Is facial emotion recognition impairment in schizophrenia identical for different emotions? A signal detection analysis

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Abstract

Patients with schizophrenia have difficulty recognising the emotion that corresponds to a given facial expression. According to signal detection theory, two separate processes are involved in facial emotion perception: a sensory process (measured by sensitivity which is the ability to distinguish one facial emotion from another facial emotion) and a cognitive decision process (measured by response criterion which is the tendency to judge a facial emotion as a particular emotion). It is uncertain whether facial emotion recognition deficits in schizophrenia are primarily due to impaired sensitivity or response bias. In this study, we hypothesised that individuals with schizophrenia would have both diminished sensitivity and different response criteria in facial emotion recognition across different emotions compared with healthy controls. Twenty-five individuals with a DSM-IV diagnosis of schizophrenia were compared with age and IQ matched healthy controls. Participants performed a "yes-no" task by indicating whether the 88 Ekman faces shown briefly expressed one of the target emotions in three randomly ordered runs (happy, sad and fear). Sensitivity and response criteria for facial emotion recognition was calculated as *d-prime* and $In(\beta)$ respectively using signal detection theory. Patients with schizophrenia showed diminished sensitivity (*d-prime*) in recognising happy faces, but not faces that expressed fear or sadness. By contrast, patients exhibited a significantly less strict response criteria ($In(\beta)$) in recognising fearful and sad faces. Our results suggest that patients with schizophrenia have a specific deficit in recognising happy faces, whereas they were more inclined to attribute any facial emotion as fearful or sad.
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1. Introduction

Substantial evidence supports the suggestion that individuals with schizophrenia have difficulties recognising the correct emotion of a given facial expression (Feinberg et al., 1986; Archer et al., 1992; Salem et al., 1996; Addington and Addington, 1998; Kohler et al., 2003). This facial emotion recognition impairment has been shown to adversely affect the interpersonal and social functioning of people with schizophrenia (Mueser et al., 1996; Hooker and Park, 2002; Kee et al., 2003; Brekke et al., 2005; Addington et al., 2006).

Furthermore, patients with schizophrenia are worse at recognising negative, as opposed to positive, facial emotions (Kohler et al., 2003; Bediou et al., 2005; van't

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Wout et al., 2007). This finding raises a question whether positive and negative facial emotion recognition engage different processes. Several hypotheses have been put forward to explain the difference in performance between positive and negative facial emotion recognition in schizophrenia. According to the social-cognitive hypothesis, patients avoid stimuli that induce negative emotion (Walker et al., 1980). Phillips et al. (1999) and Gur et al. (2002) have additionally proposed that amygdala activation specific to negative facial emotion is reduced in schizophrenia.

In addition to those described, there may be other explanations for the differences in positive and negative facial emotion recognition in schizophrenia. Johnston et al. (2003, 2006) argued that patients with schizophrenia perform poorly at recognising negative facial emotions because positive facial emotions are generally easier to recognise than negative emotions (and so less likely to be adversely affected by the illness). Such differences in discriminability are not so obvious in healthy subjects because they usually score at or near the maximum possible performance level in the standard facial emotion recognition tests for all emotions ("ceiling effect"). This argument is strengthened by the fact that previous studies of facial emotion recognition in schizophrenia used relatively long stimulus exposure times that ranged from 500 ms (Edwards et al., 2001) to 15 s (Addington et al., 2006). One potentially useful method to avoid the ceiling effect in healthy control subjects is to manipulate stimulus presentation duration (Kirouac and Dore, 1984; Ogawa and Suzuki, 1999). For example, Grimshow et al. (2004) presented face stimuli for 30 ms and they were able to observe sex differences in emotion recognition. The use of such rapid visual presentation would increase task difficulty, during which subjects might be in a high degree of uncertainty and thus more liable to make errors.

