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Probing the magnocellular and parvocellular visual pathways in facial emotion perception in schizophrenia

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ABSTRACT

Schizophrenia patients have well-established deficits in facial emotion perception, which contribute to their poor social functioning. A number of studies have related these deficits to a differential dysfunction in the magnocellular (M) versus parvocellular (P) visual pathway. We assessed 35 schizophrenia patients and 35 healthy individuals on an emotion identification task, in which facial stimuli were either unaltered (broad spatial frequency, BSF) or manipulated to contain only high (HSF) or low (LSF) spatial frequencies, thereby respectively biasing the visual system toward the P- or M- pathways. As expected, patients were less accurate and slower in recognizing emotions across all conditions, relative to controls. Performance was best in the BSF condition followed by the HSF and finally the LSF condition, in both groups. A significant group by spatial frequency interaction reflected a smaller magnitude of impairment in the HSF condition, compared to the other two conditions that preferentially engage the M-system. These findings are consistent with studies showing a differential M-pathway abnormality in schizophrenia with a less pronounced impairment in P-function. The current study suggests that patients have less difficulty extracting emotional content from faces when LSFs are attenuated and supports the need to remediate basic visual processing deficits in schizophrenia.

1. Introduction

Individuals with schizophrenia have well-established perceptual and social cognitive deficits that contribute to their poor social functioning (Green et al., 2012). In the visual domain, they have difficulties perceiving simple visual information, such as spatial frequency (O'Donnell et al., 2002), and more complex stimuli, such as facial expressions (Kohler et al., 2010). The patients' impaired emotion recognition ability has been shown to be related to their deficits in basic, early-stage visual processing (Norton et al., 2009). Facial affect recognition involves the processing of facial features and emotional cues, which are conveyed from the retina to the visual cortex through two major cortical processing streams: the ventral and dorsal pathways dominated by parvocellular (P) and magnocellular (M) input, respectively. These pathways have differential psychophysical properties. The M-pathway consists of neurons that process large, low-spatial frequency (LSF) stimuli, whereas the P-pathway consists of neurons that respond preferentially to small, high-spatial frequency (HSF) stimuli (Merigan and Maunsell, 1993).

Faces are initially detected by rapidly conducting M-neurons that provide gross information about shape and coarse emotional cues, and subsequently by the more slowly conducting P-neurons that convey fine grained information about facial properties (Obayashi et al., 2009; Silverstein et al., 2010). Therefore, LSFs contain rough configural information and are generally processed more quickly than HSF components, which convey details of the face, such as wrinkles and exact contours of the eyes and mouth. LSFs are thought to be important for the rapid processing of emotional information, whereas HSFs are needed for the precise recognition of gender and facial identity (Calder et al., 2000; Schyns et al., 2002). This dissociation between fast subcortical processing of coarse emotional LSF information and cortically mediated perception of fine-grained HSF facial information has been demonstrated in neuroimaging studies (e.g., Vuilleumier et al., 2003).

Many studies to date have attempted to bias processing towards the M- versus P-pathway by changing the contrast level (Butler et al., 2009)

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or spatial frequency composition (Calderone et al., 2013) of visual stimuli. The majority of reports that employed LSF and HSF stimuli to differentially activate the M- or P-pathway suggest that schizophrenia patients have deficiencies in both pathways, with a more pronounced impairment in the M-pathway (e.g., Martinez et al., 2008; Butler and Javitt, 2005). Using faces and objects as stimuli, Silverstein et al. (2010) and Calderone et al. (2013) found impaired LSF processing, in addition to increased processing of HSF information in schizophrenia.

Spatial frequency information has been shown to have a direct impact on facial emotion recognition in schizophrenia (McBain et al., 2010). Several studies reported that patients required more visual information to correctly discriminate between facial expressions, compared to controls (Lee et al., 2011), and underutilized facial information presented at the lowest levels of spatial frequency (Clark et al., 2013). Conversely, Laprevote et al. (2010) found that patients preferentially used LSF information to perform a rapid emotion categorization task, suggesting a deficit in the integration of information across spatial frequencies. Therefore, it remains unclear whether the facial emotion perception impairments in schizophrenia are due to a deficient ability to process LSFs.

The goal of the current study was to examine whether biasing the visual system toward the M- versus P-pathway has a differential effect on the ability to recognize emotions in schizophrenia. More specifically, we wanted to assess the influence of spatial frequency filtering on the accuracy and speed of facial emotion processing in schizophrenia patients, compared to healthy controls. We hypothesized that patients will make more errors and will be slower identifying facial expressions regardless of the spatial frequency composition of the stimuli. They will also perform more poorly in the LSF condition, which is most strongly biased toward the M-pathway, compared to the two other conditions.

