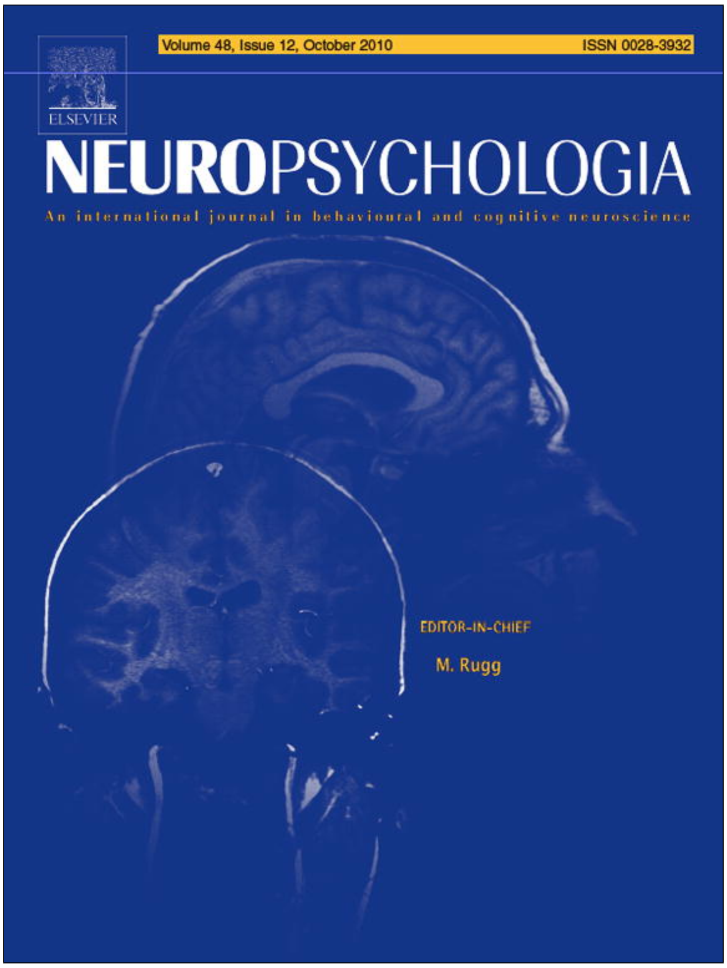
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The emotional paradox: Dissociation between explicit and implicit processing of emotional prosody in schizophrenia

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ABSTRACT

People with schizophrenia show well-replicated deficits on tasks of explicit recognition of emotional prosody. However it remains unclear whether they are still sensitive to the implicit cues of emotional prosody, particularly when they exhibit high levels of social anhedonia. A dual processing model suggesting a dissociation between the neural networks involved in explicit and implicit recognition of emotional prosody has yet to be validated.

21 participants with schizophrenia and 21 controls were recruited. In the explicit recognition task, individuals listened to semantically neutral words pronounced with two different emotions and judged their emotional prosody. In the vocal emotional Stroop task, patients and controls listened to words with a positive or negative emotional valence pronounced with congruent or incongruent emotional prosody and judged their emotional content. Patients were also assessed with the Chapman Anhedonia Questionnaire and the Schizophrenic Communication Disorders scale.

Individuals with schizophrenia were impaired in their explicit recognition of emotional prosody related to controls. In contrast, they showed a vocal emotional Stroop effect that was identical to controls for reaction time and greater for accuracy: patients were still sensitive to implicit emotional prosody. In addition the vocal emotional Stroop score increased with social anhedonia but was unrelated to communication disorders.

Whereas explicit vocal affect recognition is impaired, implicit processing of emotional prosody seems to be preserved in schizophrenia. Our results provide evidence that at a behavioural level, the implicit and explicit processing of emotional prosody can be dissociated. Remediation of emotional prosody recognition in schizophrenia should target cognitive rather than sensory processes.

1. Introduction

Individuals with schizophrenia show deficits in a wide range of social cognitive domains such as social judgements (Baas, van't Wout, Aleman, & Kahn, 2008), Theory of Mind, attributional style (the manner in which a person generates causal explanations for positive and negative outcomes) and emotion recognition (Penn, Sanna, & Roberts, 2008). For people with schizophrenia, emotion recognition is a key determinant of quality of life (Poole, Tobias, & Vinogradov, 2000) and of the ability to work and live independently (Kee, Green, Mintz, & Brekke, 2003). A strong consensus supports a stable deficit of emotional prosody recognition in individuals with schizophrenia, with a large effect size (Hoekert, Kahn, Pijnenborg, & Aleman, 2007). Furthermore, a study suggests that vocal affect recognition is more impaired in schizophrenia than in its facial counterpart (Vaskinn et al., 2007).

