



Implicit emotion perception in schizophrenia



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ABSTRACT

Explicit but not implicit facial emotion perception has been shown to be impaired in schizophrenia. In this study, we used newly developed technology in social neuroscience to examine implicit emotion processing. It has been shown that when people look at faces, they automatically infer social traits, and these trait judgments rely heavily on facial features and subtle emotion expressions even with neutral faces. Eighty-one individuals with schizophrenia or schizoaffective disorder and 62 control subjects completed a computer task with 30 well-characterized neutral faces. They rated each face on 10 trait judgments: attractive, mean, trustworthy, intelligent, dominant, fun, sociable, aggressive, emotionally stable and weird. The degree to which trait ratings were predicted by objectively-measured subtle emotion expressions served as a measure of implicit emotion processing. Explicit emotion recognition was also examined. Trait ratings were significantly predicted by subtle facial emotional expressions in controls and patients. However, impairment in the implicit emotion perception of fear, happiness, anger and surprise was found in patients. Moreover, these deficits were associated with poorer everyday problem-solving skills and were relatively independent of explicit emotion recognition. Implicit emotion processing is impaired in patients with schizophrenia or schizoaffective disorder. Deficits in implicit and explicit emotion perception independently contribute to the patients' poor daily life skills. More research is needed to fully understand the role of implicit and explicit processes in the functional deficits of patients, in order to develop targeted and useful remediation interventions.

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1. Introduction

The expression and perception of emotions are essential in non-verbal communication and social functioning. Researchers have shown that in everyday life, our affective states are made of blended emotions of low to moderate intensity, and our facial expressions are generally quite subtle (Matsumoto and Hwang, 2013; Scherer et al., 2004). Moreover, during daily social exchanges, emotional expressions are processed implicitly. This is in sharp contrast with research on facial emotional recognition conducted in

laboratory settings, which most of the time, probes explicit emotion recognition of intense expressions of “pure” emotions. “Implicit” in social cognition does not necessarily mean “unconscious” but refers to the perception of emotions with as little awareness as possible (Fazio and Olson, 2003). The distinction between implicit and explicit processes has been the subject of various theories in social cognition (Chaiken and Trope, 1999), parallels the distinction between automatic and controlled processes (De Houwer et al., 2009), and has received support from neuroimaging studies (Lieberman, 2007).

In order to test implicit processing of emotional faces, investigators have resorted to two types of behavioral techniques, which are differentiated by the use of one or two different stimuli in each trial (see Fazio and Olson, 2003). In priming studies, emotional faces are presented before the task stimuli, and the

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impact of emotional faces on performances (such as reaction time, accuracy or judgment) is examined. The exposure time of the primes can vary from a few milliseconds to seconds. As the effect of primes tend to dissipate very quickly over time (De Houwer et al., 2009), this method is not optimal when participants take more than a few seconds to choose their answers. The second method (called thereafter incidental task method) is derived from the Emotional Stroop task (Williams et al., 1996), but instead of emotional words, emotional faces are used, and subjects are instructed to process another-than-emotion dimension of the faces such as in sex- or age-classification tasks (which is called the incidental task). Consequently, emotional expressions are present until participants reach a decision, and a distracting or facilitating effect of emotion on the incidental task is examined.

Implicit studies with non-clinical subjects have shown that emotional faces can modulate psychophysiological responses (Esteves et al., 1994), cognition (Yang et al., 2011) and attitudes (Murphy and Zajonc, 1993). Moreover, not only affect (positive or negative) but also individual emotions (for example: anger versus fear) are processed under implicit conditions, and even during very short exposure times (Rohr et al., 2012). In schizophrenia, more than 200 individual studies and reviews have shown that explicit facial emotional recognition is quite impaired. However, a very different picture emerges regarding implicit processing of facial emotions. Compared to controls, schizophrenia patients showed increased psychophysiological responses when implicitly processing emotional faces (Williams et al., 2007). The impact of emotional faces on cognition was examined, and no differences between schizophrenia patients and controls was reported (Aichert et al., 2013; Becerril and Barch, 2011; Evans et al., 2011; Harvey et al., 2009; Linden et al., 2010; Park et al., 2011; Schwartz et al., 2010, 2009; Sergerie et al., 2010). In an incidental sex-classification task, again no significant group differences were found (van't Wout et al., 2007). In three judgment studies, emotional faces were used as primes, and participants rated the target stimuli (Chinese characters or neutral faces) on pleasantness. A greater judgment shift with negative emotional faces was found in schizophrenia patients in one study (Hoschel and Irlle, 2001). In the other two studies (Suslow et al., 2003, 2005), different patterns of priming effects were found according to the presence of affective symptoms in patients and whether subliminal or supraliminal primes were used. However, the significance of the group differences was not reported.

