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**Recollection and familiarity in schizophrenia:
An ERP investigation using face recognition exclusion tasks**

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1. Introduction

Individuals with schizophrenia show impaired performance on identification and recognition tasks, including face recognition, emotion recognition and identity matching (Baudouin et al., 2002; Bediou et al., 2005; Guillaume et al., 2007, 2013a; Martin et al., 2005). These face-related recognition deficits should be regarded as a trait-like feature in schizophrenia (e.g., Doop & Park, 2009). Episodic memory deficits also represent a major cognitive impairment, which is predictive of patients' overall functioning (e.g., Green, 1996). Many studies have shown that conscious recollection is consistently impaired in schizophrenia (e.g., van Erp et al., 2008). The two components postulated in dual-process models of recognition memory are familiarity and recollection. Familiarity is defined as a feeling that an event has been previously experienced, unaccompanied by memory for contextual details of the previous occurrence. Recollection is defined as the retrieval of the contextual details of an event, such as verbatim or contextual information. Recollection may occur, for example, when we see someone in an atypical setting, as we retrieve information about where we saw them before and who they are (e.g., Mandler, 1980). In signal detection terms, familiarity can be modeled as an automatic and continuous process reflecting the memory strength signal, and recollection as a threshold-like, all-or-none process where the critical information is either recollected or not (e.g., Yonelinas, 1999).

While early studies investigating recognition memory in schizophrenia concluded that familiarity, unlike recollection, is spared in individuals with schizophrenia, more recent studies suggest that both processes are affected, with larger effect sizes for recollection than familiarity (see Libby et al., 2012 for review). This suggests that rather than being a unitary phenomenon, the recollection deficit observed in schizophrenia may depend on the features of the information whose retrieval is required. For example, recollecting that a person's name

is Jack and he is the brother of my friend Daniel is different than recollecting that Jack's hair is brown. The recollection required in these different cases could be based on different brain mechanisms, and could be differently impaired in schizophrenia (e.g., Guillaume et al., 2007). One interpretation of the evidence from existing studies is that memory performance is particularly impaired in schizophrenia when the retrieval of associative or relational information, rather than intrinsic features, is required (Achim & Lepage, 2003; Ranganath et al., 2008). And while it is generally accepted that familiarity is not involved in the retrieval of episodic details, recent studies suggest that familiarity may support the retrieval of specific information when it is integrated and unitized with the recognition target at study (e.g., Diana, Yonelinas, & Ranganath, 2008).

Research on the neural underpinnings of recollection and familiarity has shown that these processes rely on dissociable brain networks, with recollection depending on the hippocampus and parahippocampal cortex, while perirhinal cortex may be sufficient for familiarity judgments (see Montaldi & Mayes, 2010 for a review). The prefrontal cortex (PFC), however, is critical for both processes (e.g., Duarte et al., 2005). Frontal hypoactivation has consistently been demonstrated in schizophrenia, including during episodic memory retrieval (Achim & Lepage, 2005; Ragland, Angela, Laird, et al., 2009). It has been suggested that this activation deficit (Ragland et al., 2012) may contribute to the familiarity deficit observed in schizophrenia (Libby et al., 2012). This prefrontal deficit is asymmetrical, and might be related to an impaired ability to initiate retrieval processes (Lepage et al., 2006). Besides brain localization and laterality, the timeline of the processing sequence is critical for both familiarity and recollection. Event-related potentials (ERP) have the temporal resolution to detect anomalies in the processing sequences behind recognition judgments. In differential ERPs for correctly recognized old items and correctly rejected new items ("old/new" effects), familiarity is associated with a mid-frontal old/new effect (300-

500 ms), often called the “FN400 old/new effect,” whereas recollection is associated with a later (500-800ms) parietal old/new effect (see Friedman & Johnson, 2000, for a review). Although previous studies have interpreted these ERP old/new effects in terms of the dual-process view, alternative interpretations in terms of memory strength signal and decisional factor(s) have also been suggested (e.g., Finnigan et al., 2002). During face recognition, a larger FN400 effect is observed for correctly rejected new faces compared to correctly recognized old ones (e.g., Guillaume & Tiberghien, 2013a), a pattern that has not been found to be sensitive to the retrieval of contextual details (e.g., Curran & Hancock, 2007). However, recent studies have found that familiarity, as reflected by the FN400 potential, is sensitive to the recollection of specific information when that information is encoded as a detail of a unitized item (Diana et al., 2011; Guillaume & Etienne, 2015). The parietal old/new effect, on the other hand, has been linked to recollection and to the retrieval of contextual aspects of the encoded stimulus, such as the voice that pronounced a word (Rugg et al., 1996) or the expression of a recognized face (Guillaume & Etienne, 2015). It has also been associated with the involvement of the medial temporal lobe (MTL), whereas the FN400 may index early PFC activity (Heckers et al., 1998; Voss & Paller, 2008). Intracranial study has also provided evidence that these two ERP old/new effects reflect synchronization between these brain structures (Guillem et al., 1995; 1999). Interestingly, these two regions are also known to be involved in the neurophysiological dysfunction observed in schizophrenia (see Wong & Van Tol, 2003 for review).

Different studies on the ERP correlates of familiarity and recollection in schizophrenia have yielded divergent results (e.g., Kayser et al., 2010; Tendolkar et al., 2002). Kayser and collaborators (2010) showed FN400 and parietal old/new effects in both patients and healthy controls in word and face recognition tasks. Others, in contrast, have found anomalies in ERP old/new effects in schizophrenia during word recognition (Tendolkar et al., 2002) or face

recognition (Guillem, Bicu, & Debruille, 2001) judgments. For example, some studies have observed an abnormal FN400 amplitude and a decreased late parietal potential in schizophrenia (e.g., Guillem, Bicu, & Debruille, 2001). Recent work has converged toward the view that the properties of the stimuli, and more particularly target-context unitization, are critical for the modulations of the ERP old/new effects observed in healthy subjects (Guillaume & Etienne, 2015; Rhodes & Donaldson, 2007; Zheng et al., 2015). For example, the FN400 old/new effect is modulated by intrinsic changes (e.g., object colors: Ecker et al., 2007; Groh-Bordin et al., 2006), but not necessarily by extrinsic changes (the color of the background: Zimmer & Ecker, 2010). One possibility is that target-context unitization accounts for divergent results in the literature on familiarity and recollection deficits in schizophrenia. Individuals with schizophrenia may perform as well as healthy subjects when the episodic detail to recollected has been unitized with the target at study, but show impaired recollection when the required episodic detail was encoded in a non-unitary way.

