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Impact of intention on the ERP correlates of face recognition

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ABSTRACT

The present study investigated the impact of study-test similarity on face recognition by manipulating, in the same experiment, the expression change (same vs. different) and the task-processing context (inclusion vs. exclusion instructions) as within-subject variables. Consistent with the dual-process framework, the present results showed that participants performed better on the inclusion task than on the exclusion task, with no response bias. A mid-frontal FN400 old/new effect and a parietal old/new effect were found in both tasks. However, modulations of the ERP old/new effects generated by the expression change on recognized faces differed across tasks. The modulations of the ERP old/new effects were proportional to the degree of matching between the study face and the recognition face in the inclusion task, but not in the exclusion task. The observed modulation of the FN400 old/new effect by the task instructions when familiarity and conceptual priming were kept constant indicates that these early ERP correlates of recognition depend on voluntary task-related control. The present results question the idea that FN400 reflects implicit memory processes such as conceptual priming and show that the extent to which the FN400 discriminates between conditions depends on the retrieval orientation at test. They are discussed in relation to recent controversies about the ERP correlates of familiarity in face recognition. This study suggests that while both conceptual and perceptual information can contribute to the familiarity signal reflected by the FN400 effect, their relative contributions vary with the task demands.

1. Introduction

We have all experienced a feeling of familiarity toward a face without remembering when or where we last saw the person, his/her name, or certain differences in his/her physical features. A common distinction in contemporary research on episodic memory is between familiarity (F) and recollection (R). The epitome of pure familiarity—as in déjà vu or butcher-on-the-bus experiences (Mandler, 1980)—suggests that memory experiences depend on contextual variations occurring between the first encounter of the face and the retrieval time. Despite divergence about the exact nature of the recognition processes, dual-process models of recognition converge with the view that familiarity is relatively automatic and recollection is a more controlled process (see Yonelinas, 2002, for a review). Alternatively, single-process models argue that familiarity is simply sub-threshold recollection (e.g., Wixted, 2007). Within the past 20 years, many studies have been conducted to isolate the event-related potential (ERP) correlates of recognition. A common ERP finding is that the presentation of old/repeated items elicits more positive-going ERPs than new/unrepeated items do (for reviews, see Friedman & Johnson, 2000; Rugg & Curran, 2007). Most relevant here, the FN400 old/new effect (300–500 ms)—also called the mid-frontal old/new effect—has been linked to familiarity (Curran & Cleary, 2003; Rugg & Curran, 2007—but see Voss, Lucas, & Paller, 2012 and Zimmer & Ecker, 2010, for alternative interpretations), whereas the parietal old/new effect (500–1000 ms)—or late positive complex (LPC)—varies in a manner consistent with recollection. The parietal old/new effect has been linked to retrieval of specific information associated with the target, such as its temporal source (Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999), landscape/object association (Tsivillis, Otten, & Rugg, 2001), or 'Remember' compared to 'Know' responses (Düzel, Yonelinas, Mangun, Heinze, & Tulving, 1997). It is topographically dissociable from the late frontal old/new effect typically associated with the monitoring of the retrieved episode and decisional processes (Hayama, Johnson, & Rugg, 2008; Johnson, Kreiter, Russo, & Zhu, 1998).

Although familiarity and recollection are undeniably distinct memory experiences, theoretical controversy currently abounds with respect to the neural correlates of familiarity. The idea that the FN400 reflects familiarity has been questioned in recent studies showing its sensitivity not only to perceptual variations but also to the retrieval of episodic details (Ecker & Zimmer, 2008; Ecker, Zimmer, & Groh-Bordin, 2007; Tsivillis et al., 2001). According

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to Paller, Voss, and Boehm (2007), the neurocognitive processes that support conceptual priming also drive familiarity. In this view, the FN400 is not different from the N400 component, which is largely linked to implicit semantic access during language processing, and more generally, during the processing of all meaningful stimuli including faces (Voss & Federmeier, 2011). Testing in situations where implicit memory is decoupled from familiarity eliminates the correlation between FN400 and subjective familiarity (Voss & Paller, 2009). The decoupling of FN400 effects from explicit memory is in line with the idea that implicit memory is relevant to FN400. For example, the FN400 old/new effect has not been found for stimuli with little ability to support conceptual processing, such as novel faces (MacKenzie & Donaldson, 2007; Yovel & Paller, 2004). On the other hand, a number of studies that challenge the position that the FN400 indexes conceptual implicit memory processing such as conceptual priming and ERP findings continue to offer strong support for the claim that the FN400 is a neural correlate of familiarity and is not limited to conceptual priming or amodal familiarity (Mecklinger, Frings, & Rosburg, 2012; Rugg & Curran, 2007). Others propose that both conceptual and perceptual information can contribute to the familiarity signal reflected by the FN400 effect, but that the relative contributions of the two classes of information vary with the task demands and the stimuli involved (Groh-Bordin, Zimmer, & Ecker, 2006).

