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Mismatched Expressions Decrease Face Recognition and Corresponding ERP Old/New Effects in Schizophrenia

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Objective: The objective was to investigate the electrophysiological (ERP) correlates of mismatched expression on face recognition in schizophrenia. ***Method:*** Expression-change effects and associated ERPs were explored in patients with schizophrenia ($n = 20$) and paired comparison participants ($n = 20$) on a long-term face-recognition task. ***Results:*** A facial-expression change decreased discriminability for patients with schizophrenia than for healthy participants. The patients' recognition deficit was accompanied by the absence of the midfrontal FN400 and late parietal ERP old/new effects in the mismatched-expression condition. By contrast, preserved midfrontal FN400 and late parietal ERP old/new effects were found in both groups in the unchanged-expression condition. Thus, the preserved parietal old/new effect previously observed in schizophrenia was no longer found here in the situation in which expression changes took place between the study and recognition phases. ***Conclusions:*** These findings suggest that, when they are not supposed to take the change of expression into account, the recognition deficit observed here in patients with schizophrenia resulted from an impairment in the mechanisms underlying the emergence, assessment, or utilization of familiarity—as indexed by the ERP old/new effects. In these natural conditions, the impact of the expression change on the implementation of retrieval processes offers new insight into schizophrenia-linked deficits in face recognition, with substantial phenomenological differences with respect to the emergence of familiarity.

Keywords: ERP old/new effect, face recognition, familiarity, FN400, schizophrenia

Social functioning relies strongly on face recognition and the identification of facial affect in others. Although the most noticeable symptoms of schizophrenia are the positive ones (e.g., delusional identification, hallucinations), recognition—which lies at the interface between perception and memory—provides an interesting way of approaching cognitive impairment in schizophrenia. Although several studies have found that patients with schizophrenia are impaired in recognition memory for faces (Conklin, Calkins, Anderson, Dinzeo, & Iacono, 2002; Guillaume et al., 2007; Kayser et al., 2010; Martin, Baudouin, Tiberghien, & Franck, 2005), the exact nature of the functional mechanisms causing this deficit remains unclear. It is especially unclear whether this represents a specific deficit in face processing or a more generalized deficit in memory function. Our goal in this study was to understand the influence of face-intrinsic perceptual variations on the implementation of recognition processes in schizophrenia. What effects do these variations have on face recognition by patients with schizophrenia? To what extent, and based on what mechanisms, does the effect of this particular type of variation differ between patients with schizophrenia and healthy controls? The deficit in affect recognition observed in schizophrenia is not the purpose of the present study (e.g., Gaebel & Wölwer, 1992; Kohler, Bilker, Hagendoorn, Gur, & Gur, 2000). Here, we focus on the impact of a facial-expression change and how it interferes with face recognition and identification by individuals with schizophrenia.

Dual-process models of recognition postulate two ways in which information can be recognized, referred to as "recollection" and "familiarity." *Recollection* is defined as the mental reinstatement of a previous event with episodic details such as sensory information or scene contexts, whereas *familiarity* is an unsubstantiated sense of having previously encountered an item. Although previous studies have concluded that patients with schizophrenia exhibit intact familiarity but impaired recollection, the extent of the impairment of these processes remains a matter of some debate (Achim & Lepage, 2003; Huron et al., 1995; Tendolkar, Ruhrmann, Brockhaus, Pukrop, & Klosterkotter, 2002; van Erp et

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al., 2008; Waters, Maybery, Badcock, & Michie, 2004). The degree to which familiarity processing is spared in schizophrenia is an important topic of discussion in the domain of face recognition. Recent work using the remember/know procedure (Martin et al., 2011) or the process-dissociation procedure (Guillaume et al., 2007) has revealed recollection but also familiarity impairment for previously seen faces. One reason for these discrepancies could arise from the study/test mismatch introduced in these studies to demonstrate familiarity impairment. Yet such perceptual variations correspond to the natural conditions under which faces are recognized in everyday life.

Electrophysiological (ERP) methods have proven sensitive to memory retrieval processes and are well-suited to detecting anomalies in the sequence of cognitive processes taking place during recognition. Although the time course and the topographic distribution of the so-called ERP old/new effects depend on many variables, the basic finding is that late positive ERPs elicited by new items are not as great as those elicited by correctly recognized old items. ERP old/new effects have gradually come to be regarded as the neurophysiological indicator of the dissociation of familiarity and recollection processes (for a review, see Friedman & Johnson, 2000). An early frontal N400-like component (FN400 or midfrontal old/new effect) has been shown to indicate familiarity, with greater amplitude (300–500 ms) for correctly rejected new items than for correctly recognized old items, without being sensitive to the recollection of details such as the occupations associated with the faces at study time (Curran & Hancock, 2007). The idea that the FN400 is a specific correlate of familiarity has nevertheless been questioned in recent studies showing its sensitivity to the retrieval of episodic details and to the task instructions (Azimian-Faridani & Wilding, 2006; Ecker, Zimmer, Groh-Bordin, & Mecklinger, 2007; Tsivilis, Otten, & Rugg, 2001). The later parietal old/new effect (500–1,000 ms), also called the late positive complex (LPC), varies in a manner consistent with recollection (Düzel, Yonelinas, Mangun, Heinze, & Tulving, 1997; Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999; Wilding, Doyle, & Rugg, 1995). It has been associated with the medial temporal lobe's involvement in episodic recollection, whereas a right frontal old/new effect may index dorsolateral prefrontal cortex activity (Voss & Paller, 2008). We find it interesting that these two regions have been associated with the pathophysiology of schizophrenia (for a review, see Wong & Van Tol, 2003).