In the present study, we attempted to test this hypothesis by investigating the ERP correlates of familiarity and recollection in schizophrenia as a function of the critical information in a memory retrieval task. We sought to determine whether the nature of the target-context relation explains the divergence in results between studies showing a recollection deficit alone (Kazes et al., 1999; van Erp et al., 2008) and studies suggesting both recollection and familiarity deficits (Guillaume et al., 2007; Martin et al., 2005; Weiss et al., 2008) in schizophrenia. To this end, we contrasted tasks where the critical information about a face picture was either intrinsic (facial expression) or extrinsic (background natural scene). Unlike lexical stimuli, where there is generally a certain degree of pre-experimental familiarity, the novelty of unfamiliar faces makes them well suited to addressing this question. “Intrinsic” information consists in automatically processed and integrated features of the item as a whole (e.g., the emotional expression of a face). The “extrinsic” context consists in environmental

features that are spatially separated from and not part of the face (e.g., the background of the face). We chose to contrast intrinsic and extrinsic information because of differential unitization. The intrinsic information (expression) can be expected to be unitized to the face, and changes in it thus interact with the structural facial encoding; the latter should affect the overall familiarity of the stimulus, but not the structural encoding of the face. To test the unitization effect, we used exclusion tasks requiring the recollection of a critical feature. Performance on these tasks, derived from the process dissociation procedure (Jacoby, 1991), is thought to depend on the recollection of specific details (context) from the study episode. Exclusion tasks measure recollection through the ability to accurately retrieve specific source information in order to exclude an old non-target stimulus (lure), which either is familiar but different, in some respects, from the specific source required, or has undergone feature changes between study and test. This disqualifying monitoring occurs when the true recollection of one event logically allows an individual to reject the possibility that another event occurred. For example, “I met this scientist after his last talk in Berlin two years ago” could be rejected as false if inconsistent information is recalled: “No, I wasn’t in Berlin two years ago, because I recall losing my passport just before I was supposed to take the plane. I met this scientist three years ago in Sydney.”

To our knowledge, ERP old/new effects have not yet been investigated during the exclusion task in schizophrenia. Given the generally observed recollection deficit, we hypothesized that healthy controls would perform better than participants with schizophrenia in both exclusion tasks. We also expected to observe greater accuracy overall in the facial expression exclusion task compared to the background scene exclusion task, as facial expression is intrinsic to, and unitized with, the face, unlike the background scene. Stimulus changes should decrease the FN400 familiarity-related potential, while the recollection of a specific feature (whether intrinsic or extrinsic) should modulate the parietal old/new effect. The question was whether

individuals with schizophrenia would detect stimulus change during the exclusion task in the same way as control subjects. Would these stimulus changes affect the ERP correlates of recognition in the same way in both groups? Our hypothesis was that perceptual changes would differentially affect these ERP correlates in the two groups, depending on the critical information. If unitization in fact allows familiarity to contribute to the retrieval of episodic details, intrinsic change could be detected on the basis of familiarity signals. It could thus modulate the FN400 recognition effect in healthy controls (Diana et al., 2011; Guillaume & Etienne, 2015). In this view, the recollection of facial expression may be supported by a familiarity-based modulation in the mechanisms underlying the early FN400 ERP old/new effect, while the recollection of the background scene, as it is extrinsic to the face, should modulate only the parietal old/new effect. This unitization effect should be diminished in schizophrenia, where a familiarity deficit has been reported (e.g., Libby et al., 2012). Finally, the parietal old/new effect should be reduced in schizophrenia compared to controls (Guillem, Bicu, & Debrulle, 2001; Kostova et al., 2003). However, given the recollection deficit generally observed in schizophrenia, the parietal old/new effect could be modulated by the nature of the critical information in each group.

2. Method

2.1. Participants

Twenty clinically stable individuals with schizophrenia fulfilling the DSM-V criteria (American Psychiatric Association, 2013) and twenty healthy subjects paired for age, sex, and parental socio-educational status) participated in this study. Participants in the clinical group had been receiving antipsychotic medication at fixed doses for at least two months before the study (Mean = 413 ± 284 mg CPZeq/day, without benzodiazepines). They were

assessed with the Brief Psychiatric Rating Scale (BPRS) and the Positive and Negative Symptoms Scale (PANSS). Performance was not correlated with either age at onset or antipsychotic dose. Parental socio-economic status was defined by the occupation of the head of the household (usually the father) according to the National Occupational Classification (NOC, 2016). No between-group differences were found in SES (9.8 ± 2.2 years versus 9.3 ± 3.5) [$t(38) = 1.33$, $p = .19$], gender ($\chi^2 = 1.13$), or age [$t(38) = 0.99$, $p = .33$]. The experiment was approved by the local ethics committee and informed consent was obtained from all participants. All participants were right-handed, with no history of neurological/psychiatric disorders (control group) or neurological/psychiatric comorbidities (clinical group), neurological, epilepsy, traumatic brain injury or prosopagnosia symptoms. All reported normal or corrected-to-normal vision. Table 1 summarizes sociodemographic and clinical data on the participants.

Insert Table 1 here

2.2. Stimuli

A total of 400 black and white photographs of young white adults without distinctive facial features (e.g., jewelry, eyeglasses, or particular facial marks) served as stimuli. They were carefully edited to maintain standard contrast and brightness. The size of the pictures was 400 x 600 pixels. The stimuli were presented on a medium grey background at the center of a computer monitor. The monitor was placed 1 m from the participant, and the stimuli subtended a visual angle of no more than 5.5° (vertical) \times 4° (horizontal). Four sets of 100

stimuli comprising two series were constructed: one study series (40 faces) and one test series (20 physically identical pictures + 20 of the faces in the study series [old faces] with stimulus change + 40 new faces). Different faces were used in each set, and the order of presentation was randomized for items in both the study and test lists.

In the sets prepared for the facial expression exclusion task, each face had two versions with two different expressions (one happy and one neutral) chosen for their low emotional impact and their widespread use in recognition studies in both schizophrenia (Guillaume et al. 2007; Loughland et al., 2002) and healthy participants (Graham & Cabeza, 2001). Each face was superimposed on two easily distinguishable landscape scenes: one mountain scene (List 1) and one forest scene (List 2). In the other two sets, prepared for the task focused on the face's extrinsic background (Lists 3 and 4), there were two versions of each face, with identical expressions and different background scenes. The faces in Lists 3 and 4 were shown with the same two landscape backgrounds as in the expression exclusion task (20 with the forest landscape and 20 with the mountain landscape). All faces were presented with one expression: neutral for one list (List 3) and happy for the other (List 4). The presentation order of the lists was counterbalanced between participants.