Emotional prosody recognition is usually assessed with paradigms requiring explicit judgements, and the implicit aspects of emotional prosodic processing have received limited attention in studies of schizophrenia. In the domain of facial emotions, a dual model has been proposed to distinguish implicit from explicit processing of emotional information, with a dissociation at the behavioural level (Mathersul et al., 2009), and distinct underlying neural bases (Gorno-Tempini et al., 2001; Whalen et al., 1998; Winston, O'Doherty, & Dolan, 2003). Two studies have validated this dual model processing of facial emotions in schizophrenia, as both showed that patients were impaired in explicit categorization of facial emotions whereas implicit recognition was preserved (Linden et al., 2009; van't Wout et al., 2007). However, it is unclear whether a dual processing mechanism exists for emotional prosody. As yet no single study shows convincing evidence that implicit and explicit processing of emotional prosody can be disso-

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ciated at the behavioural level, although some studies lend support to this hypothesis. The right temporal cortex is a candidate region for localizing where implicit processing of emotional prosody takes place as it has sensory-integrative functions in affective prosody recognition (Schirmer & Kotz, 2006). Explicit processing of emotional prosody could be mediated by frontal structures such as the right inferior frontal gyrus which plays an evaluative role in emotional prosody recognition (Ethofer et al., 2006; Leitman et al., 2010). The amygdala seems to be preferentially activated in implicit perception of vocal emotions and becomes deactivated for explicit recognition tasks (Adolphs, 2002; Morris, Scott, & Dolan, 1999; Wildgruber, Ackermann, Kreifelts, & Ethofer, 2006). As people with schizophrenia are impaired in their explicit categorization of emotional prosody, they are an ideal population on which to test this model. To our knowledge, no study has measured the implicit recognition of vocal emotions in schizophrenia. We hypothesise that this implicit recognition may be preserved in schizophrenia, which would support the dual model of emotional prosody processing.

To assess the implicit processing of emotional prosody, we used a vocal emotional Stroop paradigm. In this task, participants had to judge the emotional valence conveyed by the meaning of a word pronounced with congruent or incongruent emotional prosody. Implicit prosodic processing is measured by the effect of emotional prosody on emotional-content judgement. It can be quantified by the vocal emotional Stroop effect, i.e. the slowdown of performance for incongruent versus congruent items. Several studies have demonstrated a significant vocal emotional Stroop effect in normal participants in different languages: German (Schirmer & Kotz, 2003; Schirmer, Zysset, Kotz, & Yves von Cramon, 2004), Cantonese (Schirmer et al., 2006) and English (Nygaard & Queen, 2008). As such, we expected to observe the vocal emotional Stroop effect in French control participants.

Investigating the vocal emotional Stroop effect in patients with schizophrenia can address the question of whether the perceptual stage of emotional prosody processing is impaired or preserved for these patients. It has been proposed that the schizophrenic deficit in emotional prosody recognition could be the consequence of a sensory impairment in fundamental frequency discrimination (Leitman et al., 2005, 2007; Rabinowicz, Silipo, Goldman, & Javitt, 2000). According to this hypothesis, the first perceptive stage of emotional prosody processing would be impaired, leading to a decrease in the implicit influence of emotional prosody on emotional semantic judgement. This should reduce the vocal emotional Stroop effect in patients compared with controls. In contrast, if people with schizophrenia are impaired in emotional prosody recognition solely as a result of a deficit in the explicit categorization stage, then implicit perception of emotional prosody should be preserved. According to this second hypothesis, the vocal emotional Stroop effect should thus not be lower in individuals with schizophrenia as compared to controls. Thus, if the same group of patients who show intact implicit perception of emotional prosody demonstrate an impaired explicit recognition of emotional prosody as compared to controls, this would give evidence for a dissociation between explicit and implicit processing of emotional prosody.

Emotional conflict resolution might also be worse in patients with schizophrenia than in controls, which would lead to an increase of their vocal emotional Stroop effect. A differentially stronger subliminal priming effect using emotional facial expressions has been demonstrated in people with schizophrenia as compared with controls (Hoschel & Irle, 2001), suggesting an increase in the automatic processing of emotional information. In another study, participants made an emotional semantic judgement about a word superposed on a picture with either a congruent or an incongruent emotional valence (Park, Park, Chun, Kim, & Kim, 2008). Here, patients with schizophrenia made more errors than controls on incongruent but not on congruent trials, suggesting an inefficient top-down control of bottom-up emotional information, leading to a deficit in emotional conflict resolution. The neural networks which monitor conflict in emotional prosody and emotional semantic content in young normal individuals include the medial prefrontal areas and particularly the anterior cingulate cortex (Schirmer et al., 2004; Wittfoth et al., 2010). A deficit in cognitive conflicts monitoring has been associated with hypoactivity in these areas in schizophrenia (Kerns et al., 2005). These finding suggest that individuals with schizophrenia may present difficulties in resolving vocal emotional conflicts. To our knowledge, our study is the first one to explore conflict resolution for emotional prosody in schizophrenia.

Finally, we have also explored correlations between the vocal emotional Stroop effect and two symptoms of schizophrenia: anhedonia and communication disorders. Anhedonia is defined as a diminished capacity to experience pleasant emotions either from social-interpersonal sources (talking, socializing, being with people in other ways) called *social anhedonia*, or from physical-sensual ones (smell, touch, taste, sight, etc.) called *physical anhedonia* (Chapman, Chapman, & Raulin, 1976). This condition is stable, disabling and frequent in schizophrenia (Horan, Kring, & Blanchard, 2006). It has been linked to a reduced effect of amygdala activation in response to positive versus negative stimuli, suggesting a failure to mark stimulus salience (Dowd & Barch, 2009). Moreover, normal participants with low social orientation (i.e. low interest and concern for other individuals as in social anhedonia) show a decrease in amygdala and orbitofrontal cortex reactivity to emotional prosody (Schirmer et al., 2008). Thus, it is possible that in schizophrenia, social anhedonia could be explained as a decrease in sensitivity to implicit emotional prosody. The sensitivity to visual emotional cues has been assessed in deficit syndrome schizophrenia (Strauss, Allen, Duke, Ross, & Schwartz, 2008). This form of schizophrenia is characterized by predominant negative symptoms such as anhedonia and blunted affect, in which emotional expressivity is decreased (Neale, Blanchard, Kerr, Kring, & Smith, 1998). The authors used a classical emotional Stroop paradigm in which participants named the colour of written words conveying different emotional meanings while attempting to ignore these meanings. Interference score was measured by the delay in response time in naming the colour of the emotional words versus the neutral ones. Interference was smaller for positive emotions in patients with deficit syndrome schizophrenia than in patients with non-deficit syndrome schizophrenia and controls, as if their attention was not automatically drawn toward the environmental cues of positive emotions. Paradoxically, emotional sensitivity and affect recognition seem to be preserved despite high levels of blunted affect (Kring, Kerr, Smith, & Neale, 1993; Sweet, Primeau, Fichtner, & Lutz, 1998). That's why we choose to investigate the correlation between implicit emotional processing and anhedonia rather than blunted affect. According to the hypothesis that anhedonia in schizophrenia is due to a decreased sensitivity to implicit emotional prosodic cues, vocal emotional Stroop scores should decrease as levels of anhedonia increase.