It thus appears that the implicit processing of emotional faces is not impaired in schizophrenia (see also Mano and Brown, 2013). This is quite surprising if one considers other findings that suggest otherwise: 1) early visual processes are impaired when schizophrenia patients look at faces (McCleery et al., 2015) and emotional faces (Butler et al., 2009), 2) patients with schizophrenia show poor strategies when they scan emotional faces (Beedie et al., 2011), 3) behavioral studies found that implicit processing of emotional stimuli is impaired with stimuli other than faces (Dieleman and Roder, 2013), and 4) neuroimaging studies show less neural activation in schizophrenia during implicit tasks than in control subjects (Taylor et al., 2012). Lack of impairment in laboratory studies may be explained by the use of intense, non-blended and prototypical emotional expressions.

In the current study, we used an incidental task (rating social traits) to examine the implicit processing of very subtle emotional expressions. We took advantage of recent advances in social neuroscience that show how implicit perception of facial emotions impacts on social trait judgments. Indeed studies have shown that when looking at people's faces, we rapidly evaluate them on multiple personality and social traits (Bar et al., 2006), and make judgments of their attractiveness and how sociable, trustworthy, dominant and aggressive they are. A major factor involved in our

social trait judgments is facial emotional expression (Montepare and Dobish, 2003), from which we infer not only others' current affective states but also their tendencies and personality traits (Montepare and Dobish, 2003). This reliance on emotional expressions extends to apparently-neutral faces. Researchers have shown that very subtle emotional expressions can be perceived implicitly even in neutral faces and used to form impressions of others in non-clinical subjects (Said et al., 2009b) and people with schizophrenia (Antonius et al., 2013). For example, it has been shown that even a subtle expression of happiness makes people judge a face as more sociable or attractive than a face without such emotional expression (Said et al., 2009b). Consequently, we examined the prediction of ten trait judgments (attractive, trustworthy, intelligent, emotionally stable, fun-to-be-with, sociable, dominant, aggressive, mean and weird) by the subtle emotional expressions of neutral faces in people with schizophrenia or schizoaffective disorder and healthy controls. We hypothesized that the impact of facial emotions would be less in patients than in controls. In a subgroup of patients, we examined the relationship between implicit and explicit emotion perception and performance in daily life skills. We hypothesized that implicit and explicit perceptions were independently linked to social functioning.

2. Material and methods

2.1. Participants

Subjects included 81 individuals with schizophrenia or schizoaffective disorder and 62 non-patient control subjects. Patients were inpatients in a research unit at the Nathan Kline Institute for Psychiatric Research (NKI) or outpatients at Bellevue Hospital, New York. All subjects were English-speaking and between 18 and 65 years of age, and had capacity to give consent. Diagnosis of schizophrenia or schizoaffective disorder was assessed using the Structured Clinical Interview for DSM-IV (SCID, First et al., 1998) or the Diagnostic Interview for Genetic Studies (DIGS, Nurnberger, Jr. et al., 1994). Patients had normal or corrected vision. Non-patient control participants had no psychiatric history and diagnosis as assessed with the Non-patient version of the SCID or the DIGS. They were community subjects who responded to advertisement and volunteered to participate in research studies conducted at NKI or Bellevue Hospital. After complete description of the study to the subjects, written informed consent was obtained. The study was approved by the local Institutional Review Boards.

2.2. Procedures

A computer task was developed with thirty neutral faces (15 females, 15 males) from the Karolinska Faces¹ (Lundqvist et al., 1998). From a previous study (Said et al., 2009b), we selected the nine social traits that were quite easy to comprehend, and we added the positive trait of "fun to be with". Participants were asked to rate faces on these ten social traits, tested in the following sequence: attractive/good looking, mean, trustworthy, intelligent, dominant, fun to be with, sociable, aggressive, emotionally stable and weird. For example, for "intelligent", participants viewed the 30 Karolinska faces one by one, and were asked to rate "how intelligent the person seems to be" on a 1 to 5 point-Likert scale (from "not at all" to "extremely"). For each trait, the presentation order of the 30 faces was randomized and kept constant across subjects. Exposure/response times were not limited.