2.3. Procedure

After providing informed consent, participants were seated comfortably in a quiet room, 1 m from the computer monitor. Prior to the study block, participants were told that they should attempt to memorize the stimuli so they could recognize them later. They were instructed to minimize blinks, eye movements, and muscle tension while the stimuli were presented. Each participant completed four sessions in order to obtain enough stimulus trials for the ERP

analysis: two facial expression exclusion task sessions, and two background exclusion task sessions. Thus, all participants were recorded with all four lists. The order of presentation of both lists and tasks was counterbalanced across participants. The minimum interval between successive experimental sessions was two days.

Each task consisted of a study phase followed, 10 minutes later, by a face recognition exclusion task. Before study, the participants were informed that a change would occur in some of the pictures, and told that they would have to detect these changes during a subsequent recognition test. Each trial began with a fixation cross (lasting 500 ms) at the center of the screen. The face pictures were then presented at the same location for 2500 ms. The intertrial interval (ITI) was 2500 ms during the study phase and 3000 ms during the test phase. At test, the participants were instructed to respond “yes” (with right index finger) exclusively to faces appearing with their original expression and context (old target faces = physically identical pictures), and “no” (left index finger) to any face with changes in either facial expression or background scene (old non-target faces) as well as to completely new faces. Their task was thus to recognize old faces presented at study in the same configuration, while excluding both new faces and old faces presented in a new configuration. The procedure and the correct responses in each condition are summarized in Figure 1. In the old non-target condition, half of the faces shown with a smiling (neutral) expression at test were presented with a neutral (smiling) expression at test. The same design was used for the background scene exclusion task using two different and easily distinguishable natural background scenes.

Insert Figure 1 here

This resulted in 40 study trials and 80 test trials in each session: 40 repeated faces (20 old target faces, in the same configuration; 20 old non-target faces, in a new configuration) and 40 new faces (20 new faces with each of the two facial expressions and background scenes). Thus, in both sessions for each exclusion task, there were 40 trials in the old target condition, 40 trials in the old non-target condition, and 80 trials in the new condition.

2.4. Electrophysiological data acquisition

Electroencephalograms (EEGs) were recorded at test from 32 silver/silver chloride electrodes embedded in an elastic cap positioned according to the 10-20 system and referenced to the linked earlobes. The ground electrode was placed at Fpz. Vertical and horizontal eye movements were recorded from additional electrode pairs placed below and on the outer canthus of the left eye, respectively. The impedance of all electrodes was kept below 5 K Ω . EEG data were recorded continuously at 256 Hz and stored on a hard disk along with codes identifying the stimulus type, stimulus onset, and the participant's response. Trials containing EOG artifacts with amplifier blocking for more than 100 ms, or any absolute amplitude exceeding 100 μ v, were rejected, as were those with non-ocular artifacts, saccades, and incorrect behavioral responses. A blink correction procedure (Elbert, Lutzenberger, Rockstroh, & Birbaumer, 1985) was applied where appropriate to minimize the number of trials rejected on the basis of blink artifacts. EEG signals were recorded with a bandwidth of 0.01-30 Hz and re-referenced off-line after EOG correction/rejection. The EEG was then segmented into 1300-ms epochs, including a 200-ms baseline before stimulus onset and a 1100-ms interval after stimulus onset for ERP averaging. Average ERPs in artifact-free trials were then created for each of the three conditions.

2.5. Data analyses

2.5.1. Behavioral data

Correct responses (YES to old target items; NO to old non-target and new items) and the corresponding reaction times (RTs) in each condition were analyzed in each exclusion task using an omnibus repeated measures analysis of variance (ANOVA) with group (schizophrenia vs. control) as a between-subjects factor and condition (old target vs. old non-target vs. new) as a within-subjects factor. Psychophysical indexes (discriminability, d' , and decision criterion, c) were computed, with: hits = YES responses to old target faces and false alarms (FA) = YES responses to new faces for d'_1 and c_1 ; hits = YES to old target faces and FA = YES to old non-target faces for d'_2 and c_2 . Using YES responses to old targets and YES responses to old non-targets, d'_2 gives an indication of the ability to retrieve the exact presentation of the stimulus, whereas d'_1 indicates the ability to discriminate old faces from new ones. These indexes were used to compare the exclusion tasks through a repeated-measures ANOVA with group (schizophrenia vs. control) as a between-subjects factor and task (expression-exclusion vs. background-exclusion task) as a within-subjects factor. The effect of the task on overall accuracy (percentage of correct responses in all conditions) was also analyzed using t -tests for independent groups.

2.5.2. EEG data

Two epochs corresponding to the periods of the different ERP old/new effects during face recognition (e.g., MacKenzie and Donaldson, 2007; Yick & Yonelinas, 2014) were identified

and selected: an early time window (300-500ms) for the FN400, and a late time window (550-900ms) for the parietal old/new effect. ERPs during the exclusion task were analyzed using mixed-model ANOVAs on correct responses only (hits and correct rejections) at the frontal and parietal regions of interest (ROIs), with group (schizophrenia vs. control) as a between-subjects factor, and task (expression vs. background exclusion task), condition (old target vs. old non-target vs. new), region (frontal: F3, F4, F7, F8, FC3, FC4; and parietal: P3, P4, CP3, CP4, TP78, TP8) and electrode laterality (left vs. right) as within-subjects factors. Where there was a significant Group \times Task interaction, ERP data were analyzed separately at the frontal and parietal regions of interest (ROIs) with group (schizophrenia vs. control) as a between-subjects factor, condition (old target vs. old non-target vs. new), region (frontal: F3, F4, F7, F8, FC3, FC4; and parietal: P3, P4, CP3, CP4, TP78, TP8) and laterality (left vs. right) as within-subjects factors. For each ANOVA, the Geisser-Greenhouse adjustment was applied to the degrees of freedom (df) to correct for violations of sphericity associated with repeated measures. Accordingly, for all F tests with more than 1 df in the numerator, both the corrected p -value and the corresponding epsilon value are reported below. Partial eta-squared (η_p^2) was used to determine the magnitude of the effects for all significant single- df a priori tests, because these outcomes were central to the aims of the study. The mean numbers of artifact-free trials per participant for each condition in the expression-exclusion task were as follows: 31.8 ($SD = 5.1$) in the old target condition, 24.9 ($SD = 4.7$) in the old non-target condition, and 66.2 ($SD = 6.2$) in the new condition for healthy controls; and 27.5 ($SD = 5.3$) in the old target condition, 24.1 ($SD = 4.9$) in the old non-target condition, and 68.1 ($SD = 7.2$) in the new condition for the clinical group. In the background scene exclusion task, the mean number of artifact-free trials for controls was 29.2 ($SD = 6.7$) in the old target condition, 22.6 ($SD = 4.8$) in the old non-target condition, and 61.4 ($SD = 7.8$) in the new condition; for participants with schizophrenia the corresponding means were 24.9 ($SD = 6.5$)

in the old target condition, 20.6 ($SD = 4.3$) in the old non-target condition, and 62.1 ($SD = 7.5$) in the new condition.

