_{10} = 1.553$) and was statistically significant on second-order ToM questions, ($t(33.43) = 3.76$, $p < 0.001$, $d = 1.16$, $BF_{10} = 51.65$). There were no significant group differences on comprehension questions based on the same stories ($ps > 0.644$, $BF_{10} < 0.331$).

Apparatus and stimuli

We closely implemented a similar method to Stein et al. (2015), however we restricted our design to 4 stimulus conditions; upright and inverted faces and chairs. Participants viewed dichoptic displays on a CRT monitor (resolution: 1280×1024 , 60 Hz) through a mirror stereoscope. Participants were seated 57 cm from the screen with their head stabilised in a chin rest. Two red frames ($10.4^\circ \times 10.4^\circ$) were displayed side-by-side on the screen, separated by 21.6° of visual angle so that each frame was only visible to one eye. Prior to testing, we confirmed this with participants by asking them to report what they saw when they viewed the stimulus monocularly and binocularly. To support binocular fusion of the two eyes' images, fusion contours (width 0.5°) consisting of random noise pixels were presented within the frames. In the centre of each frame, a black fixation dot (0.2°) was also continuously presented. Participants were asked to maintain fixation on that dot for the duration of the experiment. We used the same face ($2.1\text{--}3.0^\circ \times 3.1^\circ$) and chair ($1.7\text{--}2.8^\circ \times 3.6^\circ$) stimuli implemented by Stein et al. (2015). Faces were photographs of young Caucasians selected from the "Center for Vital Longevity Face Database" (Minear & Park, 2004), and chairs were selected from the Internet. All stimuli were presented as greyscale images, with mean luminance and RMS contrast normalised to match low-level visual properties across conditions. All images were rotated 180° to create inverted stimuli. In each of the upright and inverted conditions, stimuli were presented to the non-dominant eye (established prior to testing using the near convergence test; Rice, Leske, Smestad, & Holmes, 2008). In the dominant eye, high-contrast contour-rich masks (9.2°) were presented to induce interocular suppression (see Figure 1. and Stein et al., 2015 for a detailed description of stimulus development and presentation).

Procedure

Each trial began with a one second presentation of the red frames, fusion contours, and fixation dots on a uniform black background (Figure 1.). Next, the contour-rich masks

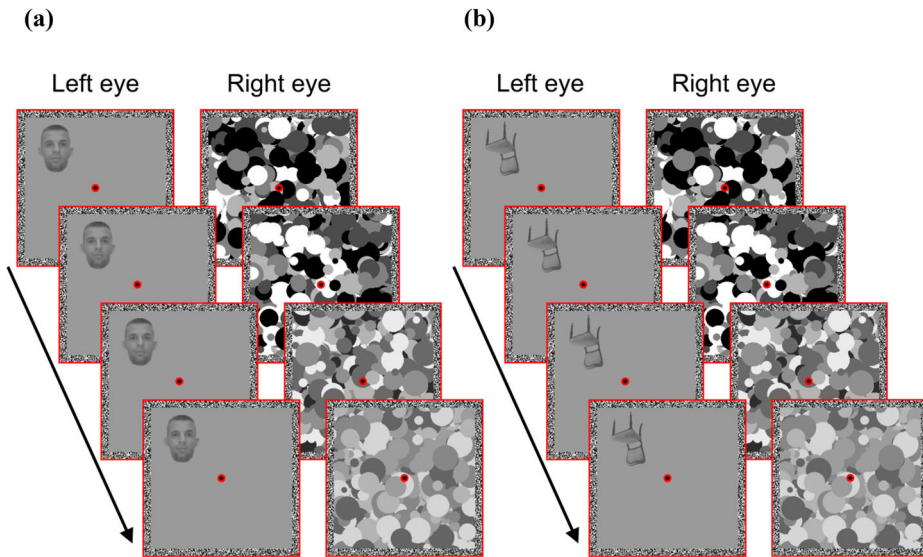


Figure 1. A schematic example of a trial using upright face stimuli (a) and inverted chair stimuli (b) the face and chair stimuli presented using the b-CFS paradigm. Participants were presented with flashing masks to their dominant eye, whilst an image of a face or chair was presented to their non-dominant eye. Stimuli were either presented upright or inverted. The mask presented to the dominant eye resulted in the temporary suppression of the face or chair stimulus from conscious awareness. Participants were required to press a button as quickly and accurately as possible to indicate which quadrant the face or chair became visible.