¹ Female faces: 03, 04, 05, 09, 10, 16, 17, 18, 21, 23, 25, 26, 28, 31, 33. Male faces: 37, 40, 42, 43, 46, 52, 53, 56, 57, 63, 64, 66, 67, 68, 70.

Prior to this study, one of the authors (AT) collaborated with a computer scientist, Niku Sebe, who developed a computerized program that detects emotional expressions in faces by comparing the positions of landmarks to those of a prototypically neutral face (Said et al., 2009a). This program allows us to examine how close a neutral face is to an expression of anger, disgust, fear, happiness, sadness or surprise, by calculating six emotion predictions (probabilities). This computer program was previously validated with 114 FACS (Facial Action Coding System) coded emotional faces (Said et al., 2009b) and with neutral faces (Oosterhof and Todorov, 2008). In our study, thirty faces were chosen from a larger pool of faces for which emotion probabilities had been calculated (available at <http://tlab.princeton.edu/databases/>). For example, as it can be seen in our [Supplementary data](#), the probability that the face AF03 expresses an expression of surprise is 0.37, an expression of sadness: 0.33, an expression of fear: 0.12, and so on. Consequently, each apparently-neutral face was considered as a blend of six emotions; each emotion being expressed with a certain degree/probability. Faces were chosen so that for each emotion, the range of emotion probabilities across all faces was rather wide.

Explicit emotion recognition was assessed using the Penn Emotion Recognition Task (ER-40, Kohler et al., 2005). This test is comprised of 40 photographs of actors expressing one of four emotions (anger, fear, happiness, sadness) or a neutral expression. As recommended by some authors (Frank and Stennett, 2001) a modified forced-choice format was used, and a sixth possible choice was added, “another emotion”. As recommended by Wagner (Wagner, 1993), unbiased hit rates were used to measure accuracy. Because of technical problems, data were available for 54 patients and 38 controls only. No demographic variables differentiated participants whose results were available from those whose data were lost.

2.3. Clinical ratings

Schizophrenia participants were assessed with the following scales: 1) the Positive and Negative Syndrome Scale (PANSS, Kay et al., 1987), using the original positive, negative and general psychopathology subscales; 2) the modified Scale for the Assessment of Negative Symptoms (SANS, Andreasen, 1989), examining Expressivity (Affective Flattening and Alogia subscales sum scores), Social Motivation (Avolition-Apathy and Anhedonia-Asociality subscales sum scores) and total scores; 3) the Calgary Depression Scale for Schizophrenia (CDSS, Addington et al., 1992); 4) the Simpson and Angus scale (Simpson and Angus, 1970) for extrapyramidal symptoms, 5) the Quick-IQ version 3 (Ammons and Ammons, 1962), and 6) the Independent Living Scales (Loeb, 1996) problem-solving factor (ILS-ps), which measures everyday problem-solving skills and has previously been used in schizophrenia in- and out-patients (Revheim et al., 2006). All raters showed good inter-rater reliability during training.

2.4. Statistical analyses

Group differences on trait ratings and the psychometric properties of the test are reported in a separate paper (submitted for publication). In the current paper, we studied implicit emotion processing by examining the degree to which trait ratings were predicted by objectively-measured subtle expressions of anger, disgust, fear, happiness, sadness or surprise. Whereas in most incidental tasks, the implicit dimension variable is categorical (an expression of anger versus an expression of happiness versus a neutral face), in our study the implicit dimension variable was continuous (the probability that a face expresses anger or happiness) and ranged from 0 to 1. Consequently, to examine the impact

of implicit dimension variable onto trait ratings, we used regression analysis, and because of the nested structure of our data, we used mixed model analyses (SAS, Proc Mixed; Singer, 1998) with “subject” random, and the six emotion probabilities of each face were entered as fixed main effects. We first estimated the effect of each emotion on each trait for the two groups separately. To examine whether groups differed in the way emotions predicted traits, “group” was entered in the model, and we were particularly interested in the interaction term, group by each emotion probability. To correct for multiple testing (six emotions by ten traits), a false discovery rate correction was applied (Benjamini and Hochberg, 1995) to all analyses, and q values are reported.