Another impairing symptom of schizophrenia is disorganization, of which regular and fundamental components are formal thought and speech disorders (Hardy-Bayle, Sarfati, & Passerieux, 2003). Disorganization has a major functional significance for schizophrenia because it predicts psychosocial status as measured 1–4 years follow-up (Kurtz, Moberg, Ragland, Gur, & Gur, 2005). Schizophrenic speech disorders have been linked with aberrant emotional processing: patients produced more speech errors in the form of referential communication failure when discussing affectively negative topics than when discussing affectively positive topics (Burbridge & Barch, 2002). It has also been demonstrated that emotional Stroop performance is related to disorganization in

Table 1
Characteristics of participants.

	Patients (14 males, 7 females)		Controls (13 males, 8 females)	
	Mean	S.D.	Mean	S.D.
Age (year)	38.2	12.6	37.3	14.5
Educational level (year)	11.5	2.9	14.8	2.1
Estimated premorbid IQ	103.7	7.0	110.2	4.3
Duration of hospitalisation (months)	20.8	19.6		
Chlorpromazine equivalents (mg/24h)	680.1	658.7		
PANSS				
Total score	90.0	13.6		
Positive syndrome scale score	21.5	4.8		
Negative syndrome scale score	24.0	5.1		
General symptoms score	44.5	7.7		
Chapman's Physical Anhedonia Scale score	17.9	9.0		
Chapman's Social Anhedonia Scale score	15.2	5.8		
SCD Score	10.9	3.4		

schizophrenia (Phillips, Deldin, Voglmaier, & Rabbitt, 2005). On this classical emotional Stroop paradigm, the interference effect was increased on negative and high-arousal emotional words in individuals with a disorganized form of schizophrenia as compared to individuals with a non-disorganized form. This suggests an overlap in the cerebral structures underlying disorganization and deficits of emotional conflict monitoring. According to this result, patients with a high level of disorganization and communication disorders should be impaired in the cognitive modulation of irrelevant cues to emotional prosody as compared with patients with low-level communication disorders. In other words, vocal emotional Stroop should increase as levels of communication disorders increase, leading to a positive correlation between vocal emotional Stroop scores and clinical ratings of communication disorders that arise from disorganization.

2. Methods

2.1. Participants

21 patients with schizophrenia and 21 non-patient controls, all native French speakers, participated in this study. All patients were recruited through the department of psychiatry at Versailles Hospital, and had been stabilized for at least 1 month. Eight of them were inpatients. The psychiatric diagnosis was confirmed by an independent psychiatrist according to the DSM-IV-R criteria for schizophrenia. At the time of testing, all patients were taking antipsychotics. The control participants were volunteers from Versailles Hospital and *Laboratoire de Sciences Cognitives et Psycholiguistique*. The control group was screened for current or past psychiatric illness with a standard psychiatric interview and participants were excluded if they met criteria for any axis I disorders of the DSM-IV-R. None of the subjects had to be excluded.

All participants underwent a standard medical history interview. Exclusion criteria included a history of head injury with loss of consciousness longer than 10 min, epilepsy, or a hearing impairment and substance use disorder in the 6 months prior. Participants were assessed with the French version (Mackinnon & Mulligan, 2005) of the NART (Nelson, 1982) (fNART) a test devised to estimate premorbid intellectual performance (IQ) with a high test–retest reliability in schizophrenia (Morrison, Sharkey, Allardyce, Kelly, & McCreadie, 2000).

Patients did not differ from controls in terms of age, $t(40) = 0.20$, $p = 0.84$, and gender ratio, $\chi^2(1, n = 42) = 0.0$, $p = 1$. However, patients had lower premorbid IQ than controls, $t(40) = 3.6$, $p < 10^{-3}$, and also lower educational levels, $t(40) = -4.2$, $p < 10^{-3}$ (see Table 1).

After receiving a complete description of the study, written informed consent was obtained from each participant. The study was approved by the local medical ethics committee.

2.2. Clinical ratings

The results are reported in Table 1. We rated the severity of schizophrenic symptoms in all patients with the Positive and Negative Syndrome Scale (PANSS) (Kay, Fiszbein, & Opler, 1987). Anhedonia was assessed with the French version (Assouly-Besse, Dollfus, & Petit, 1995) of Chapman's Social and Physical Anhedonia Scales (Chapman et al., 1976). These true/false self-report trait questionnaires measure individual differences in the capacity to experience pleasure from social-interpersonal and physical-sensual sources. Communication disorders were measured with the Schizophrenic Communication Disorders scale (SCD) (Bazin, Sarfati, Lefrere, Passerieux, & Hardy-Bayle, 2005), which assesses two cognitive disorders specific to disorganization and that appear during a structured interview: difficulties in integrating contextual information and in attributing mental states. This scale has a good level of internal consistency and a one-dimensional structure. It also exhibits good concurrent validity, sensitivity to change and specificity in relation to depression and mania.