The process of facial emotion recognition can be conceptualised using psychophysical methods such as signal detection theory. This theory has been widely applied to the study of perception. Signal detection theory attempts to explain how individuals make decisions based on the evidence they have received. Most decisions a person makes contains a degree of uncertainty (McNicol, 1972). There are two broad psychological processes involved in decision making: the sensory process and the cognitive decision process (Krantz, 1969). The sensory process refers to the transformation of physical stimuli into internal perception. The cognitive decision process involves deciding how to respond based on the output of the sensory process. Signal detection theory provides separate measures of performance in decision making to reflect these two processes. The sensory process is measured by sensitivity (*d-prime*), which determines how well the observer is able to select the correct stimuli while avoiding the incorrect ones. The response criterion (*In* (β)) corresponds to the cognitive decision process and reflects the tendency of individuals to make a certain decision with the evidence they have received from the sensory process.

In this study, we applied signal detection theory to investigate the underlying psychological processes of facial affect recognition for different emotions in schizophrenia. As a preliminary exploratory study, we focused on positive emotion (happy), negative non-threatening emotion (sad) and negative threatening emotion (fear). These emotions have been shown to be significantly disturbed in schizophrenia in the literature (Kohler et al., 2003; Bediou et al., 2005; van't Wout et al., 2007). We examined whether patients with schizophrenia differed from controls in both the sensory and the cognitive decision processes for facial emotion recognition across positive and negative emotions. The relationship between symptoms and facial emotion recognition was also evaluated. Similar analyses have been used to study facial emotion recognition in healthy volunteers (Goos and Silverman, 2002; Grimshaw et al., 2004). Schneider et al. (2006) has also recently examined the specific psychometric characteristics of facial emotion recognition in schizophrenia, with a stimulus exposure time of three seconds. In this study, we deliberately used a very short stimulus exposure time to reduce the overall accuracy in the controls in order to minimise the possible "ceiling effect" and to introduce a relatively high degree of uncertainty. To our knowledge, the current study is the first that employs signal detection theory to investigate facial emotion recognition in patients with schizophrenia. We hypothesised that individuals with schizophrenia, compared with healthy controls, would have diminished sensitivity and different response criteria in facial emotion recognition across different emotions.

2. Method

2.1. Subjects

Twenty-five patients with a DSM-IV diagnosis of schizophrenia (American Psychiatric Association, 1994) were recruited from in-patient wards (17 patients) and from the community (8 patients). Twenty-five healthy volunteers were recruited from the community as controls. The demographics of the subjects are summarised in Table 1.

Table 1
Demographics and clinical characteristics of patients and controls (*SD* in parentheses)

	Schizophrenia patients (*n*=25)	Healthy controls (*n*=25)	*p* value
Mean age (years)	37.8 (9.5, range 20 to 54)	40.5 (9.0, range 21 to 55)	0.31
Sex (male/female)	21/4	17/8	0.19
Mean years of education	12.5 (2.4)	11.9 (2.3)	0.40
Mean IQ by NART	105 (13)	106 (8)	0.65
Mean SAPS total score	25 (15)		
Mean SANS total score	11 (9)		
Mean CDSS total score	4 (4)		

The two groups did not differ significantly in age, male/female ratio, number of years of education received and IQ estimated with the National Adult Reading Test [NART] (Nelson and Willison, 1991). Exclusion criteria for both groups included the presence of a history of neurological disorders or learning disability, or a current diagnosis of alcohol or drug dependence. Both patients and controls gave written informed consent before their participation. This study was approved by the local Research Ethics Committee.

All patients were judged as clinically stable by their psychiatrists at the time of assessment. All patients except one were on antipsychotic medication. The mean daily dose in chlorpromazine equivalence was 408.6 mg (*SD*=253.0 mg). Twenty-one patients were on atypical antipsychotic medications and the other three patients were on typical antipsychotics. The mean duration of illness was 13.5 years (*SD*=9.3 years, range from 6 months to 35 years).