To examine the association between implicit emotion perception and demographic/clinical variables, the demographic/clinical variable was entered in the models as an independent variable. Groups were analyzed separately. For each social trait, only the emotions that significantly predicted this trait and for that group were kept in the model as independent variables, and we were interested in the interaction factor, demographic/clinical variable by emotion. Again, a false discovery rate correction was applied. To examine the association between explicit emotion recognition and demographic/clinical variables, ER-40 scores were used and Spearman rho correlations were analyzed. As the number of analyses was limited, no correction of multiple tests was applied. All analyses were two-tailed.

3. Results

Groups did not significantly differ for age, gender, ethnicity and parents' social economic status. Individuals with schizophrenia had a lower educational level (Table 1).

3.1. Implicit emotion perception (Table 2)

Some similarities were found between groups on how resemblance to emotional expressions impacted and predicted trait ratings. For both groups, happiness and fear were the most frequent emotions significantly predicting trait ratings: happiness positively predicted positive traits and negatively predicted negative traits; fear negatively predicted positive traits and positively predicted negative traits. Subtle expressions of anger positively and significantly predicted “dominant”, “aggressive” and “mean” in both groups. Disgust predicted “attractive”, “fun” and “aggressive” in patients, but did not significantly predict any traits in controls. Expressions of surprise positively predicted several trait ratings in controls, but did not predict any traits in patients.

Nine group comparisons were significant even after correction for multiple tests (bottom of Table 2). Patients used fear, happiness, surprise and anger expressions to a significant lesser degree than controls for at least one social trait.

3.2. Explicit emotion recognition

With the ER-40, patients were less accurate than controls for all emotions (Fig. 1). The effect sizes were of large magnitude in accord with other studies (Kohler et al., 2010). We also wanted to know whether explicit emotion recognition skills predicted social trait ratings. In each group separately, we entered 5 hit-rate scores (for neutral, anger, happiness, fear and sadness) in each regression analysis. In controls and patients, ER-40 scores did not significantly predict any social trait (even before correcting for multiple tests). As the number of participants who completed the ER-40 was lower than the number of participants who completed the implicit task, lower power may have explained the absence of significant results. Consequently, we examined whether the associations between

Table 1
Demographics and clinical characteristics.

	Patients (n = 81)	Non-patient controls (n = 62)	Test statistic
Number of females (%)	23 (28)	24 (39)	$\chi^2_{(1)} = 1.69, p = 0.19$
Age (in years) (SD)	40.32 (10.6)	38.13 (13.61)	$F_{(1, 141)} = 1.17, p = 0.28$
Education (in years) (SD)	12.22 (2.21)	14.34 (1.81)	$F_{(1, 141)} = 37.51, p < 0.0001$
Parents' Social Economic Status (Hollingshead Index for occupation) (SD)	5.34 (1.77)	5.14 (2.14)	$F_{(1, 141)} = 0.34, p = 0.54$
Race/ethnicity (%)			Fisher's exact test: 7.48, $p = 0.11$
African-American	43 (53)	22 (35)	
White	20 (25)	23 (37)	
Hispanic	12 (15)	7 (11)	
Asian	3 (4)	7 (11)	
Other	3 (4)	3 (5)	
Quick IQ (SD)	90.12 (14.34)		
Outpatients (%)	39 (48)		
Number of hospitalizations (number of patients) (%)			
Less than 5	25 (31)		
From 5 to 14	42 (52)		
More than 14	14 (17)		
Diagnostic subtypes (%)			
Schizophrenia, paranoid	33 (41)		
Schizophrenia, undifferentiated	20 (25)		
Schizophrenia, residual	3 (4)		
Schizoaffective disorder	25 (31)		
Age at first psychiatric hospitalization (SD)	21.20 (8.06)		
Duration of illness (in years) (SD)	21 (11)		
Dosage of Antipsychotic Medication (Chlorpromazine Equivalent) (SD)	509 (336)		
Antipsychotic medications (%)			
First generation	8 (10)		
Second generation	55 (68)		
Combined	17 (21)		
No antipsychotics	1 (1)		
PANSS Total score (SD)	66.35 (17.08)		
PANSS Positive Symptom Subscale (SD)	16.44 (6.66)		
PANSS Negative Symptom Subscale (SD)	16.78 (7.92)		
PANSS General Psychopathology Subscale (SD)	33.14 (8.07)		
SANS (SD)			
Expressivity (SANS Affective Flattening and Alogia subscales)	3.02 (3.20)		
Social Motivation (SANS Avolition-Apathy and Anhedonia-Asociality)	2.91 (2.87)		
Total scores	6.43 (6.42)		
ILS-ps factor (SD)	51.25 (9.26)		
CDSS (SD)	2.69 (3.46)		
Simpson and Angus Scale (SD)	2.19 (2.60)		