Chlorpromazine equivalents were calculated for each patient according to Rijcken's work (Rijcken, Monster, Brouwers, & de Jong-van den Berg, 2003).

2.3. Explicit and implicit processing of emotional prosody

We selected 400 masculine singular adjectives from the French database *Lexique 3.45* (New, Pallier, Ferrand, & Matos, 2001). Emotional valence and intensity were measured on a five-point Lickert scale in a prevalidation study with 21 non-patient volunteers who were different from the control participants of the study. In this scale, the "very negative" and "very positive" labels corresponded to negative and positive valences with high intensity (scores: −2 and 2). "Slightly negative" and "slightly positive" labels corresponded to negative and positive valences with low intensity (scores: −1 and 1). The "neutral" label corresponded to neutral valence with a null intensity (score: 0). This assessment strategy is equivalent to independent measures of valence on the one hand and intensity on the other hand (Syssau, 2005).

For the first experiment, an explicit recognition of emotional prosody task, we selected 79 neutral adjectives whose mean quotation was nearest 0 (range from −0.3 to 0.38, SD = 0.38). These words were pronounced twice, once with an angry and once with a joyful prosody by a professional actor. Two blocks of items (A and B) were constructed so that each member of a given pair appeared in a different block. Participants were instructed to judge if the word was pronounced with a pleasant or an unpleasant intonation while ignoring the meaning of this word.

For the second experiment, the vocal emotional Stroop task, we selected 80 adjectives with a negative valence (range from −1.9 to −0.9, SD = 0.61) and 80 with a positive one (range from 1.1 to 1.9, SD = 0.62). All words were pronounced with both an angry and a joyful prosody, by the same professional actor. This procedure yielded two kinds of items: incongruent items for which the semantic valence and the vocal emotion were in conflict (e.g. a semantically negative word pronounced with a joyful intonation or a semantically positive word pronounced with an angry prosody) and congruent items for which the semantic valence and the vocal emotions were either both positive or both negative. No significant statistical differences were found between the duration of congruent items and incongruent items, $F(1,158) = 0.27$, $p = 0.60$. Two blocks of items (A and B) were also constructed so that each member of a given pair appeared in a different block. Participants were instructed to judge the emotional valence of the meaning of the word while ignoring the emotional intonation of the voice with which it was pronounced.

For both experiments, half the individuals underwent Block A first and then Block B; the reverse was true for the other half of the participants. Within each block trial presentation order was pseudo randomised (no more than three consecutive items with the same vocal emotion were allowed in the first experiment and no more than three consecutive items with the same vocal emotion, congruency status or emotional meaning were allowed in the second one). Each trial ended 3 s after the beginning of the auditory presentation of the words. For each trial, the two response labels were displayed on a screen so as to avoid loading working memory. Participants answered by pressing one of two keyboard buttons. Response times were measured from the onset of each adjectives. Speed and accuracy were emphasized. The auditory stimuli were stored at a sampling rate of 44 kHz and were presented directly through headphones in a quiet room. Before the experiment began, participants received eight practice trials. During practice, the computer provided on-line feedback as to the correctness and speed of the responses. The order of the two experiments was counterbalanced between individuals: half of participants began with the emotional prosody recognition task, and the other half began with the vocal emotional Stroop task to control for possible perseveration effects between two contradictory sets of instructions. In addition, all participants took part in a control task designed to evaluate processing speed. This control task was always performed in between the two test tasks.

2.4. Control task

As yet it remains unclear whether individual with schizophrenia are impaired in emotional prosody recognition due to a general cognitive decline (Bozikas, Kosmidis, Anezoulaki, Giannakou, & Karavatos, 2004; Pijnenborg et al., 2009) or a specific impairment. In our first experiment, participants had a limited amount of time to give their answers. It is possible that the performance difference between patients and controls could be due to a general slowdown in processing speed in schizophrenia, which is a central feature of the cognitive deficit in that accompanies this disorder (Dickinson, Ramsey, & Gold, 2007). Thus, in this control experiment, we measured processing speed in a task that did not involve emotional processing, either explicitly or implicitly.

To do this, we used a computerized word detection paradigm (see Christophe, Peperkamp, Pallier, Block, & Mehler, 2004). A target word was visually presented

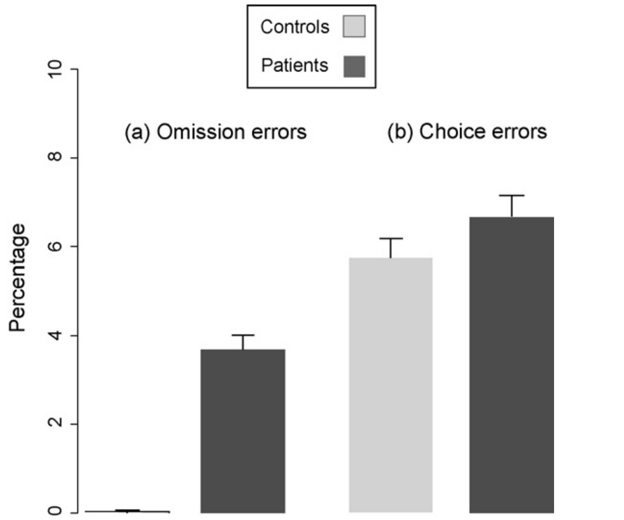

Fig. 1. Mean error rates for the explicit recognition of emotional prosody task. An omission error means an absence of response and a choice error means the selection of the wrong emotional category. Error bars represent the standard error.