3. Results

3.1. Behavioral Responses

3.1.1. Correct responses

The behavioral data for each of the two exclusion tasks are summarized in Table 2. For all participants, overall accuracy was greater on the expression-exclusion task ($M = 0.73$; $SD = 0.11$) than the background-exclusion task ($M = 0.69$; $SD = 0.12$), $t(38) = 2.89$, $p = .003$. The ANOVA showed a main effect of condition, $F(2,76) = 5.69$, $MSE = .03$, $p < .005$, with higher performance for new faces than old ones (target + non-target), $F(1,38) = 7.78$, $MSE = .017$, $p < .001$, $\eta_p^2 = .30$. No significant difference in false alarms was observed between the two tasks, $p > .6$, indicating that there was no overall response bias in either exclusion task. The ANOVA also showed a Group \times Task interaction, $F(2,76) = 4.91$, $p = .03$, $\eta_p^2 = .22$, $\epsilon = 0.81$, with healthy controls outperforming participants with schizophrenia on the expression-exclusion task, $F(1,38) = 6.72$, $MSE = 0.14$, $p = .013$, while no between-group difference was found in accuracy on the background-exclusion task, $F(1,38) = 1.18$, $MSE = 0.15$, $p = .28$. The ANOVA also revealed a Group \times Condition interaction, $F(2,76) = 6.62$, $MSE = .03$, $p = .004$, with healthy controls performing better in the old target condition, $F(1,38) = 6.79$, $MSE = .020$, $p = .002$, $\eta_p^2 = .24$, but no between-group difference in the old non-target, $p = .28$, and new, $p = .68$, conditions. No significant difference between old target and old-non-target conditions was observed in the clinical

group, $p = .32$, whereas healthy controls performed better in the old target than the old non-target condition, $F(1,38) = 12.58$, $MSE = .023$, $p = .01$, $\eta_p^2 = .23$.

3.1.2. Correct response reaction times

The ANOVA yielded a main effect of condition, with slower reaction times for old faces (target + non-target) than for new ones, $F(2,76) = 7.65$, $MSE = 4762$, $p = .001$, and no significant difference between target and non-target conditions for old faces, $p = .08$. There was no significant difference between groups in reaction times, $F(1,38) = 1.56$, $p = .22$.

Insert Table 2 here

3.1.3. Psychophysical indexes

No between-group difference was observed in the discriminability and decision criterion indexes for old vs. new faces: d'_1 ($p > .2$) and c_1 ($p > .07$). These psychophysical indexes did not differ between tasks ($p > .2$). On the other hand, discriminability between target and non-target old faces (d'_2) was greater in the expression-exclusion task than in the background-exclusion task, $F(1,38) = 9.67$, $MSE = 0.22$, $p = .004$. In the clinical group, the corresponding decision criterion (c_2) was also stricter than in healthy controls, $F(1,38) = 5.63$, $MSE = .10$, $p = .023$, with controls showing a greater tendency to accept old target faces than participants with schizophrenia, who tended to reject them as non-target lures (SZ: $M = .60$; $SD = .14$ vs. controls: $M = .70$; $SD = .15$).

Insert Figure 2 here

3.2. ERP data

3.2.1. Comparison between tasks

The grand average waveforms presented in Figures 3 and 4 show the ERPs in the expression and background exclusion tasks respectively. Two main peaks can be seen, corresponding to the ERP old/new effects usually observed during face recognition memory tasks (Guillaume & Tiberghien, 2013a; MacKenzie & Donaldson, 2009; Yick & Wilding, 2014).

N400 time window (300-500ms)

In both tasks, the amplitude of the FN400 was more negative in schizophrenia than in healthy controls, $F(1,38) = 8.89, p = .005, \eta_p^2 = .26$. As shown in Figures 3 and 4, the FN400 old/new effect was found on both tasks for the two groups of participants combined, with greater negativities for new faces than old ones (target + non-target), $F(1,38) = 7.37; p = .01, \eta_p^2 = .22$. However, there were significant Group \times Task \times Condition, $F(2,76) = 5.89, p < .02, \eta_p^2 = .21, \epsilon = 0.81$, and Group \times Task \times Laterality interactions, $F(1,38) = 5.86, p = .02, \eta_p^2 = .20$, suggesting that the effect of condition differed between groups in ways that depended on both

the task and the laterality of the frontal ERPs. Further analyses of these ERP results are explored below separately for the two exclusion tasks.

Insert Figure 3 here

Late time window (550-900ms)

The positive amplitude of the late parietal component was greater in the control group than in the schizophrenia group, $F(1,38) = 6.02, p = .018, \eta_p^2 = .19$. The parietal old/new effect was found on both tasks in both groups, with greater positive amplitude for old faces compared to new ones, $F(1,38) = 9.23, p < .005, \eta_p^2 = .30$. But a Group \times Condition interaction was found, $F(2,76) = 4.89, p = .03, \eta_p^2 = .19, \epsilon = 0.86$, suggesting that the old target/old non-target effect differed between the two groups. This interaction and the results from each exclusion task are explored in more depth below.

Insert Figure 4 here

3.2.2. Facial expression exclusion task

N400 time window (300-500ms)

Figure 5 shows topographic maps of ERP differences between old and new faces for the FN400 old/new effect (top) and the parietal old/new effect (bottom) in the facial expression exclusion task. A separate analysis on frontal regions confirmed the larger negative amplitude of the FN400 in participants with schizophrenia compared to healthy controls, $F(1,38) = 7.61$, $p = .009$, $\eta_p^2 = .27$. The ANOVA also revealed a significant Group \times Condition \times Laterality interaction, $F(2,76) = 6.31$, $p = .015$, $\eta_p^2 = .24$, $\epsilon = 0.82$, with greater negativities for new faces than old ones in both hemispheres for healthy controls, $F(1,38) = 8.12$, $p = .007$, $\eta_p^2 = .28$, but only in the right hemisphere, $F(1,38) = 7.61$, $p = .009$, $\eta_p^2 = .24$, not the left, $F(1,38) = 2.03$, $p = .16$, in the clinical group. Furthermore, no amplitude difference was found between old target and old non-target faces (with new expressions) in schizophrenic participants, $p = .21$, while healthy controls showed greater negativities for old non-target faces than old target faces during the expression exclusion task, $F(1,38) = 5.60$, $p = .023$, $\eta_p^2 = .19$.