Few studies have investigated ERP correlates of recognition-memory performance in schizophrenia, but methodological limitations and profound procedural differences impede efforts to draw general conclusions (Guillem, Bicu, & Debruille, 2001; Kayser et al., 2010; Tendolkar et al., 2002). Anomalies on the ERP old/new effects have been demonstrated in schizophrenia during word-recognition judgments (Tendolkar et al., 2002) but diverging results have been observed for face recognition (Guillem et al., 2001; Kayser et al., 2010). Guillem et al. (2001) found that patients with schizophrenia exhibited lower FN400 old/new effect than did healthy participants in both implicit and explicit unfamiliar-face recognition tasks, whereas Kayser et al. (2010) found the FN400 old/new effect for patients with schizophrenia in face- and word-recognition tasks alike. We find it interesting that in the Kayser et al. study, the decrease in the posterior old/new effect was more pronounced for common words than for unknown faces, suggesting that dual-process ERP correlates cannot be indifferent to the nature of the stimuli. Properties related to the nature of the stimuli therefore appear to be crucial when it comes to isolating the neurophysiological correlates of familiarity. One reason that schizophrenia affects recognition for words in a different way than recognition for faces could be that face recognition is driven solely by perception. As proposed by Yovel and Paller (2004), the use of lexical stimuli introduces a confound because the stimuli possess a preexisting level of familiarity, which unfamiliar faces do not. Unfamiliar faces thus provide a unique body of material for addressing the question of familiarity in schizophrenia.

To recognize a face as "old" (e.g., encountered before), our cognitive system has to distinguish between relevant and arbitrary feature details whenever perceptual changes occur between the study and the test. The ERP old/new effects should be affected by study-test perceptual change in accordance with the old/new recognition judgment (Ecker et al., 2007; Tsivilis et al., 2001; Zimmer & Ecker, 2010). In line with the view that patients with schizophrenia do not differ from controls on the probability of making correct familiarity judgments (Huron et al., 1995; Tendolkar et al., 2002), study-test mismatch appears to be a critical variable for improving our understanding of the emergence of familiarity during face recognition. Although patients with schizophrenia are known to exhibit an inability to inhibit irrelevant information (Baxter & Liddle, 1998), the study-test mismatch effect on patients' face recognition remains to be explored. Substantial interference has already been noted between face expression processing and face recognition in schizophrenia (Baudouin, Martin, Tiberghien, Verlut, & Franck, 2002; Martin et al., 2005).

By manipulating the expression on the face, we attempt to determine the impact of an expression change on face familiarity assessment and the corresponding ERP recognition effects. How does an expression change interfere with face recognition in schizophrenia? What memory process is dysfunctional in this context? Does this dysfunction occur early or late in the recognition processing sequence? In line with the idea that the FN400 ERP old/new effect is sensitive to perceptual congruity effects (Curran & Doyle, 2011; Groh-Bordin, Zimmer, & Ecker, 2006; Tsivilis et al., 2001), this effect should be larger in the matched rather than mismatched condition. So, if patients with schizophrenia base their recognition mainly on perceptual familiarity, a study-test mismatch should have a greater effect for these participants than for the control group, both in terms of behavioral performance and ERP old/new effects. Also, face expression change at recognition time should trigger controlled retrieval processes aimed at determining how relevant the change is for identifying and recognizing the face. On the basis of the recollection-deficit hypothesis in schizophrenia, manipulating the facial expression should allow us to find out whether the parietal old/new effect is more a reflection of familiarity and memory-trace strength, or corresponds instead to the implementation of controlled retrieval processes. In the former case, the changed facial expression reduces the perceptual familiarity of the face and should thereby have a negative effect on the amplitude of the parietal old/new effect, whereas in the latter case, the changed expression should increase the amplitude of this recognition effect.

Method

Participants

Twenty patients who met *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; American Psychiatric Association, 1994) criteria for schizophrenia participated in this study. All were clinically stable and had been receiving antipsychotic medication at fixed doses for at least 2 months at the time of testing (without benzodiazepines; $M = 413 \pm 284$ mg CPZeq per day). Symptoms were rated by means of the Brief Psychiatric Rating Scale and the Positive and Negative Symptoms Scale. The patients were also assessed for anxiety using the State–Trait Anxiety Inventory. No correlations were observed between performance, age at onset, and antipsychotic dose. Twenty healthy participants paired on an individual basis with the patients for age, sex, and parental socioeducational status (SES) were also recruited. Parental socioeducational status was defined based on the occupation of the head of household (usually the father). In this classification, occupations are assigned to five categories on the basis of skill level: (I) management; (II) professional; (III) technical, paraprofessional, and skilled occupations; (IV) intermediate occupations; and (V) labor and unskilled occupations. There was no difference between controls and patients in terms of gender, age, $t(38) = 0.99$, $p = .33$, or socioeducational status (9.8 ± 2.2 years vs. 9.3 ± 3.5), $t(38) = 1.33$, $p = .19$. After receiving a full description of the study, patients and controls gave their written informed consent. The protocol was approved by a local ethics committee. Participants in both groups reported normal or corrected-to-normal vision, no neurological illness, epilepsy, traumatic brain injury, or prosopagnosia symptoms. The sociodemographic and clinical data is presented in Table 1.