In this context, one motivation for examining face recognition is the possibility that unfamiliar faces activate much less conceptual information than famous faces or lexical stimuli. The typical comparison when looking at the FN400 and parietal old/new components in item recognition is between old and completely new items. Being observed during face recognition, the FN400 presents more negative amplitude for correctly rejected new items than for correctly recognized old ones (Nessler, Mecklinger, & Penney, 2005; Rugg et al., 1998; Tsivillis et al., 2001), without being sensitive to the recollection of details such as the occupations associated with the faces at study time (Curran & Hancock, 2007; MacKenzie & Donaldson, 2007). However, the fact that FN400s for original and perceptually altered stimuli are similar in some studies (Curran & Cleary, 2003; Curran & Dien, 2003) but different in others, where a smaller FN400 old/new effect has been found for altered stimuli (Groh-Bordin et al., 2006; Guillaume, Guillem, Tiberghien, & Stip, 2012a, 2012b), adds to the confusion. These discrepancies suggest that what might be crucial is the nature of the altered information, and its relation to the recognition target. For example, MacKenzie and Donaldson (2007, 2009) reported that recollection elicited by face-retrieval cues was associated with an FN400 old/new effect, whereas familiarity was associated with the parietal old/new effect. In their studies, participants made an initial old/new decision, and for faces judged old, were asked to report any contextual information they retrieved about the study episode (non-specific condition) or the name associated with the face at study time (specific condition). The studied faces were associated with a name presented auditorily (2007) or visually (2009) at study time but absent at recognition time. Considering that perceptual variations have been shown to cause modulations in the ERP correlates of face recognition (e.g., Groh-Bordin et al., 2006; Guillaume & Tiberghien, 2005), it is difficult to contend that the lack of information associated with the face at study time does not disrupt automatic matching of the recognized item and thus the ERP correlates of familiarity. The situation gets even more complicated if we consider that changes between study and recognition affect familiarity in different ways, depending on what information was modified and whether or not it was unified with the face at study time. It has been shown recently, for example, that the pattern of engagement of familiarity and recollection during successful episodic retrieval is dependent on the properties of the representations that underlie memory for an event (Rhodes & Donaldson, 2007) and that familiarity can rely on the retrieval of associations (Harlow, MacKenzie, & Donaldson, 2010). Retrieving the name or the occupation associated with a face is quite different from saying whether the study face had the same expression. In the first case, the associated information belongs to a different cognitive domain and conceptual priming is strongly involved, whereas in the second, the expression is intrinsic to the face and encoded along with it. Another critical variable found throughout the studies cited is the relevance or irrelevance of the study-test mismatch for the task at hand. If participants know that they will be questioned about their memory of the name (MacKenzie & Donaldson, 2007) or occupation (Yovel & Paller, 2004) associated with the studied face, they may search for this information in memory as soon as the face is presented, at which time the face constitutes the best cue for retrieving the critical information. The ERP correlates of familiarity may therefore not be as pure in this situation.

One way to disambiguate the controversy about the ERP correlates of familiarity is to cross-manipulate the task-processing context and the effects of perceptual change by applying the process-dissociation procedure (PDP) outlined by Jacoby (1991) and developed in the "conjoint recognition" theory (Brainerd, Reyna, & Mojardin, 1999). The PDP uses two tasks (inclusion and exclusion) wherein automatic/familiarity-related and conscious/recollection-related processes either support or oppose each other. In the inclusion task, subjects make a simple old/new judgment. In this case, information from both familiarity and recollection processes converges to achieve recognition. During the exclusion task, subjects have to recognize both the item and the study list where it was presented earlier (for example, recognize items that were in list A). This puts automatic and conscious recognition processes in opposition. If the conscious process related to recollection fails, familiarity will cause the subject to respond incorrectly to the items to be excluded (in list B). The estimates of recollection (R) and familiarity (F) are then derived based on the assumption that familiarity (automatic memory process) and recollection (controlled memory process) contribute independently to recognition (for a debate on the validity of this assumption, see Curran & Hintzman, 1995; Jacoby & Hay, 1998; Jacoby, Toth, & Yonelinas, 1993; Joordens & Merickle, 1993). However, because the initial PDP is based on discrimination of the list's membership, the exclusion criteria used is an external source of information that could be based on a recency estimation and not influence item familiarity. Unlike previous work, one important characteristic of the present study is that it manipulates the study-test mismatch on intrinsic perceptual features (facial expression), which should directly affect the memory strength of the item. Doing this causes critical information to be encoded as a whole, along with the face, and may therefore act on its familiarity to a greater extent than extrinsic or cross-domain information (e.g., list membership, name or occupation). This experimental protocol allowed us to manipulate the status of the expression change, depending on task demands. Task-processing context does not affect perceptual or conceptual priming but only the relevance of the study-test match in the memory judgment.