Late time window (550-900ms)

An ANOVA on the posterior regions revealed a significant group effect, with greater LPC amplitude in control subjects compared to participants with schizophrenia, $F(1,38) = 9.64$, $p = .0036$, $\eta_p^2 = .26$. Analysis also revealed a Group \times Condition interaction, $F(2,76) = 7.31$, $p = .009$, $\epsilon = .83$, with larger amplitudes for old than new faces in healthy controls but no significant difference between target and non-target old faces, $F(1,38) = 2.14$, $p = .15$, $\eta_p^2 = .09$. The parietal old/new effect was found again for schizophrenic participants, $F(1,38) = 7.05$, $p = .012$, $\eta_p^2 = .25$, and it was greater in the target condition than the non-

target condition in this group, $F(1,38) = 6.56, p = .015, \eta_p^2 = .23$. This old target/old non-target difference was again not found in healthy controls, $F(1,38) = 1.78, p = .19$. The background-exclusion task will allow us to check whether this between-group difference is found again when the relevant diagnostic information is extrinsic to the recognized face.

Insert Figure 5 here

3.2.3. Background exclusion task

N400 time window (300-500ms)

Figure 6 shows topographic maps of ERP differences between old and new faces for the FN400 old/new effect (top) and parietal old/new effect (bottom) in the background scene exclusion task. An ANOVA on data from frontal regions revealed a significant group effect, with a greater FN400 amplitude in participants with schizophrenia than healthy controls, $F(1,38) = 5.09, p = .03, \eta_p^2 = .19$. A condition effect was found, $F(2,76) = 6.79, p = .013, \eta_p^2 = .24$, with greater negativities for new than for old faces (target + non-target) in both healthy controls, $F(1,38) = 15.78, p < .001, \eta_p^2 = .34$, and participants with schizophrenia, $F(1,38) = 8.89, p = .005, \eta_p^2 = .27$. However, no target/non-target difference was found in either schizophrenic participants, $F(1,38) = 1.52, p = .23$, or healthy controls, $F(1,38) = 1.86, p = .18$.

Insert Figure 6 here

Late time window (550-900ms)

An ANOVA on data from posterior regions revealed a group effect with a larger-amplitude LPC in healthy controls than in participants with schizophrenia, $F(1,38) = 10.35$, $p = .003$, $\eta_p^2 = .28$. The ANOVA also revealed a Group \times Condition interaction, $F(2,76) = 5.87$, $p = .02$, $\varepsilon = 0.81$, with a parietal old/new effect for all participants, $F(1,38) = 7.50$, $p = .009$, $\eta_p^2 = .26$. On the other hand, while the parietal old/new effect differed between the target and non-target conditions in participants with schizophrenia, $F(1,38) = 4.83$, $p = .034$, $\eta_p^2 = .19$, no such difference was observed in healthy controls, $F(1,38) = 0.39$, $p = .54$. Figure 7 summarizes the mean ERP recognition effect (and SEM) in the FN400 (300-500ms) and parietal (550-900ms) old/new effect time windows, by contextual change, group, and task.

Insert Figure 7 here

4. Discussion

Diverging results on recollection and familiarity deficits in schizophrenia from previous studies are consistent with the possibility that deficits may or may not be observed depending on the relationship of the critical information with the recognition target. To test this possibility, we recorded behavioral performance and the associated ERPs in two exclusion tasks, one where the critical information was intrinsic to the target (expression), one where it was extrinsic to the target (background scene). Both groups' performance at excluding new faces was better than performance with old faces (target or non-target), which reflects the need to retrieve additional specific information about the study image in the exclusion tasks. Participants with schizophrenia did not differ from healthy subjects in the rate of false alarms. This suggests a spared ability to distinguish old faces from new ones, as confirmed by the discriminability index (d'). While there was no between-group difference in overall accuracy, participants with schizophrenia were more likely to reject old target faces than were healthy participants. This group difference was not found in the old non-target condition, where all participants were equally likely to reject non-target faces. This result is line with the recollection deficit generally observed in schizophrenia (e.g., Kazes et al., 1999; Martin et al., 2005; van Erp et al., 2008; Weiss et al., 2008). Interestingly, members of the clinical group with greater positive symptomatology showed the lowest overall accuracy in the exclusion tasks used here ($r^2 = .61$, $t(19) = 3.11$, $p = .006$). This correlation is consistent with previous findings suggesting that face processing deficits may be associated with increased positive symptoms (Baudouin et al., 2002; Martin et al., 2005). It converges with the view that episodic memory decline is associated with reality distortion and impaired face recognition (Guillem et al., 2003; Guillaume et al., 2012a).

As hypothesized, both groups performed better when the critical information for discriminating old target from old non-target faces was intrinsic (expression exclusion) than extrinsic (background exclusion). This result confirms that when the critical information is unitized with

the recognition target (here, the face), it leads to better performance (e.g., Diana, Yonelinas, & Ranganath, 2007). But while this increased target/non-target discriminability ($d'2$) was observed in healthy controls, it was not observed in schizophrenia patients, who did not benefit from this unitization. The present findings thus support the hypothesis of an “over-exclusion” mode in schizophrenia due to a context integration deficit during recognition (Amuroso, Cardona, Melloni, Seden, & Ibanez, 2012; see also Guillaume, Stip & Tiberghien, 2013). The ERP data offer further insights into the sequence of cognitive processes that take place during exclusion tasks and their alteration in schizophrenia. They revealed morphological differences between healthy controls and participants with schizophrenia: FN400 amplitude was larger in schizophrenia compared to controls, whereas LPC amplitude was smaller in schizophrenia. In line with the abnormal activation pattern in the prefrontal cortex in schizophrenia (Tendolkar et al., 2002; Velligan et al., 2002), this abnormal FN400 confirms the results of previous studies using unfamiliar face (Guillem et al., 2001; Guillaume et al., 2012a, b), picture matching (Guerra et al., 2009), and item-categorization tasks (Matsuoka et al., 1999) and converges with the behavioral deficit observed in the old target condition. This, in turn, supports the idea that increased FN400 amplitude may be linked to reality distortion (Guillem et al., 2003; Fakra et al., 2008). It is also compatible with the possibility that the PFC activation deficit observed in schizophrenic individuals during episodic memory tasks (Ragland et al., 2012) contributes to the observed recognition memory deficit (Libby et al., 2012).