Table 1
Sociodemographic and Clinical Profiles

Measures	Control participants ($n = 20$)	Participants with schizophrenia ($n = 20$)
Age (years)	29.4 ± 7.8	27.9 ± 6.5
Gender (male/female)	16/4	17/3
Parental education		
SES (% in classes I–III)	50%	55%
Onset age (years)		20.5 ± 2
Illness duration (years)		6.4 ± 4.9
Global symptomatology (BPRS)		9.5 ± 8.4
Positive symptoms (SAPS)		19.5 ± 23.3
Negative symptoms (SANS)		21.4 ± 12.6
Trait anxiety (STAI–X2)		40.5 ± 9.1
State anxiety (STAI–X1)		32.5 ± 10.7
Antipsychotic dose (mg CPZeq/day)[b]		413 ± 284

Note. Values indicate mean ± standard deviations. SES= socioeducational status: (I) management; (II) professional; (III) technical, paraprofessional, and skilled occupations; BPRS = Brief Psychiatric Rating Scale; SAPS = The Scale for the Assessment of Positive Symptoms; SANS = The Scale for the Assessment of Negative Symptoms; STAI–X2 = The State-Trait Anxiety Scale (from SATI-X2, Trait); STAI–X1 = The State-Trait Anxiety Scale (from STAI-X1, State).
[b] Nineteen patients received novel or typical antipsychotics, one patient was drug free.

Stimuli

The stimuli consisted of black and white photographs of young White adults without distinctive facial features (e.g., beard, jewelry, eye glasses, or particular facial marks) that had been carefully edited to maintain standard brightness and contrast. Two sets of stimuli were constructed, each one comprising two series: one study series (40 faces) and one test series (40 repeated faces + 40 new faces). The faces had a neutral or smiling expression (40 neutral faces + 40 smiling faces) and were superimposed on one and only one natural landscape background (see Figure 1). We used a landscape for its ecological nature and its visual complexity as compared to a one-color background. Given that intrinsic perceptual variations between the study and recognition phases was the focus of this study, not the recognition of facial emotions, the two expressions were chosen for their low emotional connotation as compared to negative facial emotions (e.g., fear or anger). Previous studies have shown the relevance of using these two expressions on recognition tasks performed by both patients with schizophrenia (Loughland, Williams & Gordon, 2002) and healthy participants (Graham & Cabeza, 2001). The size of the pictures was 400×600 pixels.

Procedure

All participants made old/new recognition judgments. Each test consisted of a study list, followed 5 min later by the recognition-test list. During the study phase, participants were informed that they would have to recognize the faces later. The recognition-test instructions were given during the study-test interval. The test required the recognition of the studied faces intermixed among new faces. The following definitions of the test-item categories were used: "old" items were faces that were on the study list with the same expression (physically identical picture); "different" items were faces that were on the study list but appeared with a different expression on the test list; "new" items were faces that did not appear on the study list (and were presented with one of two expressions: smiling or neutral). On each recognition trial, participants were asked to respond YES or NO by pressing distinct keys on the computer keyboard. The stimuli were presented on the monitor of the computer that drove the sequence. For both the study and the test, each trial began with a fixation cross (lasting 500 ms) in the center of the screen. Then the picture was displayed in the same place for 2,500 ms. The intertrial interval (ITI) was 2,500 ms for the study phase and 3,000 ms for the test. Participants' responses and reaction times (RTs) were recorded separately on the computer disk for each experimental condition.

During the recognition test, participants were asked to recognize any face, regardless of expression changes, that is, respond YES to all previously presented faces (old + different conditions) and NO to new faces. Responses to items with a new facial expression (i.e., YES to different) and responses to items with the same facial expression (i.e., YES to old) were scored separately. This made 80 trials for each recognition task: 40 repeated faces (20 with the same facial expression = old items; 20 with a new facial expression = different items) and 40 new faces (20 new faces with smiling expression and 20 with neutral expression). In the different condition, half of the face

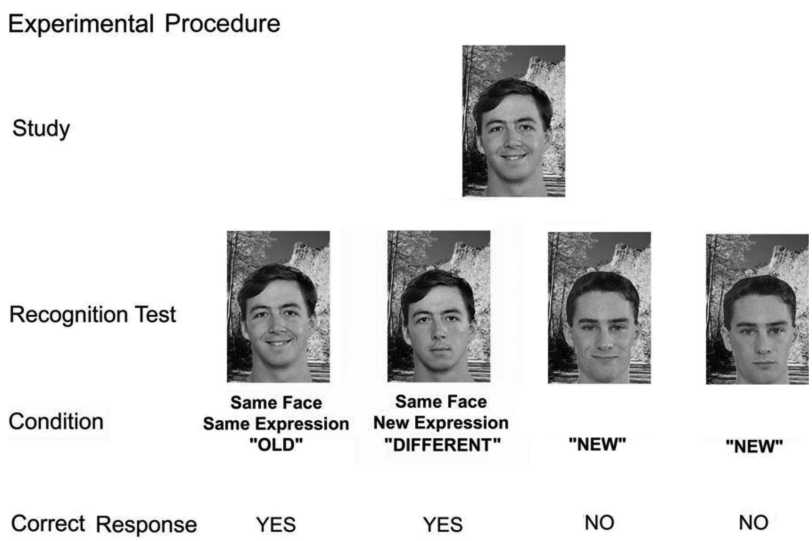

Figure 1. Face-expression manipulations and correct-recognition responses in each case.

studied with a smiling expression was presented with a neutral expression at the time of recognition and the other half, studied with a neutral expression, was presented with a smiling expression at the time of recognition. To obtain an acceptable signal-to-noise ratio, each participant was recorded during two study-test sessions. A minimum of 2 days between each experimental session was observed and different faces were presented in the two sessions. Each pair of pictures and the list-presentation order were counterbalanced across participants. Figure 1 summarizes the experimental procedure and the correct responses in each condition.