flashed at a frequency of 10 Hz to the dominant eye. In the non-dominant eye, either a face or chair 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. The mask contrast was then linearly decreased to 0% over the following 7.9 s interval. The face or chair stimulus was presented to either the top-left, top-right, bottom-left or bottom-right quadrant of the fusion contour, centred at an eccentricity of 3.3 degrees of visual angle from fixation. Participants were required to press one of four buttons (“F” or “V” and “J” or “N” using the left or right hand respectively) on a QWERTY keyboard as quickly and accurately as possible to indicate which quadrant the face or chair became visible.

Importantly, participants were instructed to respond as soon as *any part* of the stimulus became visible (i.e., broke suppression) and were not required to make judgments about the stimulus itself. Suppression time – the time taken for the participant to perceive and report the location of the stimulus – was recorded. We calculated mean response times needed to localise faces and chairs under upright or inverted presentation on trials with correct responses only. Accuracy in identifying the stimulus location was above 90% for both groups, on all stimulus category and orientation trial types (Patients $M = 91.8\%$, $SD = 7.3\%$; Control $M = 97.1\%$, $SD = 2.9\%$). Note, a Welch independent samples t-test is reported here since equality of variance between groups could not be assumed (Levene’s $p = 0.027$).

The experiment comprised 160 trials (40 upright face, 40 inverted face, 40 upright chair, 40 inverted chair). Participants were given a short break half-way through the experiment. The number of stimuli from each category (face, chair), and orientation (upright,

inverted) were counterbalanced within and across blocks. The location of stimulus presentation was also counterbalanced such that stimuli were presented to all quadrants equally. However, we did not restrict which stimulus type went to each quadrant.

Analyses

Statistical analyses were conducted using the free software JASP (JASP Team, 2017). Accuracy and suppression time effects were examined using repeated measures ANOVAs. Student *t*-tests were used for all follow-up analyses to characterise relevant interaction effects unless equality of variance could not be assumed for independent sample comparisons, in which case Welch's independent samples *t*-tests are reported. We first used a classical frequentist approach to analyse our results. We then applied Bayesian statistics in order to determine whether effects reflected genuine evidence for the null hypothesis relative to the alternative hypotheses. A default Cauchy prior width of 0.707 was used. These Bayesian analyses were interpreted using established guidelines (Jeffreys, 1961; Lee & Wagenmakers, 2013).

Results

Suppression times were recorded as the time it took for a stimulus to reach awareness, measured via button press responses. For each participant, mean suppression times were log-transformed (\log_{10}) to account for the positive skew of the data (Gayet & Stein, 2017; Heyman, Moors, & Dick, 2014). For intuitive representation of the results in standard units (seconds), the log-transformed data are transformed back and used in the reporting of descriptive statistics and the plotting of the results (Figure 2).

Analysis of accuracy scores

Accuracy data were analysed using a three-way mixed ANOVA with factors: group (patients, controls), stimulus category (chairs, faces), and orientation (upright, inverted). This revealed a significant main effect of group ($F(40) = 16.52, p < 0.001, \eta^2 = 0.292$), with more errors made by patients than controls, and a marginally significant group*stimulus category interaction ($F(40) = 4.16, p = 0.048, \eta^2 = 0.008$), with patients making more errors than controls in each stimulus condition (all $ps < 0.015$), but proportionally more for