In the present study, participants were aware that they would have to recognize faces later and that the expression on the face would be relevant during the recognition test. This gave us four situations for comparison: (1) old/new recognition judgments (inclusion task), where the picture presented on the test was identical to the picture at study time, (2) old/new recognition judgments (inclusion task), where the expression on the old faces was modified, thereby disrupting the study-test matching, (3) a recognition situation where the change of expression had to be evaluated on the recognition test (exclusion task) but the expression on the face at recognition time was the same as the expression at study time, and (4) a recognition situation where the change of expression had to be evaluated at recognition time (exclusion task) and the expression on old faces was not the same as on the studied ones. The condition where old faces have a new expression is clearly different from one situation to the next.

A comparison of these conditions should help improve our functional interpretation of the ERP correlates of face recognition. Expression change should weaken memory strength and study-test matching on both the inclusion and exclusion tasks, but automatic memory processes that lead to familiarity do not provide a sufficiently accurate basis for discriminating studied faces with an expression change, from studied faces without an expression change on the exclusion task. On the other hand, task instructions should not influence familiarity and automatic memory processes such as conceptual priming or perceptual overlap. If FN400 reflects familiarity and study-test matching processes such as perceptual or conceptual priming, the expression-change should modulate the FN400 in the same way in the inclusion and the exclusion conditions. Alternatively, modulation of the FN400 old/new effect by the task instructions in the different condition, while familiarity and conceptual priming were kept constant, may suggest that this early ERP component is related not only to automatic memory processes but also to the task-processing context. However, ERP-recollection effects should be found with more positive parietal amplitudes on the exclusion task (requiring recollection of the facial expression) than on the inclusion task. Since the expression should be evaluated for all recognized faces, we should not observe any differences in the parietal old/new effect between the faces with the same expression and the faces with a different expression on the exclusion task, whereas this mismatch should modulate the parietal old/new effect when it is not relevant to the task (inclusion).

2. Method

2.1. Participants

Twenty-four participants (age 29.4 ± 7.8 years; range 24–35) were recruited (9 females). They had normal or corrected-to-normal vision, no neurological illness, dyslexia, or symptoms of prosopagnosia. Participants with histories of traumatic brain injury, epilepsy, alcohol and/or substance abuse, other diagnosable neurological conditions, or a history of psychiatric illness were excluded from the study. After a complete description of the study, written informed consent was obtained from participants. The protocol was approved by a local ethics committee.

2.2. Stimuli

The stimuli consisted of black and white photographs of young Caucasian adults without any distinctive facial features (e.g., beard, jewelry, glasses, or particular facial marks). A set of 320 photographs (half male and half female) were selected and carefully edited to maintain standard brightness and contrast. Four 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 order of presentation was randomized for items on the study and test lists. Different faces were included in the four lists. Each face had a neutral or smiling expression and was superimposed on one, and only one, natural landscape background (see Fig. 1). These expressions were chosen for their low emotional connotation compared to negative facial emotions (e.g., sad or angry). The size of the pictures was 400 $\times$ 600 pixels.

2.3. Procedure

Participants were seated comfortably in front of a computer screen placed 1.5 m away. Faces were presented on a gray background at the center of the screen sustaining a visual angle of 5°. The stimuli were displayed on the monitor of the computer driving the sequence. At both study and test times, each trial began with a fixation cross (lasting 500 ms) in the middle of the screen. Then the face picture was presented in the same place for 2500 ms. The ITI was 2500 ms for the study phase and 3000 ms for the test. In each recognition tasks, subjects were asked to respond YES or NO on each trial by pressing distinct keys on the computer keyboard. Subjects' responses and their reaction times (RTs) were recorded separately on the computer disk in each experimental condition for subsequent analysis. At study time, participants were informed that they would have to recognize faces later and were aware that the expression on the face would be relevant during the recognition test. The test instructions were given between the study and test phases. The recognition test required the retrieval of studied faces mixed in with new faces. Faces tested with the same expression were paired with the exact same picture as the one used in the study phase. In the different-expression condition, the faces were paired with a different expression from the one studied (on half from each expression). The following definitions of the test-item categories were used: *old* items were faces that were in the study list and had 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, and *new* items were faces that were not on the study list (and were presented with one of two expressions: smiling or neutral).