EEG Data Acquisition

Electroencephalographic (EEG) activity was recorded from 32 surface electrodes according to the 10 to 20 classification system and referenced to the linked earlobes with a ground electrode placed at Fpz. Vertical and horizontal eye movements and blinks (EOG) were monitored via electrodes, placed below and on the outer canthus of the left eye, respectively. The impedance of all electrodes was kept below 5 KΩ. EEG data was recorded continuously (0.01–30 Hz bandpass), digitized online (256 Hz), and stored on a hard disk along with the codes identifying the stimulus type, stimulus onset, and the participant's response. Trials with nonocular artifacts, saccades, and incorrect behavioral responses were discarded. Trials with ocular blink contributions to the EEG were corrected (Elbert, Lutzenberger, Rockstroh, & Birbaumer, 1985). Offline averaging was performed after EOG correction. The EEG was then segmented into 1,500-ms epochs, including a 200-ms baseline before stimulus onset and a 1,300-ms interval after stimulus onset for ERP averaging. ERPs were corrected relative to the 200-ms prestimulus baseline and then extracted by creating individual averages for each electrode in each condition. Only trials with correct responses were included in the averages.

Behavioral Data Analyses

YES response rates (hits: YES to old and YES to different; false alarms: YES to new) and correct RTs in the different conditions were analyzed using a 2 × 3 multivariate analysis of variance (MANOVA) with group (schizophrenic vs. control) as a between-subjects factor and condition (old vs. different vs. new) as a within-subject factor. Two psychophysical measures (A' and B") were also quantified from hits (YES to old or YES to different) and false alarms (YES to new). A' is an index of discriminability between old and new items. It ranges from 0 for null discriminability to 1 for maximal discriminability. B" is an index of decision criterion. It ranges from −1 to + 1 with positive values of B" reflecting conservative responding, negative values indicating lenient responding and 0 indicating optimal decision. These psychophysical measures permit considering simultaneously hits and false alarms. We chose these nonparametric measures because A' and B" do not postulate normality of distribution. Hence, these psychophysical measures are particularly relevant in pathological or heterogeneous populations (see Donaldson, 1996). These psychophysical measures were analyzed using a 2 × 2 analysis of variance (ANOVA) with group (participants with schizophrenia vs. control participants) as a between-subjects factor and expression (old vs. different) as a within-subject factor.

EEG Data Analysis

ERP peaks were identified by visual inspection of the individual traces recorded at midline locations (Fz, Cz, Pz) within the 200 to 1,300 ms postonset range. Amplitudes were quantified with respect to the baseline in time windows centered on each peak. Two epochs were selected as typical, based on previous studies of ERP old/new effects: the midfrontal old/new effect (FN400) and the LPC. The mean peak latencies and the time windows used for amplitude quantification are shown in Table 2 for each group.

For the recognition ERPs, the mean voltage in each temporal window was analyzed separately for frontal (F3, Fz, F4) and

Table 2
Mean Peak Latency and Time Windows Used for ERP Quantification

	Control participants		Participants with schizophrenia	
ERP Old/New effect	*M* latency (ms postonset)	Latency window	*M* latency (ms postonset)	Latency window
N400 (familiarity)	389.2 (41.2)	340–440	398.6 (48.3)	350–450
LPC (recollection)	787.4 (45.3)	600–1,000	798.5 (74.1)	600–1,000

Note. Standard deviations are in parentheses. ERP = Event-related potentials; LPC = late positive complex.

parietal (P3, Pz, P4) sites. Only correct responses in each condition were analyzed. It would have been interesting to compare correct responses to incorrect ones in the change-of-expression condition (the most difficult one), but incorrect responses represented 40% of the responses by patients with schizophrenia (16 trials out of 40) and only 28% by controls (11 trials of 40). This did not give us an adequate signal-to-noise ratio for a between-group comparison, so we chose the analytical method conventionally used in the ERP literature on recognition memory, namely, analyzing correct answers only. The model included the participant group (participants with schizophrenia vs. control participants) as a between-subjects factor, and the condition (old vs. different vs. new) and the electrode site (left vs. central vs. right) as within-subject factors. Differences in scalp distribution across conditions were analyzed after normalization of the data (McCarthy & Wood, 1985). This procedure allows to account for the possibility that a given scalp-distribution effect can be due to multiplicative differences in distinct neural source strength. Thus, any interaction involving the site factor will be reported only if it was significant in the normalized dataset. Significant interactions involving the site factor were followed by separate analyses on each site using mixed-model ANOVAs, with group (patients vs. controls) as a between-subjects factor, and condition (old vs. different vs. new) as within-subject factors. Significant interactions involving the group factor were detected using contrast analyses for each group. The Geisser–Greenhouse correction was used to correct for violations of the assumption of covariance homogeneity in within-subject ANOVAs with more than two levels. These ANOVA results are reported in terms of uncorrected degrees of freedom values, the F value, the epsilon-corrected p value, and the corresponding epsilon value. Only significant interactions ($\alpha = .05$) between region, site, or laterality and the experimental factors (group or condition) are presented in the results. The partial eta-squared statistic (η^2) was used to determine the magnitude of the effects for all significant single-degree of freedom a priori tests because these outcomes are central to the study aims.