for 1.5 s, the screen was left blank for another second and then an auditory sentence was played. 80 sentences were presented, 64 with and 16 without the target word. Participants were asked to push a keyboard button as soon as they recognized the target word in the sentence and to do nothing if they did not hear the word. Each trial ended 7 s after the beginning of the auditory presentation and new trials began 1 s after the end of the previous trial. Response times were measured from the onset of target words, in sentences which contained target words. Speed and accuracy were emphasized. Both target words and test sentences were emotionally neutral.

2.5. Statistical analysis

For the first task (explicit recognition of emotional prosody), ANCOVAs were conducted on individual means of reaction time and accuracy with participants as random factor. There was one between-subject factor, Group (patient versus control); premorbid IQ and Educational Levels were entered as covariates for analyses as they differed between patients and controls. Correlation coefficients (Pearson's) were computed to test for associations between emotional prosody recognition performance and some of the patients' characteristics (chlorpromazine equivalents and PANSS scores) with a Bonferroni correction for multiple comparisons.

For the second task (vocal emotional Stroop task), we conducted repeated measures ANOVAs on reaction time and accuracy with participants as a random factor. There were one within-subject factor, Congruency (congruent versus incongruent) and one between-subject factor, Group. The important effects here are Congruency and the interaction between Group and Congruency. Because the main effect of Group on absolute performance is not of central importance to this study, we did not include the relevant covariates in analysis. In addition, we computed a vocal emotional Stroop score for each patient (mean reaction time for incongruent items minus mean reaction time for congruent items). Correlation coefficients (Pearson's) were computed between vocal emotional Stroop scores and patient characteristics (PANSS, SCD and Chapman's Social and Physical Anhedonia scores) with a Bonferroni correction for multiple comparisons.

For the control task (processing speed), an ANCOVA was conducted on individual means of reaction time with participants as a random factor. There was one between-subject factor, Group; premorbid IQ and Educational Levels were entered as covariates.

3. Results

3.1. Experiment 1: explicit recognition of emotional prosody

3.1.1. Accuracy

The results are displayed in Fig. 1. The error rate analysis revealed a significant main effect of Group, $t(1,40) = 2.144$, $p = 0.039$, after taking into account a marginal effect of Premorbid IQ, $t(1,40) = 1.953$, $p = 0.058$, and a non-significant effect of Educational Level, $t(1,40) = 1.234$, $p = 0.225$. On average patients had lower accuracy rates than controls.

For patients, higher global error rates correlated significantly with higher chlorpromazine equivalents, $r = 0.63$, *corrected p-value* = 0.007, and higher total PANSS scores, $r = 0.59$, *corrected p-value* = 0.014. A post hoc analysis revealed that error rates were particularly correlated with General Psychopathology subscale, $r = 0.51$, *corrected p-value* = 0.057. Higher chlorpromazine equivalents also correlated with higher total PANSS scores, $r = 0.57$, *corrected p-value* = 0.023.

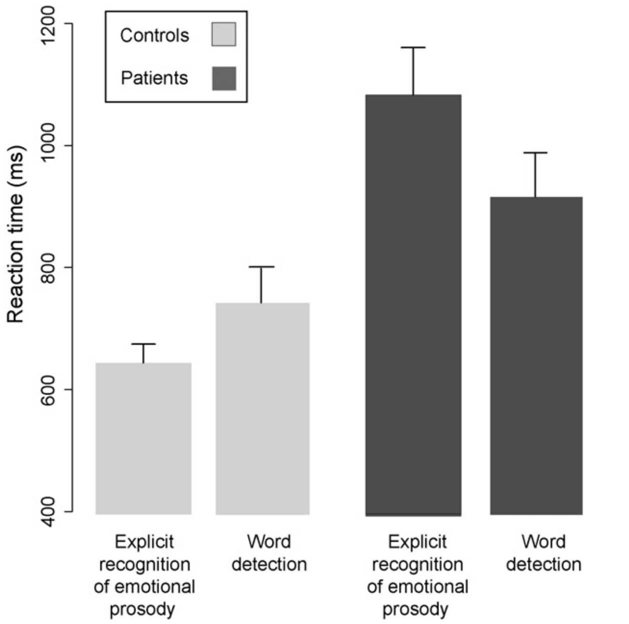

Fig. 2. Mean reaction times for the explicit recognition of emotional prosody task (Experiment 1) and the processing speed control task. Error bars represent the standard error.

3.1.2. Reaction times

The results for the two groups are displayed in Fig. 2. The reaction time analysis revealed a significant main effect of Group, $t(1,40) = 4.445$, $p < 10^{-3}$, after taking into account non-significant effects of Premorbid IQ, $t(1,40) = -0.215$, $p = 0.831$, and Educational Level, $t(1,40) = 0.268$, $p = 0.780$. Overall patients exhibited slower reaction times than controls. For patients, longer reaction times correlated significantly with higher total PANSS scores, $r = 0.65$, *corrected p-value* = 0.001, but not with chlorpromazine equivalents, $r = 0.37$, *corrected p-value* = 0.151. A post hoc analysis revealed that reaction times were particularly correlated with General Psychopathology, $r = 0.57$, *corrected p-value* = 0.012, and with Negative subscales, $r = 0.61$, *corrected p-value* = 0.006.