Two types of recognition instructions were given. For the inclusion task, participants were asked to recognize any face regardless of a change in expression, i.e., respond YES to any previously presented face (old and similar face pictures) and NO to new faces. The two types of YES responses were scored separately, i.e., YES to items with a new expression (different condition) and YES to items with the same expression (old condition). In the exclusion task, participants were instructed to make affirmative recognition judgments only for faces that had their original expression (respond YES to old items only), and to reject any face with a change of expression (NO to different items) or a completely new face (NO to new items). With the combination of the two blocks, this made 160 trials for each recognition task: 80 repeated faces (40 with the same expression: old items, and 40 with a new expression: different items) and 80 new faces (40 new faces with a smiling expression and 40 new faces with a neutral expression). Fig. 1 summarizes the experimental procedure and the correct responses in each task.

In order to obtain an acceptable signal-to-noise ratio, all participants completed two sessions separated by at least 1 week, one with two inclusion tasks and one with two exclusion tasks. The task order was counterbalanced across participants. This was designed to alleviate the problem of violations of the independence assumption. In each session, a break of 30 min was allowed between each inclusion or exclusion test. Each test consisted of a study list followed five minutes later by the recognition test list. Different faces were presented in each test. For all participants, the presentation order was randomized for all items on the study and test lists.

2.4. EEG data acquisition

Electroencephalographic activity was recorded from 32 surface electrodes according to the 10–20 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 were 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,

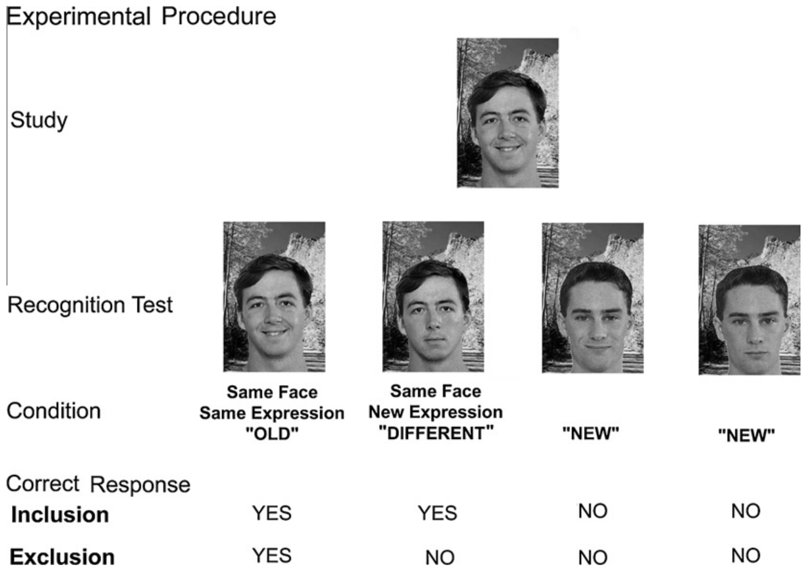

Fig. 1. Face-expression manipulations and correct recognition responses in the inclusion and exclusion tasks.

and the subject's response. Trials with nonocular artifacts, eye movements (EOG over 100 μv), or 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 1500 ms epochs, including a 200 ms baseline before stimulus onset and a 1300 ms interval after stimulus onset for ERP averaging. ERPs were corrected relative to the 200 ms pre-stimulus baseline and then extracted by creating individual averages for each electrode in each condition.

2.5. Data analyses

2.5.1. Behavioral data

Correct responses in the old and different conditions, false alarms (YES to new) and correct response time (RT) were analyzed using a 2×3 repeated measures analysis of variance (ANOVA) with task (inclusion/exclusion) and condition (old/different/new) as within-subject factors. The validity of the counterbalancing in the experimental procedure was checked using an ANOVA with task order (inclusion → exclusion vs. exclusion → inclusion) and block order (first vs. second) as within-subject factors. The ANOVA showed that the counterbalanced factors had no significant effects on the behavioral measure H'c (H'c = %Correct responses in the old and different conditions – %FA): task order, $F(1,23) = 0.91$, $p = .35$, block order, $F(1,23) = 1.84$, $p = .19$, with no interaction between these factors.

2.5.2. EEG data

The analysis focused on spatial regions and temporal epochs, based on visual inspection of the individual curves recorded at midline electrodes Fz and Pz within the 200–1300 ms post-onset range. The temporal windows corresponded to those in previous studies of ERP old/new effects: the mid-frontal old/new effect (FN400) and the late positive complex (LPC). These peaks consisted of an N400 (mean peak latency = 389.2, SD = 41.2; latency window = 300–480 ms) and a late positive complex (mean peak latency = 787.4, SD = 45.3; latency window = 600–1000 ms). Amplitudes were quantified with respect to the baseline within each time window.

For the recognition ERPs, the mean voltage of correct responses in each temporal window was analyzed separately for frontal and parietal regions, using repeated-measures ANOVAs ($\alpha = .05$) with task (inclusion/exclusion) and condition (old/different/new) as within-subject factors.