Results

Behavior

The behavioral data are summarized in Table 3. The MANOVA on the YES responses revealed a main type-of-face effect (old vs. different vs. new), $F(2, 76) = 390.7$, $MSE = 0.013$, $p < .001$. As Table 3 shows, the participants as a whole got more hits (old + different) than false alarms, which means they followed the instructions, $F(1, 38) = 586.7$, $MSE = 0.013$, $p < .001$. The MANOVA also revealed an interaction between the type of face and the group, $F(2, 76) = 5.07$, $MSE = 0.01$, $p = .009$. Contrast analyses showed that controls made more hits than patients with schizophrenia, both in the old condition, $F(1, 38) = 0.01$, $MSE = 0.13$, $p = .01$, and in the different condition, $F(1, 38) = 13.7$, $MSE = 0.008$, $p < .001$. On the other hand, there was no group difference in false recognitions, $F(1, 38) = 0.47$, $MSE = 0.012$.

Although a changed facial expression caused a drop in the number of hits among controls, $F(1, 38) = 8.23$, $MSE = 0.027$, $p = .007$, and among patients, $F(1, 38) = 18.86$, $MSE = 0.007$, $p = .001$, the decline in performance was greater for the patients (see Table 3). A t test on the difference between the hit rate in the old and different conditions (dropping from 0.74 to 0.61 for patients vs. 0.8 to 0.72 for controls) indicated that the expression change lowered the hit rate more for patients than for controls, $t(38) = 2.61$, $p = .013$.

The ANOVAs on the psychophysical measures yielded greater discriminability (A') among control participants than among participants with schizophrenia, $F(1, 38) = 8.49$, $MSE = 0.006$, $p = .006$, with a marginally significant difference between the old and different conditions, $F(1, 38) = 2.89$, $MSE = 0.003$, $p = .097$, and no significant interaction between group and expression, $F(1, 38) = 0.73$, $MSE = 0.002$, $p = .40$ (see Table 3). There was no group effect, $F(1, 38) = 0.18$, $MSE = 0.24$, $p = .68$, or expression-change effect, $F(1, 38) = 1.37$, $MSE = 0.06$, $p = .25$, on the decision criterion (B"). We also conducted an analysis of covariance (ANCOVA), with

Table 3
Recognition Performance

	Control participants		Participants with schizophrenia	
Behavioral measures	*M*	*SD*	*M*	*SD*
Hits (YES to old)	0.80	0.08	0.74	0.14
Hits (YES to different)	0.72	0.06	0.61	0.11
FA (YES to new)	0.14	0.11	0.15	0.12
Hits RT/old (ms)	1,679	303	2,043	483
Hits RT/different (ms)	1,825	359	2,179	543
Correct rejection RT (ms)	1,737	345	2,010	596
Discriminability/old (A')	0.90	0.05	0.83	0.09
Discriminability/different (A')	0.86	0.06	0.82	0.07
Response criterion/old (B")	0.24	0.40	0.22	0.44
Response criterion/different (B")	0.25	0.43	0.36	0.28

Note. Hit rates were based on YES to old, YES to different. False-alarm (FA) rates were based on YES to new. RT = reaction time; A' = discriminability index; B' = decision criterion.

response bias (B") as a continuous covariate, to find out if the effects obtained on discriminability depended on a response bias. This was not the case: the ANCOVA showed that the observed group effect on discriminability (A') was not due to a response bias related to the decision criterion, $F(2, 35) = 5.30$, $p = .01$.

Finally, the MANOVA on response times corresponding to the correct responses in the old, different, and new conditions showed that patients with schizophrenia were slower than control participants, $F(1, 38) = 6$, $p = .019$. A main type-of-face effect was also observed, $F(1, 38) = 7.2$, $p = .001$, but no interaction with group, $F(1, 38) = 0.73$, $p > .05$. All participants were slower in the different condition than in the old one, $F(1, 38) = 20.57$, $p < .001$, with no significant difference between the old and the new conditions, $F(1, 38) = 0.08$, $p > .05$.

ERP Findings

The grand average ERPs at representative electrodes are shown separately for patients with schizophrenia and healthy controls in Figure 2, which give the ERPs for correctly recognized old and different faces, and for correctly rejected new faces. Figure 2 shows main peaks similar to those previously reported in an explicit memory task on unfamiliar faces (e.g., Guillem et al., 2001; Kayser et al., 2010; Yovel & Paller, 2004). They correspond to the ERP correlates of familiarity and recollection usually described in the literature and consist of an FN400 and a LPC.

Midfrontal FN400 Old/New Effect

ANOVA on frontal sites (F3, Fz, F4) in the FN400 time window resulted in a significant group effect, with larger FN400 for participants with schizophrenia than for control group, $F(1, 38) = 19.45$, $p < .001$, and a condition effect with a larger FN400 amplitude on correctly rejected new faces than on correctly recognized faces, $F(2, 76) = 5.53$, $p = .022$, $\varepsilon = .73$. The ANOVA also yielded a group-by-condition-by-site interaction, $F(4, 152) = 3.98$, $p = .01$, $\varepsilon = .81$, with a greater FN400 amplitude in the right (F4) compared to the left (F3) frontal location among participants with schizophrenia, $F(1, 38) = 16.72$, $p = .002$, $\eta^2 = .27$, but no significant site effect among controls, $F(1, 38) = 0.95$, $p > .05$.