2.2. Experimental procedure and task

On the day of testing, all participants were interviewed to obtain demographic information. They then performed a facial emotion recognition "yes-no" task in a quiet well-lit room. The stimuli of the task consisted of twenty-four black and white photographs from the Pictures of Facial Affect (POFA) (Ekman and Friesen, 1976). These photographs feature two males and two females exhibiting each of the following six facial expressions: happiness, sadness, fear, disgust, surprise and anger. Hair features and clothing were occluded from all these faces (Phillips et al., 1999). These stimuli were presented with the Presentation software package (Neurobehavioral Systems Inc., San Francisco) on a laptop computer (screen size: 28.8 cm × 21.3 cm, stimuli size: 14.4 cm × 21.3 cm at the centre of screen). Participants sat approximately 60 cm from the computer screen.

Participants were instructed to decide whether the faces shown on the screen expressed one of three target emotions: happiness, sadness or fear. They were told to press a button on a mouse connected to the computer as quickly as possible to indicate whether the face shown was displaying the target emotion. The participants were asked to press a different button to indicate that the face shown was not expressing the target emotion. There were 88 faces shown for each block and participants were asked to identify a specific target emotion in each block. Therefore, there were three different blocks for three target emotions and the sequence of these blocks was randomised. Each stimulus was shown for 50 ms, and then followed by a 1300 ms central-fixation cross, during which a response was to be made. There were 28 faces in each block with the target emotion (7 faces from 2 males and 2 females). The other 60 faces with non-target emotions included the other five emotions from the 2 males and 2 females (3 faces for each person expressing one non-target emotion). Participants were given a five-minute break between each block.

Before the experimental procedure, subjects viewed sample photographs from the POFA (including both male and female but these photographs were different from those used in the actual experiment) exhibiting the six different emotions. All participants had 12 practice trials for each target emotion, using the sample photographs.

After the facial emotion recognition task, the patient group were assessed with: (1) the Scale for the Assessment of Positive Symptoms (SAPS) (Andreasen, 1984) and Negative Symptoms (SANS) (Andreasen, 1983) for symptom severity; (2) the Calgary Depression Scale for Schizophrenia (CDSS) (Addington et al., 1990) for depressive symptoms.

2.3. Statistical analysis

Sensitivity and response criterion for facial emotion recognition were calculated as *d-prime* and $In(\beta)$ respectively, according to signal detection theory. The calculation of *d-prime* and $In(\beta)$ was based on the formula reported in the paper by Macmillan and Creelman (1990). Adjusted Hit Rate (HR) and False Alarm Rate (FAR) according to Corwin (1994) were

used in the calculation to avoid problems of division by zero or result in infinite values of the calculated *d-prime* and $In(\beta)$. The sensitivity measure *d-prime* refers to the sensory dimension of facial emotion recognition, i.e. the ability to distinguish target facial emotion from non-target emotions. A larger *d-prime* means a better ability to differentiate the target emotion from other emotions. The response criterion $In(\beta)$ reflects the cognitive dimension of facial emotion recognition and it measures the tendency for a subject to judge a facial emotion as a specific emotion. If the $In(\beta)$ is positive, the subject has adopted a strict criterion and is biased towards judging that any facial emotion is a non-target emotion. The more positive the $In(\beta)$, the stricter criterion the subject has adopted. On the other hand, a negative $In(\beta)$ indicates that a subject has adopted a lax criterion and is biased towards judging that any facial emotion is the target emotion. A zero $In(\beta)$ would suggest an unbiased judgement.

D-prime, $In(\beta)$ and reaction time (RT) were examined as dependent variables and these variables were entered into a 2×3 multivariate analysis of variance (MANOVA), with a between-subject variable of group (schizophrenia or controls) and within-subject variables of emotion (fear, happiness or sadness). Pearson's correlation analysis was used to examine associations between dependent variables and clinical characteristics. Statistical significance was set at 0.05 and all statistical tests were two-tailed.