The FN400 was analyzed over anterior channels. The model included task (inclusion vs. exclusion), condition (old/different/new), and electrode site (F3, Fz, F4) as within-subject factors. The parietal old/new effect was analyzed over the three posterior locations (P3, Pz, P4) in addition to anterior locations (F3, Fz, F4), with the same model. ERP waveforms created by averaging the ERPs within each electrode and across subjects are shown in Fig. 2. Table 1 shows the mean number of correct artifact-free trials in each experimental condition, depending on the task instructions.

Repeated measures ANOVAs with significant interactions involving the task factor were followed up by planned comparisons in order to clarify the effect of condition in each task. The Geisser-Greenhouse correction was applied to correct for violations of the assumption of the homogeneity of covariance in within-subject ANOVAs with more than two levels. These ANOVA results are reported here as follows: uncorrected *df* values, *F*-value, the epsilon value, and the epsilon-corrected *p*-value. Only significant interactions between site and the experimental factors (task or condition) are presented in the results. The partial eta squared (η^2) statistic was used to determine the magnitude of the effects for all significant, single *df*, a priori tests, because these outcomes were central to the study aims.

3. Results

3.1. Behavioral performance

The behavioral data are summarized in Table 2. ANOVAs indicated more correct responses on the inclusion task than on the exclusion task in the old condition, $F(1,23) = 5.52$, MSE = 0.012, $p = .028$, and the different condition, $F(1,23) = 55.29$, MSE = 0.009, $p < .0001$. No task effect was found on false alarms, $F(1,23) = 0.48$, MSE = 0.008, $p = .49$, showing no difference in response bias induced by the task instructions. The ANOVA also revealed a task-by-condition interaction, $F(2,46) = 19.37$, MSE = 0.008, $p < .0001$. A contrast analysis showed that the expression change caused performance to drop, both in the inclusion task, $F(1,23) = 4.86$, MSE = 0.009, $p = .038$, and in the exclusion task, $F(1,23) = 67.54$, MSE = .013, $p < .0001$, but the decrease in correct responses in the different condition was greater for the exclusion