As shown in Figure 2, control-group contrasts indicated a larger FN400 amplitude on frontal sites in the new condition as compared to the old condition, $F(1, 38) = 9.34$, $p = .004$, $\eta^2 = .27$, or to the different condition, $F(1, 38) = 4.98$, $p = .032$, $\eta^2 = .17$. A greater FN400 amplitude was also found in the different condition as compared to the old condition in this group, $F(1, 38) = 4.52$, $p = .04$, $\eta^2 = .15$. Things were quite different among participants with schizophrenia, in which there was a larger FN400 amplitude in the different and new conditions compared

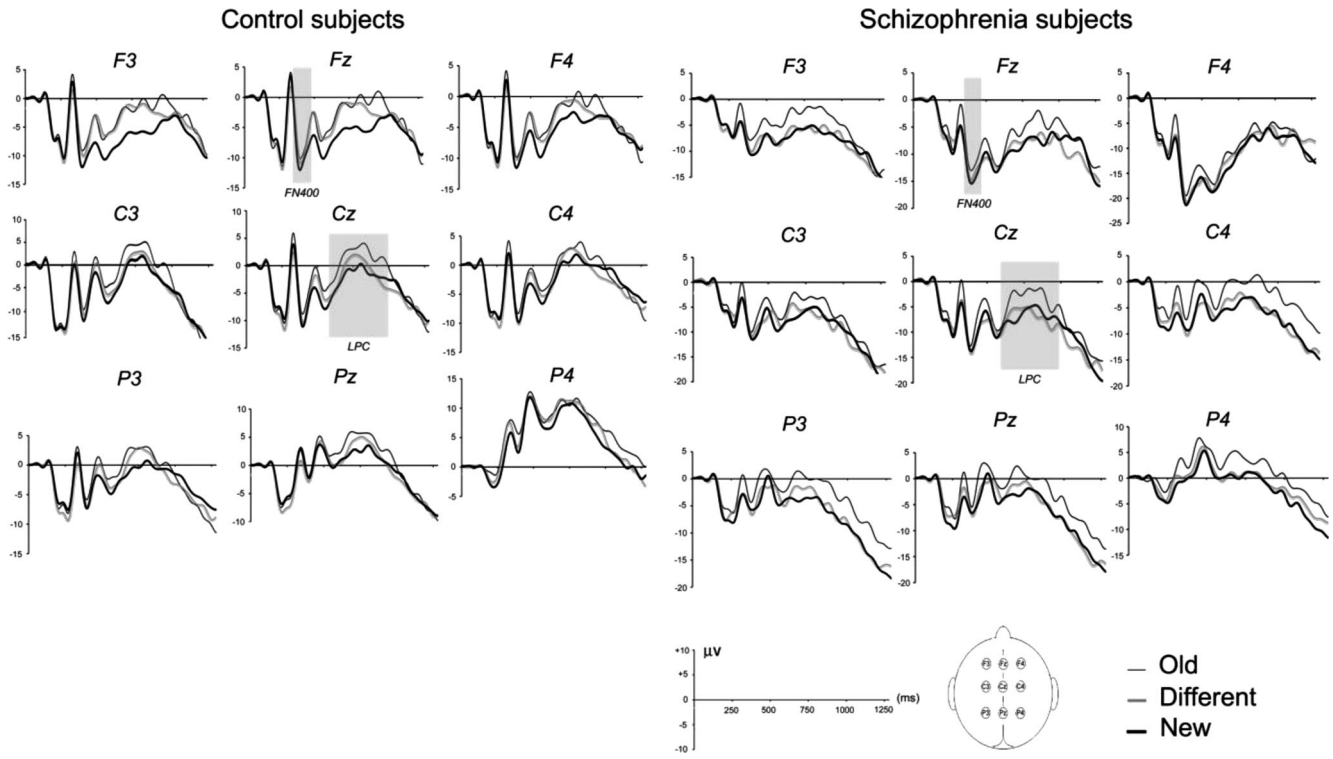

Figure 2. Group mean electrophysiological (ERPs) on correctly recognized faces in the old and different conditions, and on correctly rejected new faces for controls (top) and patients with schizophrenia (at the bottom). The waveforms shown are from the three midline scalp locations (Fz, Cz, and Pz) and the selected lateral locations on the frontal (F3: left fronto-central, F4: right fronto-central), central (C3: left central, C4: right central) and parietal (P3: left parietal, P4: right parietal) electrode locations.

to the old one, $F(1, 38) = 5.32$, $p = .027$, $\eta^2 = .18$, whereas no significant difference was observed between the different and new conditions, $F(1, 38) = 0.76$, $p > .05$. Table 4 presents the follow-up contrasts in each group for the midfrontal FN400 and late ERP old/new effects.

Late Old/New Effects (LPC)

ANOVA on the parietal locations resulted in a main effect of group, $F(1, 38) = 18.93$, $p < .001$, with larger late parietal positive amplitudes for control participants than for participants with schizophrenia (see Figure 2). The ANOVA also yielded a significant interaction between group and condition, $F(2, 76) = 5.31$, $p = .024$, $\varepsilon = .85$. Compared to correctly rejected new faces, control participants exhibited higher positive amplitudes on parietal locations in the old, $F(1, 38) = 10.56$, $p = .002$, $\eta^2 = .27$, and different conditions, $F(1, 38) = 5.02$, $p = .03$, $\eta^2 = .17$, with a greater amplitude in the old than in the different condition, $F(1, 38) = 5.22$, $p = .028$, $\eta^2 = .14$. The parietal old/new effect was found again in participants with schizophrenia, with higher positive amplitudes in the old than new condition, $F(1, 38) = 14.67$, $p = .004$, $\eta^2 = .32$, but unlike the controls, the patients' parietal old/new effect did not differ between the different and new conditions, $F(1, 38) = 0.83$, $p > .05$. Thus, although recognition effects were found in both groups for unfamiliar faces, they were modulated differently by the change of expression across groups: for the patients, no parietal old/new effect was found in the different condition, whereas for the controls it was significant.