PANSS: Positive and Negative Syndrome Scale.

SANS: modified Scale for the Assessment of Negative Symptoms.

MASS: Motor-Affective-Social Scale.

CDSS: Calgary Depression Scale for Schizophrenia.

ILS-ps: Independent Living Scales problem-solving factor.

emotion predictions and social traits remained significant in the participants who completed the ER-40 as well. In patients and controls, all but one (the prediction of "sociable" by fear in patients) associations remained significant. We were also interested to know whether implicit emotion perception predicted social traits independently of explicit recognition. We entered the ER-40 scores for each emotion in the model and for each group separately. In controls, the prediction of "aggressive" and "mean" by expressions of fear lost its significance. In patients only the prediction of "attractive" by fear lost its significance.

3.3. Associations with demographics and clinical ratings

Few variables were associated with implicit emotion perception. In controls, females used expressions of fear to predict "aggressive" to a lesser degree than males. In patients, females used fear expressions to negatively predict "attractive" more than males, and used disgust expressions to negatively predict "fun" whereas males used them to positively predict "fun". In- and out-patients did not significantly differ in any predictive analyses. The higher the Quick-IQ score was, the more the patients used happy expressions to positively predict "attractive", "fun", "intelligent", and "sociable".

However, after entering IQ scores in the model, the significance of the prediction of social traits by emotion perception did not change in any analyses. Among clinical variables, one analysis survived correction for multiple tests: the more depressed the patients were, the more they used expressions of anger to rate "mean".

We were particularly interested in the association between our social skills measure (ILS-ps) and implicit emotion perception in patients. ILS-ps scores were significantly associated with the prediction of "attractive", "emotionally stable", "fun", "intelligent" and "sociable" by expressions of happiness (β estimate = 0.09, $F = 7.8$, $q = 0.03$; β estimate = 0.04, $F = 7.02$, $q = 0.04$; β estimate = 0.06, $F = 12.78$, $q = 0.004$; β estimate = 0.04, $F = 6.01$, $q = 0.05$; and β estimate = 0.08, $F = 19.68$, $q = 0.0002$ respectively), and with the prediction of "aggressive" by expressions of disgust (β estimate = 0.09 $F = 12.07$, $q = 0.004$). These results remained significant even after controlling for Quick-IQ scores. In the 54 patients who completed the ER-40, ILS-ps scores were still significantly associated with the prediction of "emotionally stable", "fun", and "sociable" by expressions of happiness, when all ER-40 scores were entered in the model.

In controls, ER-40 hit rates were not associated with any demographic variables. In patients, Quick-IQ scores were significantly

Table 2
Prediction of trait ratings by emotional expressions (mixed model analyses).