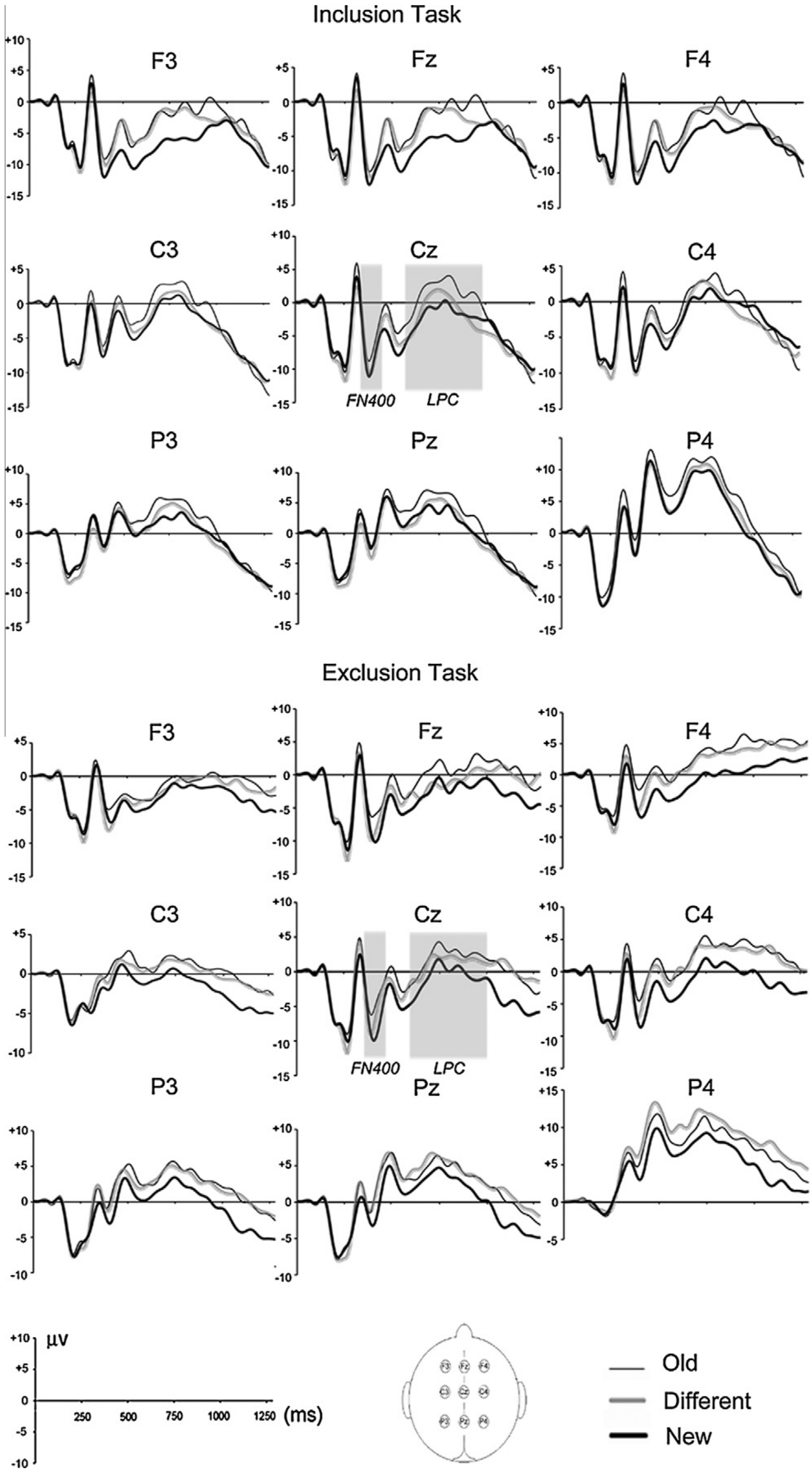

Fig. 2. Grand-average ERPs corresponding to correct responses in the old, different, and new conditions on the inclusion (upper) and exclusion (lower) tasks. The waveforms shown are from the three midline scalp locations (Fz, Cz, and Pz) and the selected lateral locations on the frontal (F3: left fronto-central, F4: right fronto-central), central (C3: left central, C4: right central), and parietal (P3: left parietal, P4: right parietal) electrodes.

Table 1
Mean number of correct response ERP trials in each condition.

	Inclusion task		Exclusion task	
	Mean number of trials	Range	Mean number of trials	Range
Old	29	23–36	27	21–35
Different	26	19–35	21	15–31
New	61	51–74	60	49–72

Table 2
Summarized behavioral data: Correct responses in the old and different conditions and false alarms (Yes to New) mean rates (M), correct-response times (RTs), and corresponding standard deviations (SDs) depending on the task—with PDP estimates of recollection (R estimate) and familiarity (F estimate).

Condition	Inclusion		Exclusion	
	M	SD	M	SD
Correct responses				
Old	0.80	0.08	0.71	0.16
Different	0.72	0.06	0.57	0.13
False alarms				
New	0.14	0.11	0.15	0.12
Correct responses RT (ms)				
Old	1679	303	1939	388
Different	1826	359	2083	337
New	1708	342	1720	349
R estimate[a]	0.37			
F estimate[a]	0.68			

[a] The process dissociation procedure (PDP) provides estimates of recollection (R) and familiarity (F) by comparing inclusion and exclusion scores. R and F estimates were computed using the following PDP equations: (1) R = *p*(YES to Old) Inclusion–*p*(YES to Different) Exclusion, and (2) F = *p*(YES to Different) Exclusion/(1 − R).

Table 3
Follow-up contrasts for mid-frontal FN400 and late ERP old/new effects.

	Inclusion task		Exclusion task	
	$F(1,23)$	p	$F(1,23)$	p
Mid-frontal old/new effect (FN400)				
Old/new	11.05	.003**	10.36	.004**
Old/different	4.42	.047*	9.25	.006**
Different/new	5.31	.031*	1.91	n/s
Late parietal old/new effect				
Old/new	14.03	.001**	7.62	.011**
Old/different	7.23	.013*	1.22	n/s
Different/new	4.81	.039*	9.15	.006**
Late frontal old/new effect				
Old/new	11.36	.003**	7.82	.01*
Old/different	2.13	n/s	1.43	n/s
Different/new	8.27	.009**	7.16	.013*

* Differs from zero at $p < .05$.
** Differs from zero at $p < .01$.

task than for the inclusion task, $F(1,23) = 24.25$, MSE = 0.017, $p < .0001$.

The ANOVA on reaction times revealed a task-by-condition interaction, $F(2,46) = 8.24$, $p < .001$, with a slower reaction time on the exclusion task than on the inclusion task in the old condition, $F(1,23) = 11.8$, $p = .002$, and in the different condition, $F(1,23) = 13.02$, $p = .002$, but not in the new condition, $F(1,23) = 0.03$, $p = .86$. Expression change increased reaction time on the inclusion task, $F(1,23) = 13.15$, $p = .0015$, but not on the exclusion task, $F(1,23) = 3.78$, $p = .064$, suggesting similar processing times in the old and different conditions for the exclusion task.