ANOVA on the frontal locations yielded a significant effect of condition with increased late positive amplitude in the old compared to the new condition for controls, $F(1, 38) = 12.50$, $p = .001$, $\eta^2 = .28$, as well as for participants with schizophrenia, $F(1, 38) = 9.87$, $p = .003$, $\eta^2 = .26$. Although FN400 amplitude was greater for patients with schizophrenia than for control participants on the right frontal site, the late frontal ERP old/new effects were larger for control participants than for patients with schizophrenia, $F(1, 38) = 18.48$, $p = .001$ (see Figure 2). ANOVA also yielded a significant interaction between group and condition on frontal sites, $F(2, 76) = 4.97$, $p = .03$, $\varepsilon = .80$, which showed that the condition had a different impact on the late frontal old/new effect in each group. As shown in Figure 2, compared to correctly rejected new faces, control participants had a higher amplitude in the old condition, $F(1, 38) = 7.95$, $p = .008$, $\eta^2 = .26$, and in the different condition, $F(1, 38) = 6.02$, $p = .019$, $\eta^2 = .23$, with no significant difference between these last two conditions, $F(1, 38) = 2.01$, $p > .05$. Among participants with schizophrenia, increased positive amplitudes were observed on frontal sites in the old condition as compared to the different condition, $F(1, 38) = 4.86$, $p = .033$, $\eta^2 = .14$, and to the new condition, $F(1, 38) = 6.09$, $p = .018$, $\eta^2 = .21$, with no significant difference between the different and new conditions, $F(1, 38) = 1.76$, $p > .05$. Figure 3 presents the mean amplitude difference corresponding to the late ERP recognition effects at midline electrodes. This figure shows that the late recognition effects disappeared among patients in the different condition.

Discussion

The patients with schizophrenia recognition performance was inferior to that of the controls, with fewer hits and greater response times. By contrast, no group difference was observed on false recognitions. In line with our hypotheses, between-group ERP differences were observed when participants were required to treat both unchanged old faces (old condition) and old faces with a new expression (different condition) as old. This result suggests that patients with schizophrenia are more sensitive to the expression change and appears to be inconsistent with studies showing spared familiarity in schizophrenia (Huron et al., 1995; van Erp et al., 2008; Weiss, Goff, Duff, Roffman, & Schacter, 2008). However, assuming that false recognition arises from an illusory familiarity, the absence of a between-groups difference in the false-alarm rates (YES to new) shows that patients with schizophrenia exhibited a spared capacity to distinguish repeated faces from new ones. The poorer discriminability observed on patients with schizophrenia arose from substantial misrecognition rather than from false alarms in the present situation. The fact that study-test incongruity was involved was the main cause of face misrecognition.

This difficulty in extracting face identity in the present situation converges with previous face-recognition studies reporting problems among patients with schizophrenia in processing one dimen-

Table 4
Follow-Up Within-Group Contrasts on Midfrontal FN400 and Late ERP Old/New Effects

	Control participants		Participants with schizophrenia	
Contrasts	$F(1, 38)$	p	$F(1, 38)$	p
Mid-frontal old/new effect (FN400)				
Old–new	9.34	.004**	5.32	.027*
Different–new	4.98	.032*	0.76	*ns*
Late frontal old/new effect				
Old–new	7.95	.008**	6.09	.018*
Different–new	6.02	.019*	1.76	*ns*
Late parietal old/new effect				
Old–new	10.56	.002**	14.67	.004***
Different–new	5.02	.03*	0.83	*ns*

Note. ERP = electrophysiological.
* $p < .05$. ** $p < .01$. *** $p < .001$.

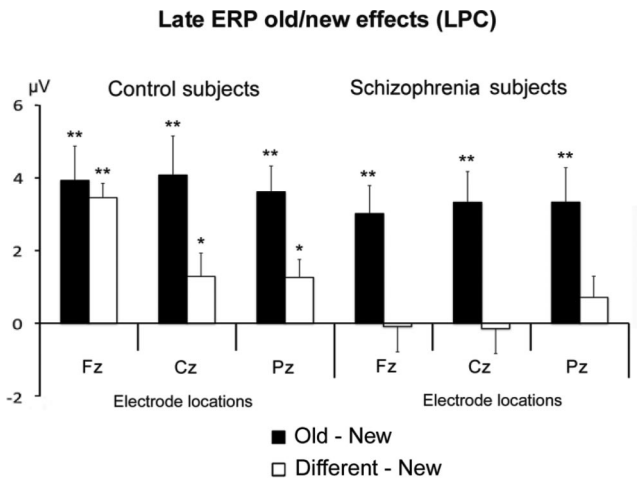

Figure 3. Mean (and *SEM*) ERP recognition effect using the amplitude averaged within the LPC time window, for correctly recognized faces in the old and different (new expression) conditions, for controls (on the left) and participants with schizophrenia (on the right). ERP = electrophysiological; LPC = late positive complex. $^{*}p < .05$. $^{**}p < .01$ (effects are expressed as the old minus new amplitude difference).

sion without interference from the other (Baudouin et al., 2002; Guillaume et al., 2007). One possible interpretation of the excessive rejection of faces with a new expression (NO to different = .39) is that the participants with schizophrenia based their recognition mainly on a global matching strategy and the retrieval of perceptual codes as a whole. Indeed, if in our daily lives, faces generate a feeling of familiarity irrespective of contextual and environmental variations, it is partly because configural processing of faces enables us to disregard sensory variations to recognize a person. In line with the proposal that patients with schizophrenia base their face identification on the processing of perceptual features, indistinctively, rather than on the processing of configural information (Fakra, Salgado-Pineda, Delaveau, Hariri, & Blin, 2008; Joshua & Rossell, 2009), the present results confirm that this kind of cognitive functioning has some implications on face recognition when face-intrinsic changes occur (Baudouin et al., 2002; Martin et al., 2005). Everything points to the idea that patients are in an "overexclusion" functioning mode, even when the situation does not require it. Another explanation could be that participants with schizophrenia suffer from a deficiency in the control processes needed to assess the relevance of any detected changes and perceptual incongruities linked to the expression change. Although the lack of an interaction between the type-of-face and the participant group on response time suggests that the expression change did not trigger an additional processing step among patients in the mismatch condition. A finer analysis of the ERP time course provided further insight into these interpretations.