Patients (n = 81)										
(Estimated coefficients)										
Traits										
Emotion	Emotionally									
	Attractive	Fun	Sociable	Trustworthy	Stable	Intelligent	Dominant	Aggressive	Mean	Weird
Happy	1.19	1.07	1.04	0.55	0.93	0.76	-0.43	-1.02	-0.84	-0.86
Surprised	0.64	0.48	0.62	0.37	-0.07	0.58	-0.53	-0.70	-0.64	-0.25
Sad	-0.23	-0.23	-0.32	-0.29	0.16	-0.13	0.04	0.3	0.58	-0.14
Fearful	-0.60	-0.17	-0.68	-0.89	-0.65	-0.49	-0.53	0.23	0.63	1.26
Disgusted	1.11	0.71	0.49	0.42	-0.23	0.24	-0.58	-0.68	-0.37	0.48
Angry	0.07	0.25	-0.26	-0.10	0.37	-0.11	0.75	0.60	0.33	-0.33
Control Participants (n = 62)										
(Estimated coefficients)										
Emotion	Emotionally									
	Attractive	Fun	Sociable	Trustworthy	Stable	Intelligent	Dominant	Aggressive	Mean	Weird
Happy	0.73	1.28	1.75	1.48	1.18	1.24	0.05	-1.11	-0.66	-1.7
Surprised	0.05	0.71	1.18	1.15	1.23	0.94	-0.21	-0.56	-0.54	-1.12
Sad	-0.41	-0.28	-0.2	-0.17	-0.2	0.07	0.34	0.72	0.74	-0.07
Fearful	-1.27	-1.09	-1.11	-0.86	-1.82	-1.73	-0.11	0.79	0.69	2.96
Disgusted	0.33	0.02	0.23	0.53	-0.34	0.19	-0.26	-0.56	0.23	0.38
Angry	0.02	0.04	0.06	-0.15	0.01	-0.24	1.33	1.48	0.7	-0.44
Patients versus Controls										
(q-values of the interaction term, group by emotion, after False Discovery Rate correction, when q <= 0.05)										
Emotion	Emotionally									
	Attractive	Fun	Sociable	Trustworthy	Stable	Intelligent	Dominant	Aggressive	Mean	Weird
Happy			0.03	0.001						0.002
Surprised					0.03					
Sad										
Fearful		0.03			0.003	0.001				0.001
Disgusted										
Angry								0.001		

	Positive	Negative
Q value < 0.05		
Q value < 0.01		

Q value < 0.05	Controls > Patients
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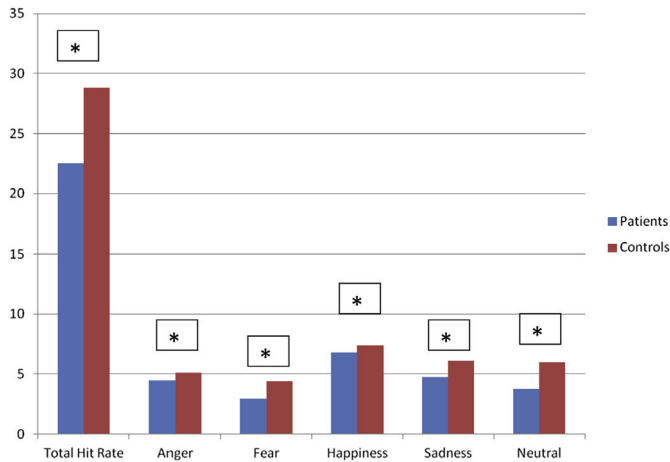


Fig. 1. Emotion recognition scores with the ER-40 (to facilitate comprehension, raw accuracy scores are represented in the figure, but all analyzes were done with the unbiased hit rates). * if $p < 0.05$. Total scores: patients: $m = 2.61$, $SD = 1.25$; Controls $m = 3.65$, $SD = 1.01$; $F_{(1, 91)} = 18.22$, $p < 0.001$, Cohen's $d = -0.92$. Unbiased Hit Rate for anger: patients: $m = 0.42$, $SD = 0.23$; Controls $m = 0.55$, $SD = 0.19$; $F_{(1, 91)} = 8.33$, $p = 0.005$, $d = -0.62$. Unbiased Hit Rate for fear: patients: $m = 0.30$, $SD = 0.29$; Controls $m = 0.48$, $SD = 0.27$; $F_{(1, 91)} = 9.86$, $p = 0.002$, $d = -0.64$. Unbiased Hit Rate for happiness: patients: $m = 0.68$, $SD = 0.29$; Controls $m = 0.87$, $SD = 0.20$; $F_{(1, 91)} = 12.39$, $p = 0.01$, $d = -0.76$. Unbiased Hit Rate for sadness: patients: $m = 0.44$, $SD = 0.22$; Controls $m = 0.58$, $SD = 0.20$; $F_{(1, 91)} = 10.30$, $p = 0.002$, $d = -0.67$. Unbiased Hit Rate for neutral: patients: $m = 0.36$, $SD = 0.31$; Controls $m = 0.62$, $SD = 0.26$; $F_{(1, 91)} = 18.24$, $p < 0.001$, $d = -0.91$.