3.2. Experiment 2: vocal emotional Stroop task

The results for the two groups are displayed in Table 2. The results of one patient were excluded from the analysis because his mean error rate suggested that he judged the emotional valence of

Table 2
Accuracy scores and reaction times on the vocal emotional Stroop task.

	Patients		Controls	
	Mean	S.D.	Mean	S.D.
Accuracy				
Congruent items	0.849	0.378	0.971	0169
Incongruent items	0.828	0. 358	0.965	0.185
Reaction time (ms)				
Congruent items	1308.9	488.9	912.3	280.0
Icongruent items	1338.0	517.4	942.2	309.9

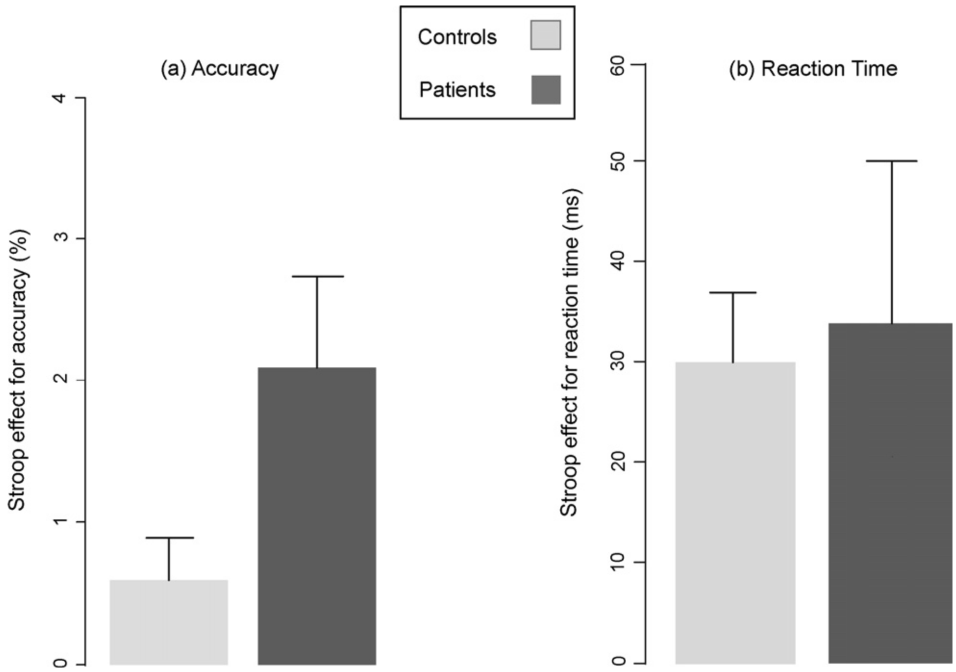

Fig. 3. (a) Mean Stroop effect for accuracy (congruent items minus incongruent ones) for the vocal emotional Stroop task. (b) Mean Stroop effect for reaction times (incongruent items minus congruent ones) for the vocal emotional Stroop task. Error bars represent the standard error.

the word prosody rather than the emotion of the word meaning (7.5% on congruent items, and 83.4% on incongruent items).

3.2.1. Accuracy

The repeated measures ANOVA analysis revealed a main effect of Group, $F(1,39) = 9.95$, $p = 0.003$, Congruency, $F(1,39) = 14.65$, $p < 10^{-3}$, and a significant interaction between Group and Congruency, $F(1,39) = 4.68$, $p = 0.037$. Patients made more errors overall than control participants. More errors were made on incongruent items than on congruent ones, suggesting that emotional prosody interferes with semantic judgement of emotional valence. The effect size of Congruency was 2.09% for patients, $F_1(1,19) = 12.2$, $p = 0.003$, whereas it was smaller for controls, at 0.60%, $F_2(1,20) = 4.1$, $p = 0.056$ (see Fig. 3a).

3.2.2. Reaction times

The repeated measures ANOVA analysis revealed a significant main effect of Group, $F(1,39) = 19.58$, $p < 10^{-3}$, and Congruency, $F(1,39) = 14.65$, $p < 10^{-3}$. Reaction times were longer for incongruent items than for congruent ones, suggesting a Stroop effect of the emotional prosody on the emotional semantic judgement. Our main prediction was that the Congruency effect in patients should not be smaller than it is in controls: indeed, the interaction between Congruency and Group was not significant, $F(1,39) = 0.06$, $p = 0.803$ (see Fig. 3b).

For patients, higher vocal emotional Stroop scores for reaction times marginally correlated with higher social anhedonia scores, $r = 0.54$, *corrected p-value* = 0.052, but not with physical anhedonia, $r = 0.33$, *corrected p-value* = 0.612, SCD, $r = -0.14$, $p = 1$, or total PANSS scores, $r = 0.29$, *corrected p-value* = 0.879.

3.3. Control experiment: processing speed

The results are displayed in Fig. 2 together with reaction time data from Experiment 1 for comparison. The reaction time analysis revealed no significant main effect of Group, $t(1,40) = 0.905$, $p = 0.371$, after taking into account a non-significant effect of Premorbid IQ, $t(1,40) = -0.796$, $p = 0.431$, and a marginally significant effect of Educational Level, $t(1,40) = -1.761$, $p = 0.086$. Thus participants tended to respond faster when they had a higher educational level but patients did not respond significantly slower than controls. An additional repeated measures ANOVA directly comparing reaction times between Experiment 1 and the control task revealed a significant interaction between the within-subject factor Experiment and the between-subjects factor Group, $F(1,39) = 8.373$, $p = 0.006$. Control participants were faster in Experiment 1 than in the processing speed task, $F_1(1,19) = 445.45$, $p < 10^{-3}$, while the reverse was true for patients, $F_2(1,18) = 87.69$, $p < 10^{-3}$.