As stated in our hypotheses, the expression mismatch modulated the midfrontal old/new effect in a different way in each group. Although the FN400 midfrontal old/new effect is found in both groups, the modulations observed in the control group were graded according to the perceptual congruity of the repeated faces (old > different). The higher FN400 amplitude in the mismatched expression condition as compared to old condition confirms that the FN400 old/new effect was sensitive to perceptual-congruity effects (Groh-Bordin et al., 2006). This was not the case in the patient group. Early recognition processes reflected by the FN400 thus seem to be unsuited to the recognition situation for patients with schizophrenia, in whom (1) FN400 amplitude was greater as a whole than among controls, and (2) FN400 amplitude was not separable in the different and new conditions. The lack of a recognition effect among the patients with schizophrenia when the facial expression was modified shows that the FN400 amplitude was no longer in keeping with a perceptual matching, but was more a reflection of an all-or-none familiarity process. These findings support the idea of an abnormal activation pattern in the prefrontal cortex of patients with schizophrenia (Heckers et al., 1998; Tendolkar et al., 2002; Velligan, Ritch, Sui, DiCocco, & Huntzinger, 2002).

The present study also confirms the claim that the parietal old/new effect is relatively well preserved in schizophrenia face recognition (Guillem et al., 2001; Kayser et al., 2010). Old faces indeed triggered larger amplitudes on the late parietal and late frontal old/new effects than did new faces in both groups. By contrast, the parietal old/new effect was no longer found for patients when the expression was different. The above remarks concerning FN400 seem to apply equally well to the parietal old/new effect. The disappearance of the parietal old/new effect reveals that the participants with schizophrenia did not compensate later on for early dysfunction on FN400-related processes. These findings are in line with studies showing deficits in the early stages of visual face processing in schizophrenia. It has been shown that patients with schizophrenia have magnocellular, visual-processing deficits, which cause them to focus more on the high spatial frequency minutia of complex visual stimuli such as faces rather than on the low spatial frequency or global aspects of stimuli (Butler et al., 2008). This way of operating implies that patients with schizophrenia are likely to be influenced by changes in high-spatial-frequency features such as facial expression.

As a whole, then, it seems as if, depending on the perceptual variations at stake, familiarity—as reflected by ERP correlates of recognition—is absolute (all or nothing) for patients but relative for controls. Which unit is used as a memory cue for participants with schizophrenia? The lack of ERP recognition effects suggests that facial expression and face identity interfere with each other so strongly that face familiarity cannot emerge. On the other hand, and contrary to our hypotheses, the expression change did not cause either group to increase the amplitude of the parietal old/new effect, which appears to be modulated by memory strength and the familiarity assessment rather than by the controlled processes required for evaluating the study-test mismatch in this task context. In this respect, our results are consistent with the idea that, contrarily to word recognition, ERP correlates of recognition are redundant in the case of face recognition (MacKenzie & Donaldson, 2007, 2009; Yovel & Paller, 2004).

Taken together, the present data suggest that we need a more precise definition of exactly what is meant by "spared familiarity" in schizophrenia. The use of the term *familiarity* is perhaps too general because it does not look at whether the familiarity is dependent on, or independent of, perceptual variations between the study phase and the recognition test. The recognition deficit observed here resulted from an impairment in the mechanisms underlying the emergence and assessment of familiarity—as indexed

by both the discriminability measure and the ERP old/new effects. It is the lack of perceptual variation that accounts for preserved familiarity in schizophrenia (Huron et al., 1995; Kazes et al., 1999; van Erp et al., 2008; Waters et al., 2004). Whenever such variations do exist, recognition performance declines (Guillaume et al., 2007; Guillaume, Guillem, Tiberghien, & Stip, 2012; Martin et al., 2005; Weiss et al., 2008). Such a face-recognition deficit jeopardizes social interactions and can explain the phenomenological aspect of recognition performance among individuals with schizophrenia, who may experience a feeling of strangeness toward a familiar person. For example, the sense of depersonalization often observed in delusional syndromes may be interpreted clinically as a loss of the feeling of familiarity with respect to a past experience (Weinstein, 1994). This can occur when someone is seen in an atypical setting, as in the classic example of seeing the butcher on the bus (Mandler, 1980). The present data suggest that intrinsic variations in faces can engender a substantial loss in the feeling of face familiarity among patients with schizophrenia, even when the environmental context remains the same. This finding suggests that the butcher-on-the-bus phenomenon can also occur inside the butcher shop for individuals suffering from schizophrenia. To shed light on the discrepancies observed between studies, the definition of the recognition deficit observed in schizophrenia must specify not only the controlled/automatic nature of the retrieval processes, but also the study-test mismatch sensitivity that may constitute a critical factor for the recognition deficit highlighted in schizophrenia. Further research is therefore needed to find out whether the familiarity "deficit" found here is specific to face recognition or can be generalized to other types of material.

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