With regard to ERP recognition effects, while the two old/new effects were observed in both groups in both exclusion tasks, stimulus changes modulated the early FN400 old/new effect differently in the two groups. The early old/new effect was observed in both hemispheres on both tasks in healthy controls. This was not the case for participants with schizophrenia, in whom this effect was observed in both hemispheres in the background exclusion task, but only in the right hemisphere in the expression exclusion task. The asymmetrical early frontal activity

observed in schizophrenia thus might be related to a defective ability to initiate retrieval processes (e.g., Lepage et al., 2006). Facial expression change modulated the FN400 old/new effect in healthy controls, but not in participants with schizophrenia. This between-group difference was not found when the background scene was the critical information. These early modulations thus fit well with the behavioral data (d'_{2}), and confirm that the FN400 old/new effect is sensitive to the unitization of the critical information with the face in healthy controls, but not in schizophrenia (Tsvivilis et al., 2001; Guillaume & Tiberghien, 2013a; Guillaume & Etienne, 2015). Taken together, the observed modulations of the FN400 show that an early phase of the retrieval process underlying episodic memory performance differed in schizophrenic participants relative to healthy controls. These ERP data suggest that the clinical group may have failed to detect the critical information in the early stage of recognition (300-500ms). The FN400 old/new effect was not modulated by a unitization of the critical information with the stimulus in participants with schizophrenia, in contrast to healthy controls. Turning now to later neurocognitive processes, both groups showed a parietal old/new effect – greater positive amplitudes for old faces than new ones. This confirms that the later ERP recognition effect is spared in schizophrenia (Guillem, 2003; Guillaume et al., 2012a, b; Kayser et al., 2010). However, the present data also confirm previous findings that the amplitude of the LPC is reduced in schizophrenia (e.g., Kostova et al., 2003). The magnitude of the parietal old/new effect was modulated by stimulus changes (expression or background) in participants with schizophrenia, but not in the control group. In the clinical group but not in controls, the parietal old/new effect was smaller in the study-test stimulus change condition (old non-target) than in the condition where the stimulus was unchanged between study and test (old target). This study-test mismatch effect suggests that the parietal old/new effect is graduated with respect to a stimulus change signal in schizophrenia (e.g., Guillaume et al., 2012a). In healthy controls, in contrast, the observed modulations reflected the detection of

the critical information in both conditions. This confirms that the parietal old/new effect reflects the specificity of the retrieval orientation during exclusion tasks (Herron & Rugg, 2003; Evans, Wilding, Hibbs, Herron, 2010). One possibility is that the two groups adopted different retrieval orientations when searching in memory for the critical information embedded in the face pictures. In healthy controls, the amplitude of the parietal old/new effect reflects the implementation of this controlled, goal-based retrieval mechanism regardless of stimulus change. The pattern in the schizophrenia group is different: these participants seem to have discriminated between target and non-target faces on the basis of a continuous, graduated process, related to memory strength and a study-test matching signal in the later time window (550-900 ms). Healthy controls are able to prioritize the recollection of a specific feature, while participants with schizophrenia seem to have excluded study-test stimulus change on the basis of the memory strength signal. This accounts for the over-exclusion pattern observed in the clinical group in the old target condition, and its correlation with the participants' positive symptomatology.

Taken together, the anomalies in the ERP correlates of recognition processes observed here support the hypothesis that both familiarity and recollection are affected in schizophrenia (Guillaume et al., 2015b, Libby et al., 2012). While participants in the clinical group showed anomalies in the early FN400 time window, their performance seems to have been based on a process involving a continuously varying study-test matching signal to detect stimulus change in the late temporal window. This would explain the patients' greater propensity to reject old items in the target condition. The present results thus confirm the existence of a recollection deficit in schizophrenia, and a corresponding alteration in the parietal old/new effect (Kazes et al., 1999; van Erp et al., 2008; Weiss et al., 2008). Individuals with schizophrenia have difficulty controlling the retrieval of specific information concerning the study episode. Their memory search processes are impaired (e.g., Myung-Sun et al., 2004).

Our results suggest that this recollection deficit may be due to the activation of different retrieval modes in both the earlier and later time windows. This deficit was not manifested in lower overall accuracy, but was revealed by comparing the performance of the clinical group and controls on correctly recognized faces and the associated ERP correlates. The present study supports the view that individuals with schizophrenia rely on the retrieval of the stimulus as a whole, rather than on more specific contextual information, to perform episodic memory tasks (Joshua & Rossell, 2009; Guillaume et al., 2013b). This study-test matching mode may be suitable when detecting perceptual mismatch is required, but can lead to a familiarity deficit and the over-exclusion of old stimuli.

5. Conclusion

This study shows that the retrieval processes involved in the recollection of specific episodic information function differently in schizophrenia. In healthy controls, the parietal old/new effect reflects the recollection of the specific critical information required to distinguish new from previously seen stimuli in an on-off fashion. In schizophrenic participants, however, the parietal old/new effect varies in a graduated manner, likely reflecting a continuous process that is proportional to the study-test matching signal. Participants with schizophrenia thus seem to base their recollection on an abnormal retrieval mode, which may account for aspects of their symptomatology. These findings offer promising avenues for future research.

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Figure legends

Figure 1. Face-landscape background manipulations and correct recognition responses in each exclusion task.

Figure 2. Box plots of correct responses in the facial expression exclusion task (left) and the background exclusion task (right) for patients with schizophrenia (medium grey boxes) and matched healthy controls (dark grey boxes).

Figure 3. Group mean ERPs on correctly recognized faces in the old target, old non-target and new conditions in the facial expression exclusion task, from healthy controls (left) and patients with schizophrenia (right). The waveforms shown are selected ROIs in the frontal regions (LF: left frontal, RF: right frontal) and parietal regions (LP: left parietal, RP: right parietal).

Figure 4. Group mean ERPs on correctly recognized faces in the old target, old non-target and new conditions for healthy controls (left) and patients with schizophrenia (right) in the background exclusion task. The waveforms shown are selected ROIs in the frontal regions (LF: left frontal, RF: right frontal) and parietal regions (LP: left parietal, RP: right parietal).

Figure 5. Topographic maps of ERP difference between old (target+non-target) and new faces for the FN400 (top) and LPC (bottom) intervals in the facial expression exclusion task. Difference values are indicated by color.

Figure 6. Topographic maps of ERP difference between old (target+non-target) and new faces for the FN400 (top) and LPC (bottom) intervals in the background scene exclusion task. Difference values are indicated by color.

Figure 7. Mean ERP recognition effect (and SEM) using amplitudes averaged in the N400 (300-500ms) and LPC (500-800ms) time windows, for correctly recognized faces in the old target and old non-target conditions, in controls (left) and schizophrenic subjects (right).