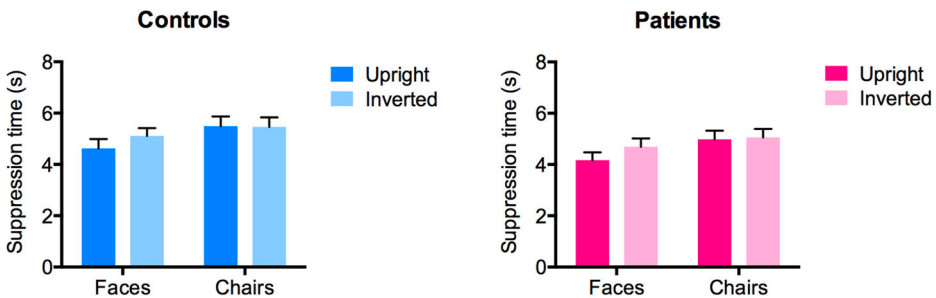


Figure 2. Mean back-transformed suppression times for upright and inverted face and chair stimuli in patients with schizophrenia and control participants. Error bars denote standard error.

chairs (upright, $M = 0.93$, $SD = 0.04$; inverted, $M = 0.94$, $SD = 0.04$) than faces (upright, $M = 0.95$, $SD = 0.03$; inverted, $M = 0.94$, $SD = 0.04$) relative to controls (upright chairs, $M = 0.97$, $SD = 0.03$; inverted chairs, $M = 0.98$, $SD = 0.03$; upright faces, $M = 0.97$, $SD = 0.03$; inverted faces, $M = 0.97$, $SD = 0.03$). We found no main or interaction effects for stimulus orientation (i.e., inversion; all $p > 0.439$).

Analysis of mean suppression scores

The log-transformed suppression times were analysed using a three-way mixed ANOVA with factors: group (patients, controls), stimulus category (chairs, faces), and orientation (upright, inverted). This analysis verified a significant main effect of stimulus category on suppression times ($F(40) = 41.60$, $p < 0.001$, $\eta^2 = 0.508$), with faster breakthrough occurring for faces compared to chairs (mean difference = 601.05, $SD = 583.56$); a significant main effect of orientation ($F(40) = 19.70$, $p < 0.001$, $\eta^2 = 0.330$), with upright stimuli breaking suppression faster than inverted stimuli (mean difference = 266.95, $SD = 439.33$); and a significant stimulus category*orientation interaction ($F(40) = 21.64$, $p < 0.001$, $\eta^2 = 0.350$). This interaction was characterised by a significant effect of orientation (i.e., inversion) for faces with “strong” evidence for the alternative hypothesis ($t(41) = -5.44$, $p < 0.001$, $d = -0.839$, $BF_{10} = 6642.54$) but no inversion effect for chairs, with “substantial” evidence for the null hypothesis ($t(41) = -0.63$, $p = 0.534$, $d = -0.097$, $BF_{10} = .201$). We found no evidence of a significant group difference between patients ($M = 4725.00$, $SD = 1509.76$) and controls ($M = 5171.57$, $SD = 1573.92$), with no significant effect of group $F(40) = 0.725$, $p < 0.400$, $\eta^2 = 0.018$) or interaction between the above factors and group (all $ps > 0.611$).

Analysis of inversion effect scores

The primary focus of this study was to determine whether the face inversion effect under b-CFS differs between groups. We calculated a chair inversion effect as a control comparison to examine face-specific effects (see Figure 3). For each participant, inversion effect scores were calculated for each stimulus category as the mean log suppression time for the inverted stimulus minus the mean log suppression time for the upright stimulus. These data were then analysed using two-way mixed ANOVA with factors: group (patients, controls) and stimulus category (chairs, faces). This analysis verified a significant main effect of stimulus category ($F(40) = 21.64$, $p < 0.001$, $\eta^2 = 0.350$, $BF_{10} = 2530.88$, with “decisive” evidence of larger inversion effects for faces ($M = 0.055$, $SD = 0.065$) than chairs ($M = 0.004$, $SD = 0.042$). We found no evidence of a significant main effect of group ($F(40) = 0.046$, $p = 0.831$, $\eta^2 = 0.001$, $BF_{10} = .272$), nor a group*stimulus category interaction ($F(40) = 0.196$, $p = 0.660$, $\eta^2 = 0.003$, $BF_{10} = .318$), with substantial evidence for the null hypothesis for both effects. Using a standard Pearson correlation, we also found no evidence of any association between individual differences in face inversion effects and higher-order ToM performance, for either patients or controls (all $ps > 0.08$).