3. Results

Patients with schizophrenia showed a significant lower Hit Rate (HR) in recognising happy faces [$F(1,48)=6.55$, $p=0.01$, *power*$=0.71$], but not in recognising faces with fear or sadness (Table 2). False Alarm Rate (FAR) was higher in the patient group for all three emotions [fear: $F(1,48)=5.03$, $p=0.03$, *power*$=0.59$; happy: $F(1,48)=5.42$, $p=0.02$, *power*$=0.63$; sad: $F(1,48)=10.07$, $p<0.01$, *power*$=0.88$]. These data were

further analysed using signal detection theory in order to take account of the possibility that subjects may be more inclined to indicate that *every* face was displaying the target emotion and hence could lead to higher hit rate for at the expense of false alarms. Furthermore, as indicated by the significant interaction effect (group by emotion) [$F(2,96)=4.15$, $p=0.02$, *power*$=0.72$] in false alarm rate, any such bias produced could induce differential effects on different facial emotions in the patient and control groups.

3.1. Sensitivity for different emotions (d-prime)

There was a significant interaction effect (group by emotion) [$F(2, 96)=4.08$, $p=0.02$, *power*$=0.71$]. (Table 2). The interaction was explained by the fact that *d-prime* differences between the patient and control group were statistically significant for happy faces [$F(1, 48)=7.52$, $p<0.01$, *power*$=0.77$] but not for faces showing sadness [$F(1, 48)=3.11$, $p=0.08$, *power*$=0.41$] and fear [$F(1, 48)=0.76$, $p=0.39$, *power*$=0.14$]. The main effect of emotion on *d-prime* [$F(2, 96)=112.64$, $p<0.001$, *power*$=1.00$] was significant, suggesting that *d-prime* was highest for happy faces and lowest for faces showing fear in both groups. There was also a significant main effect of group [$F(1, 48)=5.22$, $p=0.03$, *power*$=0.61$] and this indicates patients exhibited a lower *d-prime* compared with controls across different emotions.

3.2. Response criteria for different emotions (In(β))

There was a significant interaction effect (group by emotion) on $In(\beta)$ [$F(2,96)=5.58$, $p<0.01$, *power*$=0.85$] (Table 2). The interaction analysis showed that there were significant between-group differences in recognising faces with fear [$F(1, 48)=4.67$, $p=0.04$, *power*$=0.56$] and sadness [$F(1, 48)=12.37$, $p<0.01$, *power*$=0.93$] but not for happy faces [$F(1, 48)=2.23$, $p=0.14$, *power*$=0.31$]. Within each group, there was significant difference

Table 2
Performance indicators (mean values with *SD* in parentheses) of facial emotion recognition tasks for three target emotions

	Hit rate (unadjusted)	False alarm rate (unadjusted)	D-prime	In(β)	Reaction time (milliseconds)
Fear					
Schizrenia ($n=25$)	0.61 (0.19)	0.28 (0.18)	0.94 (0.51)	0.18 (0.50)	653.31 (145.13)
Controls ($n=25$)	0.54 (0.16)	0.18 (0.12)	1.08 (0.55)	0.47 (0.44)	574.49 (85.74)
Happy					
Schizophrenia ($n=25$)	0.75 (0.17)	0.12 (0.12)	2.07 (0.95)	0.52 (0.99)	608.37 (137.48)
Controls ($n=25$)	0.85 (0.12)	0.06 (0.08)	2.76 (0.81)	0.87 (0.64)	532.60 (81.19)
Sad					
Schizophrenia ($n=25$)	0.65 (0.28)	0.31 (0.31)	1.18 (0.74)	0.26 (0.99)	621.05 (134.92)
Controls ($n=25$)	0.52 (0.18)	0.10 (0.14)	1.54 (0.70)	1.20 (0.90)	546.67 (85.89)

between the *In*(β) values for faces with fear and happiness ($p = 0.02$ for patients; $p < 0.01$ for controls). The difference between the *In*(β) values for faces with fear and sadness was significant in the control group ($p < 0.001$) but not in the patient group ($p = 0.58$). The difference between the *In*(β) values for faces with happiness and sadness was also only significant in the control group ($p = 0.05$) but not in the patient group ($p = 0.12$). The main effect of group [$F(1,48) = 8.42$, $p < 0.01$, power = 0.81] indicated that value of *In*(β) was lower in the patient group than the controls across all three target emotions. The main effect of emotion [$F(2,96) = 8.83$, $p < 0.001$, power = 0.97] was also statistically significant. This suggests that the *In*(β) value was lowest (i.e. less positive) for recognising faces displaying fear in both groups.