Experimental procedure

Study :



Expression exclusion task :



**Same Face
Same Expression
Old-target**



**Same Face
New Expression
Old-non target**



New



New

Background exclusion task :



**Same Face
Same Background
Old-target**



**Same Face
New Background
Old-non target**



New



New

Correct Response :

"YES"

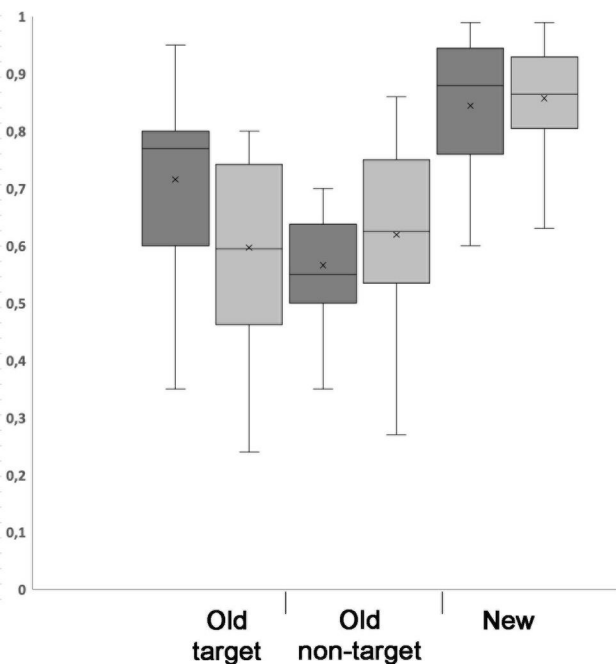
"NO"

"NO"

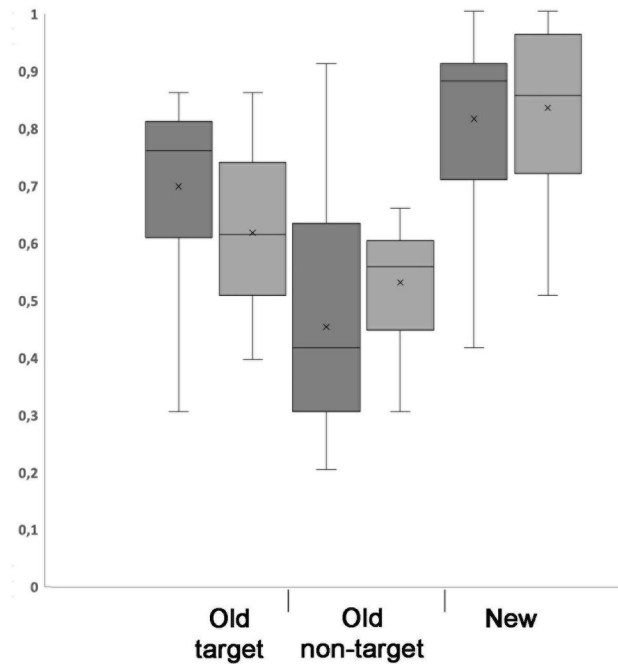
"NO"

Exclusion Task

Facial Expression



Background Scene

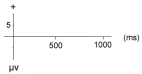
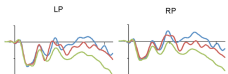
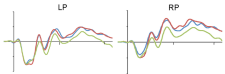
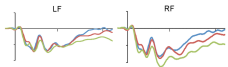
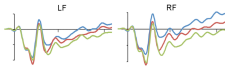


■ Controls
□ SZ patients

Facial expression exclusion task

Healthy Controls

Schizophrenia Patients

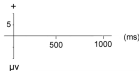
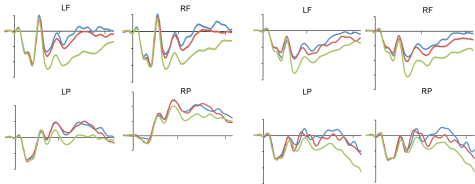


- Old target
- Old non-target
- New

Background scene exclusion task

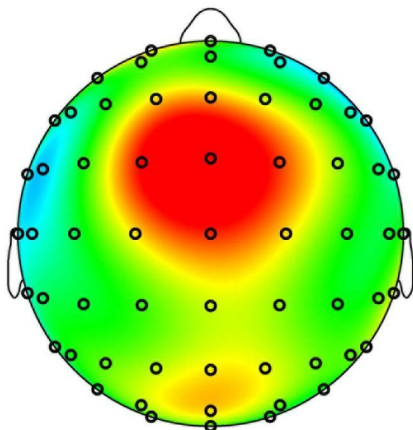
Healthy Controls

Schizophrenia Patients

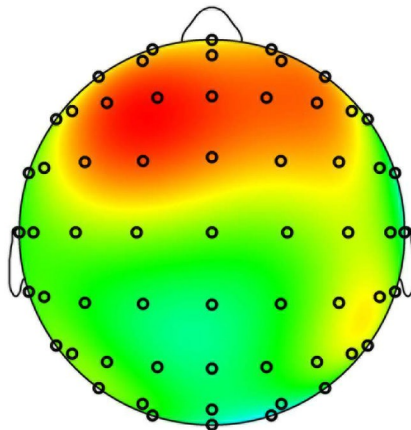


- Old target
- Old non-target
- New

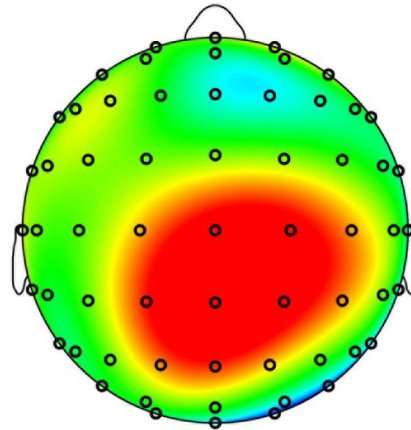
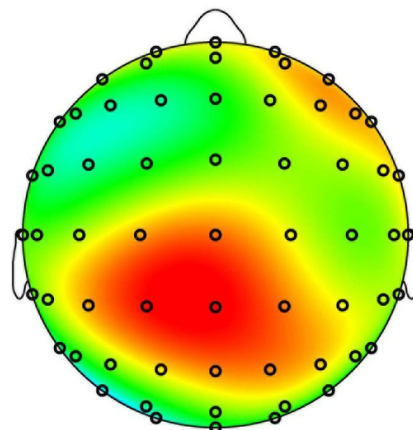
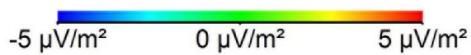
CONTROLS