Discussion

Using a technique known as b-CFS, we investigated the early fundamental stages of face processing in patients with schizophrenia. We compared suppression durations for

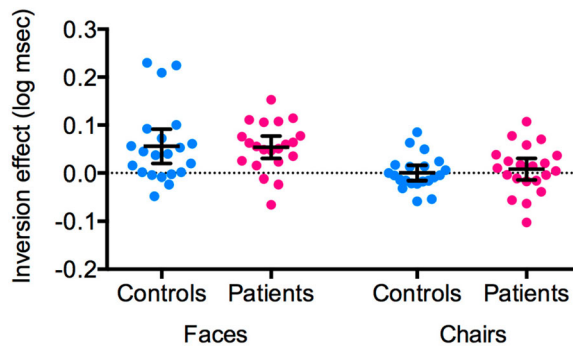


Figure 3. Mean inversion effect (i.e., inverted minus upright suppression time) on log-transformed data for face and chair stimuli in patients with schizophrenia and control participants. Error bars denote 95% confidence intervals.

upright and inverted faces and chairs using a modified version of Stein et al.'s (2015) b-CFS face inversion paradigm. We replicated the results reported by Stein et al., demonstrating that the visual processing of upright faces is prioritised by the visual system in controls. Importantly, we found no evidence of a group difference. Specifically, both patients and healthy controls became consciously aware of upright faces much faster than inverted faces, evidenced by significant face inversion effects in both groups. Strong inversion effects were not observed for chairs, consistent with previous research (Stein et al., 2015). Further, none of the main effects significantly interacted with group, and Bayesian statistics demonstrated substantial evidence for no differences in face inversion effects between groups.

Of critical importance to the current study, was that patients with schizophrenia exhibited the same early face-specific inversion effects as healthy controls. These findings align with other studies using unmasked stimuli that report intact holistic face processing in patients (Baudouin et al., 2008; Chambon et al., 2006; Joshua, 2010; Joshua & Rossell, 2009; Kim et al., 2010; Schwartz et al., 2002; Shin et al., 2007; Soria Bauser et al., 2012). While there have also been reports of a reduced or delayed face inversion effect in patients (Butler et al., 2008; Shin et al., 2007), our data suggest that preconscious stages of holistic face processing are intact in schizophrenia. Previous reports suggesting a deficit may therefore reflect an impairment in making judgments about a face once the face has reached conscious awareness.

The majority of studies reporting a deficit in face processing in schizophrenia have primarily asked participants to categorise emotional expressions from face stimuli (cf. Kohler et al., 2010), or to make conscious evaluations about whether the perceptual properties of two or more faces are the same or different (see Bortolon et al., 2015 for a review). In simple detection tasks, patients have been required to search for faces among non-face distractors (Campanella, Montedoro, Streeb, Verbanck, & Rosier, 2006; Chen et al., 2009; Chen, Norton, Ongur, & Heckers, 2007; Lee, Green, Mintz, & Brekke, 2003; McBain, Norton, & Chen, 2010; Zivotofsky, Oron, Hibsher-Jacobson, Weintraub, & Strous, 2008). In contrast, our b-CFS task required no comparative assessments or explicit judgments about the face or its features. Instead, participants were simply required to report when they noticed *any* visual stimulus and to indicate its location. In this way, our

measure of preferential processing for upright faces assessed a basic bottom-up mechanism for face perception and was unlikely to be affected by any higher-level cognitive impairment in working memory (Chen et al., 2009; Reichenberg & Harvey, 2007), attention (Beedie, Benson, Giegling, Rujescu, & St. Clair, 2012; Loughland, Williams, & Gordon, 2002; Morris, Griffiths, Le Pelley, & Weickert, 2013; Phillips & David, 1997; Silverstein et al., 2010a, 2010b; Williams et al., 1999) or social cognition (Billeke & Aboitiz, 2013). Thus, despite showing evidence for impaired social cognition in our patients (i.e., as evidence by poor ToM performance compared to controls), our findings of an intact face detection mechanism suggests no evidence for an early perceptual impairment in face-specific visual processing.