4. Discussion

4.1. Experiment 1: explicit recognition of emotional prosody

Patients had lower accuracy and were slower than controls on the emotional prosody recognition task even when differences in premorbid IQ and educational levels were taken into account. Patients' lower accuracy was mostly due to the fact that they failed more often than controls to respond within the time limit. It is important to note that their slowness in this task cannot be interpreted as a result of slower general processing, as patients were not significantly slower than controls on the processing speed control task. In fact, controls were faster in the explicit recognition of emotional prosody task than in the control task, suggesting that the emotional judgement was easier than the non-emotional judgment for them, while the reverse was true for patients, indicating that they found the emotional judgment task specifically difficult.

Thus we can conclude that the individuals with schizophrenia in our study were impaired in their explicit recognition of emotional prosody. This deficit in speed and accuracy correlated with the severity of schizophrenic illness on the total PANSS scores, and particularly with the general psychopathology and the negative symptoms scales, thereby replicating in the auditory modality what has already been demonstrated for recognition of emotions in faces (Sachs, Steger-Wuchse, Kryspin-Exner, Gur, & Katschnig, 2004; Schneider, Gur, Gur, & Shtasel, 1995; van't Wout et al., 2007).

We found a negative correlation between accuracy in emotional prosody recognition and antipsychotic doses whereas several studies reported no correlations between these two variables (Haskins, Shutty, & Kellogg, 1995; Kucharska-Pietura, David, Masiak, & Phillips, 2005; Poole et al., 2000). Moreover, deficits in emotional prosody recognition have been demonstrated for patients who had not taken antipsychotic medication during the preceding 2 weeks (Kerr & Neale, 1993). The correlation we found may be explained by illness severity, which was confounded with antipsychotics dosage.

4.2. Experiment 2: vocal emotional Stroop task

This experiment was designed to evaluate the implicit processing of emotional prosody in a group of individuals with schizophrenia who were impaired in explicit emotion recognition. We also examined whether aberrant implicit processing of emotional prosody was related to anhedonia and communication disorders.

We found a significant vocal emotional Stroop effect in both patients and controls: participants responded slower to items with an incongruity between emotional tone and emotional content than to congruent items. If the sensory stage of emotional prosody processing is disrupted in individuals with schizophrenia, as stated by the sensory hypothesis, then patients should be unable to process the prosodic cues encoding emotional prosody. As a result, all words should sound alike to them: one would expect an absence or a severe reduction of the incongruity effect. In contrast, we observed that patients suffered from an incongruent emotional prosody to the same extent than controls. This suggests that the sensory stage of emotional prosody processing is preserved in schizophrenia.[1]

In the error rate analysis, we found a significant interaction between Group and Congruency in the direction of a greater vocal emotional Stroop effect for patients than for controls. This interaction is difficult to interpret because of a floor effect on error rates in control participants which would potentially decrease their vocal emotional Stroop effect. The increase of the vocal emotional Stroop effect in schizophrenia should be demonstrated in another paradigm before we can conclude that vocal emotional conflict resolution is impaired in schizophrenia.

The marginal correlation we found between social anhedonia and the vocal emotional Stroop effect suggests a link between social anhedonia and the implicit perception of emotional prosody. Patients who were more socially anhedonic tended to exhibit a greater vocal emotional Stroop effect. Although this effect needs to be replicated on a larger sample, this result warrants further attention. Contrary to what we originally predicted, this result suggests that social anhedonia in schizophrenia cannot be explained by an insensitivity to emotional stimuli, in particular to vocal emotions. Preservation of emotional sensitivity in anhedonic schizophrenia has already been demonstrated with an affective priming task (Suslow, Roestel, Droste, & Arolt, 2003). Our results could even suggest that anhedonia in schizophrenia is linked with a hypersensitivity to vocal emotional information. This result is coherent with an increased sensitivity to affectively valenced primes found in non-schizophrenic participants with high level of social anhedonia as compared to controls (Kerns & Berenbaum, 2000; Martin & Kerns, 2010). It is also consistent with other several studies which have shown a positive correlation between subliminal sensitivity to emotional faces and anhedonia in schizophrenia (Suslow, Roestel, & Arolt, 2003). Another study has even demonstrated a better detection of positive faces for anhedonic patients in a face-in-the-crowd paradigm as compared with non-anhedonic patients and control participants (Suslow, Roestel, Ohrmann, & Arolt, 2003).

Finally, our results did not yield any links between communication disorders and the vocal emotional Stroop effect, and our hypothesis that the aberrant implicit processing of emotional prosody shares the same cognitive basis as communication disorders arising from disorganization was not validated. This might suggest that conceptual disorganization is independent from an emotional conflict resolution deficit in schizophrenia, as has previously been suggested by Kerns (2009). According to this hypothesis, different kinds of conflicts resolution relate to specific symptoms in schizophrenia. Disorganization is associated with increased response conflict on classical Stroop tasks whereas anhedonia is linked with increased emotional conflict on emotional Stroop tasks. To our knowledge, our study is the first one to establish a link between social anhedonia and emotional conflicts resolution in schizophrenia. It also gives an experimental argument in favour of an independence between emotional conflict resolution in schizophrenia and disorganization.