correlated with the explicit recognition of anger ($\rho = 0.35$, $p = 0.005$), fear ($\rho = 0.38$, $p = 0.002$), and total scores ($\rho = 0.36$, $p = 0.004$). In- and out-patients had worse scores than controls ($p < 0.0001$ for both), while patients groups did not significantly differ from each other ($p = 0.94$). ILS-ps scores were significantly correlated with the recognition of neutral ($\rho = 0.33$, $p = 0.008$), happy ($\rho = 0.30$, $p = 0.02$), angry ($\rho = 0.34$, $p = 0.006$), fearful faces ($\rho = 0.25$, $p = 0.05$), and total scores ($\rho = 0.38$, $p = 0.002$).

4. Discussion

In this study, we used newly-developed technology in social neuroscience to examine implicit emotion perception in patients with schizophrenia or schizoaffective disorder, and we found that implicit emotion processing was impaired in patients. Moreover, in patients, impaired implicit emotion processing was associated with poor daily life skills.

Previous studies have reported spared performances on implicit emotion perception tasks in schizophrenia, and to our knowledge this is the first behavioral study that clearly shows that implicit emotion processing is impaired in schizophrenia. Our facial stimuli differed from most previously-published studies on implicit emotion perception in schizophrenia, which used intense expressions of “pure” emotions and rarely more than one negative emotion. The emotional expressions used in this study were quite subtle, and it may even seem surprising that patients were able to implicitly process these subtle expressions. However, not only were patients able to use very subtle emotional expressions but they also differentiated all negative emotions: each negative emotion had a very different profile in its prediction of social trait ratings. Concurrent validity for patients' performances can be found in the findings that implicit perception was associated with social skills and with aggression for a subgroup of patients (in Antonius et al., 2013). More importantly, the validity of patients' performance is supported by the similar pattern of trait prediction in both groups and with other studies (Said et al., 2009b). For patients and

controls, subtle expressions of happiness positively predicted positive trait ratings and negatively, negative trait ratings. Both groups used expressions of fear to give low ratings on positive traits and high ratings on negative traits. Moreover, expressions of anger positively predicted ratings for dominance, aggressive and mean in both groups. Patients used disgust to rate positive traits higher and negative traits lower, whereas in controls disgust did not predict any traits. These findings seem surprising as disgust is considered a negative emotion, and in a previous and quite comparable study, disgust negatively predicted positive social traits and positively predicted negative traits in non-clinical subjects (Said et al., 2009b). Consequently, the validity of this expression with the faces we used can be questioned. It is still possible that these different uses of disgust to predict traits reflect an unusual processing of disgust expressions in schizophrenia, as shown in a previous study (Kohler et al., 2003). Sample bias cannot explain the patients' abilities to implicitly use subtle emotion expressions in our study. Most patients were chronic patients, their explicit emotion recognition was quite impaired, and the effect size of the group difference on explicit recognition was very similar to the one reported in a meta-analytic analysis (Kohler et al., 2010).

Impairment in implicit emotion perception was found for fear, happiness, anger and surprise. Our results could not identify a specific deficit, but suggest a global deficit in implicit emotion processing. These findings may reflect an impaired perception of physical facial features, poorer emotion knowledge and/or differences in strategy in patients. In other words, our results may reflect a bottom-up deficit (poor implicit emotion recognition) and/or a top-down deficit (impaired strategy). In our study, overall patients used similar strategies when they used emotion resemblance to make trait judgments (happiness resemblance positively predicted positive traits and negatively predicted negative traits; while fear and anger positively predicted negative traits and negatively predicted positive traits). However, it is possible that patients did not use emotion resemblance as much as controls (even if their implicit emotion recognition was intact). Emotion resemblance is one facial feature that people use to make trait judgments among other facial features (Montepare and Dobish, 2003). Therefore it is possible that compared to controls, patients relied more on other-than-emotion-resemblance facial features when they made trait judgments. This opens the door to new research. It also should be kept in mind that explicit emotion recognition studies have shown that impaired early-stage visual processing and strategies contribute to poor emotion recognition deficits in schizophrenia (Butler et al., 2009; Lee et al., 2011).