It has recently been proposed that social cognitive deficits reported in schizophrenia reflect a more general perturbation in early perceptual processing that is transferred to higher levels of cognition (e.g., Butler et al., 2008; Dakin, Carlin, & Hemsley, 2005; Darke et al., 2013; Doniger, Foxe, Murrariy, Higgins, & Javitt, 2002; Silverstein et al., 2014). The current data limit this hypothesis. Specifically, if such a deficit exists, the impairment must be restricted to a cortical locus where conscious processing is argued to occur (e.g., Crick & Koch, 1995a; Crick & Koch, 1995b; Eccles, 1990; Panagiotaropoulos, Deco, Kapoor, & Logothetis, 2012). In addition, while recent studies on visual disturbance in schizophrenia implicate a cortical deficit (Seymour, Rhodes, Stein, & Langdon, 2016; Seymour et al. 2013; Tibber et al., 2013; Yoon, D'Esposito, & Carter, 2006), a wealth of studies also show intact perceptual processing in schizophrenia, providing evidence against a generalised deficit (Kaliuzhna et al., 2018; King, Hodgekins, Chouinard, Chouinard, & Sperandio, 2017; Palmer, Caruana, Clifford, & Seymour, 2018a; Palmer, Caruana, Clifford, & Seymour, 2018b; Tibber et al., 2013; Yang et al., 2013). Instead, our data seem to support an alternative claim that perceptual judgements in schizophrenia are influenced by cognitive deficits or biases; Bortolon et al. 2015 (e.g., Darke et al., 2013; Davies, Teufel, & Fletcher, 2017; Fletcher & Frith, 2009; Green et al., 2008; Sterzer, Frith, & Petrovic, 2010; Tadin et al., 2005). By eliminating the impact of top-down cognitive factors from our task, we find no evidence of abnormal face processing in schizophrenia. Moreover, there is evidence that task demands have a strong influence on the processing of face information in schizophrenia (Bortolon et al., 2015; Chen et al., 2007; Seymour et al., 2017; Quintana et al. 2003, 2011). Visual scan path studies also highlight abnormal attentional biases in schizophrenia (Beedie et al., 2012; Loughland et al., 2002; Phillips & David, 1997; Williams et al., 1999), which may impact perceptual judgements about faces. Finally, an inability to accurately *evaluate* social relevance has also been suggested to influence perceptual judgments in schizophrenia (Franck et al., 2002; Seymour et al., 2017). For example, the direct gaze bias reported in schizophrenia, where patients show an increased tendency to judge averted gaze directions as looking direct (Hooker & Park, 2005; Tso, Mui, Taylor, & Deldin, 2012), can be eliminated when the task requires a simple left-right judgement, rather than a self-referential evaluation of gaze direction (e.g., Franck et al., 1998; Franck et al., 2002; Seymour et al., 2017). Given that ToM impairments are reliably reported in this group (e.g., Brüne, 2005; Langdon et al., 2014; Langdon, Coltheart, Ward, & Catts, 2002), it is possible that poor performance on face processing tasks reflect a higher-level disturbance (or bias) in the way faces are consciously evaluated.

The rapid identification of faces is an innate human ability that supports our unique capacity to navigate and regulate social interactions. Faces provide critical information

about a person's identity and mental state. Although there is evidence that patients with schizophrenia experience difficulties in using this information to make accurate judgments about the mental states of others and to regulate their social interactions, our study highlights a need to assign clearer distinctions of social impairments that are “perceptual” in nature (Green et al., 2008). This is necessary if we are to better differentiate impairments in the early representation of social stimuli encoded within our sensory systems from general cognitive deficits or impairments in interpreting social cues. In making these distinctions, future research will be better positioned to elucidate aberrant social-cognitive mechanisms in schizophrenia, their locus in cortical processing, and the targeted strategies for cognitive remediation.

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Disclosure statement

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ORCID

Nathan Caruana  <http://orcid.org/0000-0002-9676-814X>

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