3.3. Reaction time for different emotions

The reaction time was significantly delayed in the patient group compared to the control group across all three emotions as shown by the significant main effect of group [$F(1, 48) = 7.19$, $p = 0.01$, power = 0.75] (Table 2). However, there was no significant interaction effect [$F(2, 96) = 0.01$, $p = 0.98$, power = 0.05]. The main effect of emotion on the reaction time was significant [$F(2,96) = 5.28$, $p < 0.01$, power = 0.83]. The reaction time for recognising faces with fear was significantly delayed in both groups, compared to the reaction time for recognising happy faces ($p < 0.01$) and for faces displaying sadness ($p = 0.01$). There was no statistically significant difference in the reaction time of recognising happy and sad faces ($p = 0.34$).

3.4. Relationship between facial emotion recognition parameters and clinical characteristics in the patient group

There was a significant positive correlation between the SAPS delusion total score and *d-prime* in task of recognising both fear ($r = 0.40$, $p = 0.05$) as well as sad faces ($r = 0.48$, $p = 0.02$). *D-prime (fear)* had also a significant positive correlation with the CDSS total score ($r = 0.42$, $p = 0.04$). *In*(β) in task recognising happy faces had a significant positive correlation with the SANS total score ($r = 0.56$, $p < 0.01$). NART IQ, duration of illness and dosage of antipsychotic medication (in chlorpromazine equivalence) did not have significant correlations with either *d-prime* or *In*(β) in each emotion. There were no significant correlations between scores of the clinical measures and *In*(β) for the emotions of fear and sadness. There were also no significant correlations between *d-prime (happy)* and clinical ratings.

4. Discussion

Using signal detection theory, we found that individuals with schizophrenia, when compared with controls, demonstrated a diminished sensitivity (*d-prime*) in recognising happy faces, although the main effect of emotion (highest *d-prime* for happy faces recognition) suggested that happy faces were more easily recognised than other facial emotions. On the other hand, individuals with schizophrenia adopted a significantly less strict response criteria (*In*(β)) than the controls in recognising fear and sad facial emotions. This suggests that individuals with schizophrenia, when compared to the controls, were more inclined to attribute any facial emotion as fearful or sad.

We used a short stimulus exposure time (50 ms) in our experimental paradigm to avoid the potential "ceiling effect" in other facial emotion recognition tasks. The highest mean hit rate was 0.85 (controls in recognising happy faces) and it was well below the possible maximum hit rate of 1.0. There is substantial evidence suggesting that perception of facial expressions can occur automatically (Hansen and Hansen, 1994; Stenberg et al., 1998) and without conscious awareness (Morris et al., 1998) in healthy volunteers. When a negative facial emotion was presented for 20 ms as prime before a neutral face, individuals with schizophrenia judged that neural facial emotion as more unpleasant than controls (Hoschel and Irle, 2001). Taken together, the results of these studies suggest that patients with schizophrenia can perceive facial expressions even at very short stimulus exposure times.

A facial affect recognition deficit in schizophrenia may reflect a specific facial affect processing deficit (Borod et al., 1993). Alternatively, it may also be secondary to a generalised perceptual impairment (Archer et al., 1992). Previous studies reported that normal individuals had greatest accuracy in recognising happy faces from a range of facial emotion expressions (Ekman et al., 1972; Johnston et al., 2003). Hence, the differences in performance of the task between patient and control group in recognising facial emotion should be smallest for happy faces (Chapman and Chapman, 1978). Contrary to what Chapman and Chapman (1978) suggested, we found that recognition of happy faces was more impaired than recognition of sad or fearful faces in our patient sample. Our results suggest that the facial emotion recognition deficit in schizophrenia is more complex than previously thought. We have shown that there are at least two potentially different recognition processes involved in the observed deficit, namely impaired sensitivity and response bias. The underlying process of this recognition deficit is different for each

emotion. This observation suggests that impaired sensitivity and response bias may contribute independently to the recognition deficit of specific facial emotion in schizophrenia.