Jacoby's PDP may be used only if the postulate of response-bias (YES to new) invariance across the inclusion and exclusion tasks is satisfied, which was the case in the present study. The results obtained indicated that familiarity played an important part (0.68) in the tasks proposed here (see Table 1). For the participants as a whole, the PDP estimate of F was higher than the R estimate, $t(23) = -6.05$, $p < .0001$.

3.2. ERP results

Fig. 2, where grand average ERPs at representative electrodes are shown separately for the inclusion and exclusion tasks in the midline and lateral locations, gives the ERPs for correct responses in each experimental condition. This figure shows two main peaks similar to those previously reported in recognition tasks using unfamiliar faces (e.g., Kayser et al., 2010; Yovel & Paller, 2004) and corresponding to the ERP recognition effects usually described in the literature.

3.2.1. FN400 time window (300–480 ms)

If the FN400 is related to familiarity, then it should be more negative for correct rejections than for correct recognitions in the old and different conditions, as normally observed. The FN400 in the different condition should represent an intermediate task-sensitive level of familiarity. The ANOVA in the FN400 time window resulted in a task-by-condition interaction, $F(2,46) = 5.26$, $\varepsilon = 0.73$, $p = .028$, suggesting that the effect of condition was different in each task. On the inclusion task, the new condition was more negative than the old, $F(1,23) = 11.05$, $p = .003$, $\eta^2 = .24$, and different, $F(1,23) = 5.31$, $p = .031$, $\eta^2 = .16$, conditions. Correct recognition ERPs were more negative in the different than in the old condition on this task, $F(1,23) = 4.42$, $p = .047$, $\eta^2 = .15$. As shown in Fig. 2, things were quite different on the exclusion task, where the different condition was more negative than the old condition, $F(1,23) = 9.25$, $p = .006$, $\eta^2 = .27$, and the new condition was more negative than the old one, $F(1,23) = 10.36$, $p = .004$, $\eta^2 = .29$, but the amplitudes in the different and new conditions did not differ significantly from each other, $F(1,23) = 1.91$, $p = .18$. Table 3 presents all follow-up contrasts on the mid-frontal FN400 and the late ERP old/new effects and Fig. 3 shows corresponding mean ERP amplitudes (averaged over all frontal and parietal sites) in each condition depending on the task-processing context.

3.2.2. LPC time window (600–1000 ms)

3.2.2.1. Parietal old/new effect. A separate ANOVA on posterior locations resulted in a task-by-site interaction, $F(2,46) = 9.02$, $\varepsilon = 0.81$, $p = .005$. ERPs elicited on the exclusion task were more positive than those elicited on the inclusion task in the right hemisphere (P4), $F(1,23) = 6.59$, $p = .017$, $\eta^2 = .22$ (see Fig. 2). The ANOVA also revealed a task-by-condition interaction, $F(2,46) = 7.49$, $\varepsilon = 0.78$, $p = .01$, suggesting that the condition effect was different in each task. On the inclusion task, compared to correct rejections of new faces, correct recognition ERPs were more positive in both the old, $F(1,23) = 14.03$, $p = .001$, $\eta^2 = .29$, and the different, $F(1,23) = 4.81$, $p = .039$, $\eta^2 = .16$, conditions. Correct recognition ERPs were more positive in the old than in the different condition on this task, $F(1,23) = 7.23$, $p = .013$, $\eta^2 = .21$. On the exclusion task, correct response ERPs were again more positive in both the old, $F(1,23) = 7.62$, $p = .011$, $\eta^2 = .21$, and the different, $F(1,23) = 9.15$, $p = .006$, $\eta^2 = .24$, conditions, as compared to the correct rejections of new faces. By contrast, the amplitudes in the old and different conditions did not differ significantly from each other, $F(1,23) = 1.22$, $p = .28$. Hence, the parietal old/new effect was found in both tasks and for all recognized faces, but the amplitudes of hits associated with old and different faces did not differ significantly on the exclusion task.

3.2.2.2. Frontal old/new effect. A separate analysis on the frontal sites yielded a significant effect of task. ERPs elicited on the exclu-