2. Method

2.1. Participants

Participants included 35 patients with schizophrenia or schizoaffective disorder and 35 healthy controls. Patients were recruited from an inpatient psychiatric unit at a major metropolitan hospital in Bat Yam, Israel. Diagnoses were made by a staff psychiatrist and confirmed using the Structured Clinical Interview for DSM-IV (SCID-I; First et al., 1997). Patients were excluded if they had a current diagnosis of substance abuse or dependence. All patients were clinically stable and receiving antipsychotic medications (10 typical, 10 atypical, and 15 both) at the time of testing.

Healthy controls were recruited from hospital staff and the local community through advertisements. Control participants were excluded if they had any history of Axis I disorders or paranoid, schizoid, or schizotypal personality disorders, according to SCID-I and SCID-II (First et al., 1996). Exclusion criteria for both groups also included a history of a head injury or neurological illness, full-scale IQ estimate less than 70 based on the Test of Nonverbal Intelligence (TONI-3; Brown et al., 1997), and corrected visual acuity estimate (via Snellen wall chart) worse than 20/40. This research was carried out in accordance with *The Code of Ethics of the World Medical Association (Declaration of Helsinki)* for experiments involving humans. All participants provided written informed consent in accordance with the institutional review board.

2.2. Emotion identification task

After completing informed consent and diagnostic interviews, participants were administered the facial emotion identification task, which we have used in previous studies (Rassovsky et al., 2013, 2014). Stimuli consisted of black and white still photographs (2×3 cm) displaying faces with four emotional expressions (happy, sad, angry, and afraid), derived from the Karolinska Directed Emotional Faces set (KDEF, Lundqvist, D., Flykt, A., and Ohman, A.; Dept. of Neurosciences, Karolinska Hospital, Stockholm, Sweden, 1998). We randomly selected 10 actors (5 males and 5 females) displaying the four different emotions from the KDEF set, resulting in a total of 40 different face stimuli. The face pictures were trimmed to exclude the hair and non-facial contours. This task was programmed and run using e-prime software (Psychology Software Tools Inc., USA) and was administered on a Dell Pentium computer with a 17 in. (43 cm) Sony Multiscan 200PS monitor, driven at 160 Hz. Stimuli were centrally presented (3.76°×5.64° eccentricity) as dark on a light background. Participants were asked to identify the emotional expression of face stimuli by pressing one of four labeled keys on the keyboard, such that chance level performance was 25%.

Fig. 1. Example of facial emotion stimuli. The facial image (BSF) was either filtered to a high-spatial frequency (HSF) or low-spatial frequency (LSF) image.

For the high-spatial frequency (HSF) face stimuli, the normal broad-spatial frequency (BSF) faces were filtered using a high-pass filter (≥10 cycles/image), attenuating lower spatial frequencies. Conversely, for the low-spatial frequency (LSF) face stimuli, a low-pass filter (≤6 cycles/image) attenuated higher spatial frequencies (see Fig. 1). Filtering was performed in Matlab (The Natworks, Natick, MA) using second-order Butterworth filters. HSF stimuli bias the system toward the P-pathway, whereas LSF faces bias the system toward the M-pathway. The contrast and luminance of the images resulting from the filtering process were equalized across pictures in two steps. First, by reducing the minimum value from all voxels and then dividing it by the maximum value, the values were transformed to range between 0 and 1. This ensured that the contrast was the same for all pictures. Second, each pixel was multiplied by the median luminance of all pictures and then divided by the mean luminance of the picture. This ensured that the luminance was the same for all pictures.

Participants were seated 1 foot (30.5 cm) from the monitor, received instructions, and practiced the task. For the experimental trials (120 total), the order of stimuli administration was fully randomized across the ten actors, four emotions, and three spatial frequencies. Each face was presented for 500 ms, followed by four emotion labels (“happy”, “sad”, “angry”, “afraid”) presented for 10 s. Participants were instructed to select the facial affect displayed by pressing a number on a keyboard, which triggered the subsequent trial. If the participant did not press any button within 10 s, the next trial was presented.

2.3. Data analysis

For demographic variables, independent samples *t*-tests and chi-square tests were used to assess group differences for continuous and categorical variables, respectively. A 3×2 repeated-measures ANOVA with spatial frequency (BSF, LSF, HSF) as the within-subject factor and group as the between-subject factor was performed to examine the effects of frequency manipulation on the ability to correctly identify emotions depicted in faces (percent correct). The same analysis was repeated with reaction time as the dependent variable. Given the small