Deficits in implicit emotion processing were associated with poor everyday problem-solving skills. Particularly, the less patients used subtle expressions of happiness to judge a face as attractive, emotionally stable, fun, intelligent and sociable (and also the more they used subtle expressions of disgust to judge a face as aggressive), the worse their daily life skills were. Our study cannot answer the question whether this association is a direct association or is mediated by other factors, but it is interesting to notice that this association remained significant even after controlling for Quick-IQ and explicit emotion recognition. We used the ILS-ps in part because participants were in- and out-patients. Future studies should use scales that more specifically measure social skills and functioning outcomes in outpatients.

In patients, explicit emotion recognition was associated with everyday problem-solving skills. This is in accord with other studies that showed a positive association between explicit emotion recognition and social functioning (Schmidt et al., 2011). However, explicit emotion recognition did not predict any social trait rating in both groups, even though shared methodology could have been a confounding factor (both trait ratings and explicit emotion

recognition had a verbal information processing component). Altogether, our results argue for a distinctiveness between implicit and explicit emotion perception. This is consistent with previous research that overwhelmingly shows that explicit emotion recognition is impaired in schizophrenia; whereas, the few studies that examined implicit emotion perception did not find significant differences with healthy subjects. Research in social cognition and neuroimaging has supported the distinction between implicit and explicit processes, and our results suggest that the deficits in explicit and implicit emotion perception do not rely on the same processes. Interestingly, a dissociation between the impairment of explicit and implicit facial emotion recognition has also been reported in elderly non-clinical subjects (Franklin and Zebrowitz, 2013). Our results should have some therapeutic consequences. Remediation programs have only focused on improving explicit emotion recognition. Although it is not clear how remediation programs can target implicit emotion perception, a first question will be to know whether the current emotion recognition remediation programs have any impact on implicit perception in schizophrenia.

4.1. Limitations

Emotion resemblance is not the only factor guiding social trait ratings, and other facial cues – such as familiarity, beauty, baby-faceness, and stereotypes – that may impact trait judgments were not examined in our study. However, studies have shown that emotion expressions predict trait impressions independently of those other factors (Montepare and Dobish, 2003). Secondary to technical problems, data on explicit emotion recognition were not available for 33% of the patients and 39% of the controls. This certainly limited the statistical power of the analyses that included explicit emotion recognition scores. Among each group, we compared participants whose scores were available with the other participants, and no demographic or clinical data significantly differentiated these two classes of participants.

4.2. Conclusions and future developments

When inferring social traits from faces, patients with schizophrenia or schizoaffective disorder use very subtle emotion expressions that can be perceived in neutral faces, and they use each facial emotion in a rather similar pattern as healthy subjects. Nevertheless, deficits in implicit emotion perception were found in patients: they were less sensitive to subtle expressions of fear, happiness, anger and surprise, which were also the most relied-upon emotions. Moreover, these deficits were associated with poorer everyday problem-solving skills, but were relatively independent of explicit emotion recognition. Implicit and explicit social perceptions use different neural networks (Lieberman, 2007), and implicit emotion perception has been shown to interact with higher centers involved in cognition and motivation. More research is needed to fully understand the role of implicit and explicit processes in the functional deficits of patients, in order to develop targeted and useful remediation interventions.

Conflict of interest

Fabien Trémeau, Daniel Antonius, Alexander Todorov, Yasmina Rehani, Kelsey Ferrari, Sang Han Lee, Daniel Calderone, Karen A. Nolan, Pamela Butler, Dolores Malaspina and Daniel Javitt have declared that there are no conflicts of interest in relation to the subject of this study.

Contributions

Fabien Trémeau, Alexander Todorov, Daniel Calderone, Dolores Malaspina and Daniel Javitt *designed research*. Fabien Trémeau, Daniel Antonius, Yasmina Rehani, Kelsey Ferrari, Karen A. Nolan and Pamela Butler *performed research*. Fabien Trémeau, Daniel Antonius, Sang Han Lee, Karen A. Nolan, Dolores Malaspina and Daniel Javitt *analyzed data*. Fabien Trémeau, Daniel Antonius, Sang Han Lee, Karen A. Nolan, Pamela Butler, Dolores Malaspina and Daniel Javitt *wrote the paper*.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.jpsychires.2015.10.001>.

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