The reaction time for all three emotions was longer in the patient group than control group. Individuals with schizophrenia have showed a longer and more variable reaction time in sustained attention task such as the Continuous Performance Test (CPT) (Shakow, 1977; Birkett et al., 2007). Recognition of faces displaying fear took longer for both patients with schizophrenia and healthy controls, whereas happiness was the facial emotion most quickly recognised. In this aspect, our findings are consistent with the results of other studies (Russell, 1994; Palermo and Coltheart, 2004). As far as reaction times are concerned, one might expect that the *d-prime* and *In*(β) should be significantly different across all three emotions between the patient and control groups. Nevertheless, our result showed that impaired sensitivity in patients was specific to recognising happy faces. This may suggest that the under-performance in the facial emotion recognition task in our study is unlikely to be due to the differences of speed of information processing.

The severity of delusion in schizophrenia had a positive correlation with the sensitivity in recognising faces that displayed fear. This suggests that schizophrenia patients with more severe delusion symptoms were more sensitive to the facial expression showing fear. Green and Phillips (2004) suggested that an initial vigilance of threat (e.g. faces displaying fear) is important in delusion information processing. Our findings seem to support this suggestion. Depression in schizophrenia also had a significant positive correlation with sensitivity in recognition of faces showing fear but not with faces displaying the other two emotions. One possible explanation might be that those patients who were sensitive to threat became depressed. Because of the small sample size, this finding should be interpreted with caution. We are not aware of any previous studies on the effect of mood state in schizophrenia to facial emotion recognition.

There are some issues to consider in interpreting the results of this study. We have only included three emotions in this exploratory study, although these three emotions covered positive emotion (happy), negative non-threatening emotion (sad) and negative threatening emotion (fear). It is still uncertain whether there is any difference in terms of sensitivity and response criteria in recognising other facial emotions such as surprise, disgust and anger. In particular, faces displaying anger and disgust may seem to be more threatening directly. As our results suggested depressed mood correlated with

sensitivity in recognising fearful faces, future studies may want to include a psychiatric control group to investigate how specific the impairment of facial emotion recognition is to schizophrenia. Moreover, as we only used a very short stimuli exposure time in this study, the effect of different exposure durations on the signal detection parameters for facial emotion recognition remains untested. Future studies may want to use different stimulus exposure durations to investigate whether patients' emotion recognition dysfunction is due to early perceptual or later cognitive interpretation stages. In addition, it was possible that subjects did not perceive any emotion on the trials and they responded as to non-target emotion. Our current experimental design did not differentiate non-target response between 'non-target response which was recognised as other emotion' and 'non-target response due to inability to recognize any emotion'.

To conclude, our results have shown that patients with schizophrenia demonstrate a specific impaired sensitivity in recognising happy faces. These patients are also more inclined to attribute any facial emotion as fearful or sad. Our findings suggest that facial emotion recognition may involve two different processes: perceptual sensitivity and cognitive attribution, which may be different for different emotions.

Contributors

All authors contributed to the design of the study. Daniel T. Tsoi and Kwang-Hyuk Lee wrote the protocol, managed the literature searches and undertook the statistical analysis. Daniel T. Tsoi, Waqqas A. Khokhar, Nusrat U. Mir, Jaspal S. Swalli, Kate A. Gee and Graham Pluck assessed the subjects. Daniel T. Tsoi wrote the first draft of the manuscript. All authors contributed to and have approved the final manuscript.

Conflict of Interest

All authors declare that they have no conflicts of interest.

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