SZ PATIENTS



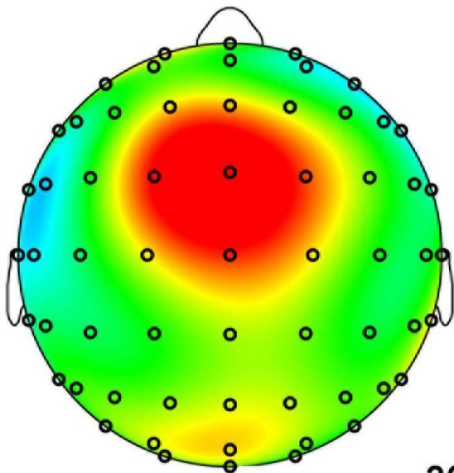
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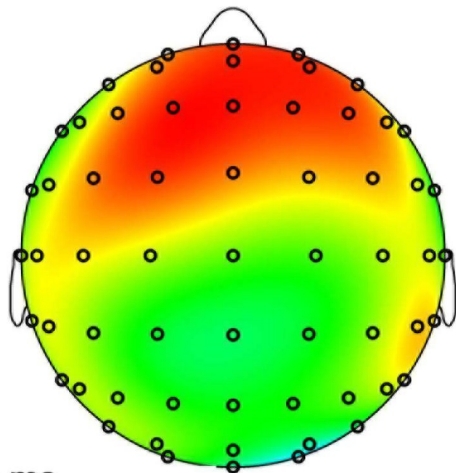
550-900 ms



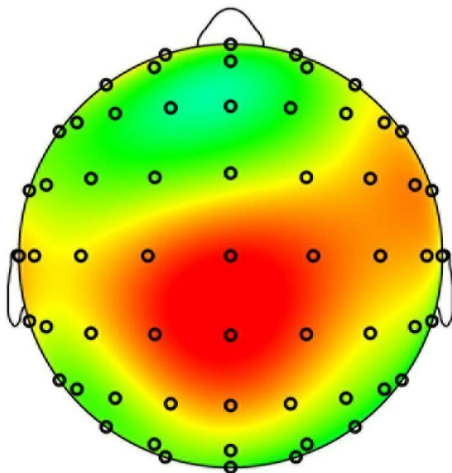
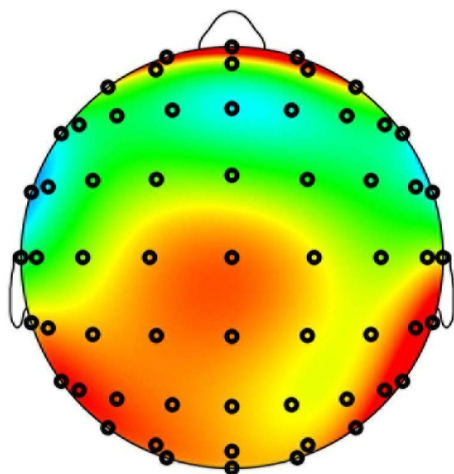
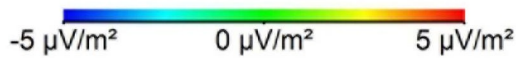
CONTROLS



SZ PATIENTS



300-500 ms



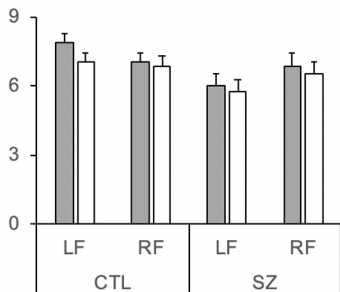
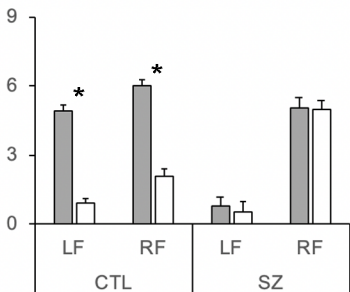
550-900 ms



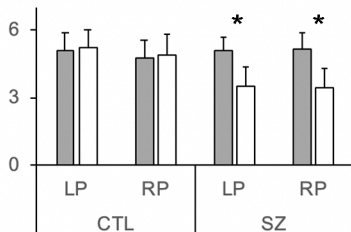
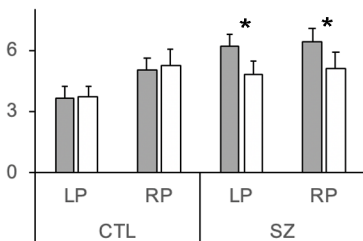
**Expression
Exclusion task**

**Background
Exclusion task**

FN400 Old/New effect (300-500ms)



Parietal Old/New effect (550-900ms)



■ Old target - New

□ Old non-target - New

Table 1. Socio-demographic and clinical profiles ^a

	Control group (N=20)	Schizophrenia group (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

a Values indicate mean ± SD.

b 19 patients were taking novel or typical antipsychotics, 1 patient was drug-free.

Table 2. Recognition Performance: Mean rates (M) correct responses in the old-target, old-non target and new conditions and corresponding reaction time (RT) for schizophrenic subjects and matched control subjects depending on the exclusion task. Discriminability index (d'_1 = old/new discriminability; d'_2 = old target/old non-target discriminability), decision criterion (c_1 = old/new decision criterion; c_2 = old target/old non-target decision criterion), and corresponding standard deviation (SD).

	Facial expression				Background scene			
	Controls		Patients		Controls		Patients	
	M	SD	M	SD	M	SD	M	SD
Global accuracy	0.74	0.12	0.72	0.10	0.69	0.11	0.69	0.13
YES/Old target	0.75	0.14	0.65	0.15	0.70	0.12	0.68	0.12
No/Old non-target	0.64	0.16	0.64	0.14	0.58	0.14	0.57	0.17
No/New	0.84	0.11	0.86	0.09	0.80	0.13	0.81	0.15
YES/Old-target RT (ms)	1940	388	2148	498	1999	488	2329	596
No/Old-non target RT (ms)	2083	337	2138	551	2196	426	2292	616
Correct rejection RT (ms)	1718	349	1927	458	1865	413	1996	655
Discriminability (d'_1)	1.67	0.52	1.47	0.53	1.52	0.61	1.79	0.60
Response criterion (c_1)	0.16	0.32	0.40	0.34	0.23	0.35	0.26	0.31
Discriminability (d'_2)	0.83	0.43	0.59	0.48	0.39	0.48	0.37	0.46
Response criterion (c_2)	-0.41	0.26	-0.19	0.28	-0.29	0.26	-0.19	0.28