4.3. General discussion

The global aim of this study was to search for a dissociation between explicit emotional prosody recognition, usually impaired in schizophrenia, and implicit perception of emotional prosody, which has been largely ignored in this disorder. In this group of patients, we observed an impairment of explicit emotional prosody recognition that was influenced by the severity of illness and particularly the severity of negative symptoms and general psychopathology. In contrast, implicit perception of emotional prosody was preserved and shown to be independent of the severity of schizophrenia. Such a dissociation implies that the emotional stimuli are initially processed by the perceptual system but that patients are not able to explicitly classify them. Our results validate the dual model of emotional prosody processing where implicit processes are dissociated from explicit ones.

The prosody recognition deficit in schizophrenia may involve a more elaborate processing stage of categorization of emotional prosody. This stage could be sensitive to impairments in executive functioning. Our result partly explains why explicit recognition of emotional prosody has been shown to correlate significantly with attention and executive functions in schizophrenia (Bozikas et al., 2004), and argues against an exclusively sensory explanation of the deficit.

[1] As suggested by an anonymous reviewer, it is still possible that the sensory stage could be partially impaired with a preserved vocal emotional Stroop effect as we found in our study. This could happen if some participants with schizophrenia also presented a deficit of inhibitory control, as is often the case in schizophrenia (Hepp, Maier, Hermle, & Spitzer, 1996). For example, some patients might not have perceived the prosody of some items, leading to a decrease of the vocal emotional Stroop effect, whereas other patients who had correctly perceived emotional prosody might have a higher vocal emotional Stroop effect because of a deficit in inhibitory control. On average, the vocal emotional Stroop effect in the group of patients would be similar to the one of controls. This alternative interpretation of our data predicts that patients who have a deficit in sensory processing of emotional prosody should have a low performance on the first experiment and should present a small Stroop effect in the second one. In contrast, patients who do not have any sensory deficit should have a high performance on the first experiment and a large Stroop effects in the second one because of a deficit in inhibition. In a post hoc analysis, we computed correlations between performance on the explicit recognition task and the vocal emotional Stroop effect for patients. The vocal emotional Stroop effect did not correlate with accuracy in the first experiment ($r = 0.09$, *uncorrected p-value* = 0.72) but significantly correlated with response time ($r = 0.47$, *uncorrected p-value* = 0.036). Patients who had a high emotional Stroop effect were slow in their recognition of emotional prosody. Thus, it seems unlikely that the group's performance on the first task was explained by an auditory sensory deficit in some patients which was counterbalanced by a deficit in inhibition in other patients. Further studies should confirm the rejection of this double deficit alternative explanation by demonstrating a preserved vocal emotional Stroop effect in schizophrenic participants who have a normal or decrease interference effect on a classical Stroop paradigm.

This finding may have impact regarding cognitive remediation of emotional prosody recognition in schizophrenia. To our knowledge, tasks to improve the perception of emotional prosody have not yet been incorporated in remediation programs dedicated to people with schizophrenia, whereas these patients can be successfully trained to recognize facial emotions (van der Gaag, Kern, van den Bosch, & Liberman, 2002; Wölwer et al., 2005). This selective impairment in categorizing vocal emotions might be similarly improved with training. Remediation programs in which emotional categories are explicitly linked with cues of emotional prosody could be more efficient than low-level auditory training. In the field of facial emotion recognition, training programs targeting cognitive rather than sensory skills have shown encouraging results for individuals with schizophrenia (Combs et al., 2008; Russell, Green, Simpson, & Coltheart, 2008). It is important to determine if such programs should be extended to emotional prosody recognition.

Our results suggest that people with schizophrenia might be impaired in resolving the conflicts between the meaning of a word and the way it is pronounced as patients were much less accurate on incongruent versus congruent word-prosody pairs. However, this conclusion still rests tentative, as control participants did not show a similar difference in accuracy between the two conditions due to a ceiling effect. Further studies should explore the monitoring and the resolution of emotional conflicts with behavioural or functional imaging paradigms. These studies may inform our understanding of the interaction between cognitive and emotional processing, which has been suggested to be abnormal in schizophrenia (Ciompi, 1997). This could explain why individuals with schizophrenia are so compromised in emotionally ambiguous social situations, such as those with sarcasm or irony (Herold, Tenyi, Lenard, & Trixler, 2002; Kern et al., 2009; Kosmidis, Aretouli, Bozikas, Giannakou, & Ioannidis, 2008; Leitman, Ziwich, Pasternak, & Javitt, 2006).

Patients who experience a high level of social anhedonia seem to be oversensitive to the implicit cues of emotional prosody as evidenced by greater vocal emotional Stroop effects. This result is consistent with Meehl's model of anhedonia in schizophrenia (Meehl, 1962): social anhedonia is not linked with a general diminution in hedonic capacities but with an increase in aversive experiences in social contexts. These experiences lead to an 'aversive drift', i.e. the tendency for activities and people to take on a burdensome and threatening affective charge. The aversive drift leads to an avoidance of any contact with the social environment. We believe that hypersensitivity to emotional prosody could be one of the cognitive bases to these negative social experiences in people with anhedonic schizophrenia.

In conclusion, the results of this study demonstrate that the cognitive component of emotional prosody recognition is impaired in schizophrenia, which should have an impact on the development of effective remediation strategies. Moreover, social anhedonia in schizophrenia should not be viewed as an emotional blindness but rather as a consequence of an ineffective cognitive modulation of prepotent emotional cues.

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