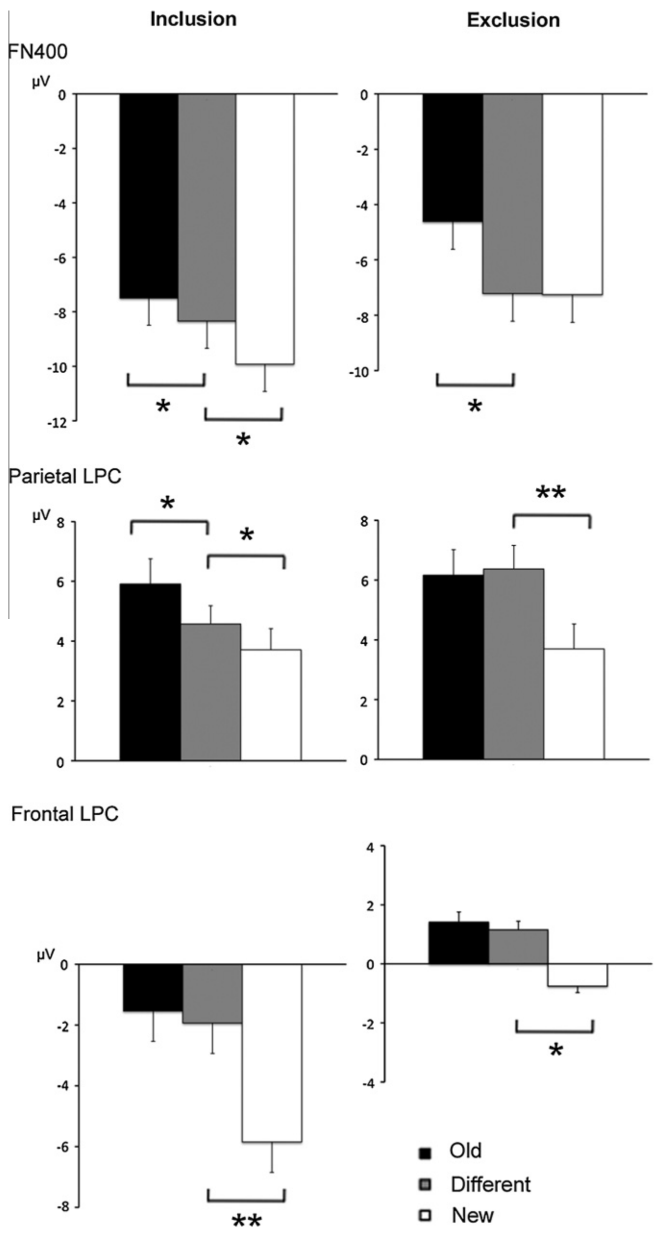

Fig. 3. Mean ERP amplitudes on the mid-frontal FN400 and the late ERP old/new effects (averaged over all frontal or parietal sites) for correct responses to old, different, and new conditions, depending on whether the task was the inclusion (left) or exclusion (right). Error bars represent the SEM (* denotes a significant difference relative to the different condition at $p < .05$; ** differs from zero at $p < .01$).

sion task were more positive than those elicited on the inclusion task, $F(1,23) = 7.13$, $p = .014$. The ANOVA revealed a significant effect of condition, $F(2,46) = 6.98$, $\varepsilon = 0.84$, $p = .012$, with no interaction between task and condition. Compared to correct rejections of new faces, ERPs on hits were more positive in both the old, $F(1,23) = 12.23$, $p = .002$, $\eta^2 = .23$, and the different, $F(1,23) = 8.53$, $p = .008$, $\eta^2 = .20$, conditions, with no significant difference between these two conditions, $F(1,23) = 2.61$, $p = .12$.

4. Discussion

The process-dissociation procedure (PDP) was used in conjunction with study-test similarity to distinguish between conscious and automatic memory processes related to recollection and familiarity, respectively. The objective was to measure the impact of the participants' cognitive orientation and the match/mismatch status of the expression, on the ERP correlates of face recognition. A comparison of the inclusion and exclusion tasks allowed us to manipulate the status of the mismatched expression according to the task at hand. Although perceptual as well as conceptual matching does not differ between the two tasks, the relevance of the study-test mismatch does. In the exclusion task, if conscious recollection of the face-expression combination fails, automatic processes related to familiarity will cause the subject to incorrectly respond "old" to a face that should be excluded. In contrast, a mismatched expression has to be ignored for a correct recognition decision in the inclusion task. Consistent with the dual-process framework, the present results showed that participants performed better on the inclusion task than on the exclusion task, whereas no difference between the two tasks was seen on false recognitions. At the same time, they revealed that participants were able to exclude similar faces whose expression had changed. This finding suggests that there was no difference in response bias between the two tasks, which is a prerequisite for the validity of the PDP estimates showing that familiarity is more involved than recollection in the face-recognition tasks proposed here.

The well-known ERP old/new effects were found again in the present study. The larger parietal LPC elicited in the exclusion task than in the inclusion task is in line with previous work showing that the parietal old/new effect reflects the implementation of controlled memory processes related to the retrieval of contextual details (Curran & Hancock, 2007; Senkfor & Van Petten, 1998; Stenberg, Johansson, & Rosen, 2006), including in the case of an exclusion task (Herron & Rugg, 2003). However, according to our hypotheses, an expression change modulates ERP old/new effects differently in each task. Modulations of the FN400 old/new effect were proportional to the degree of matching between the study face and the recognition face on the inclusion task. FN400 was larger in the different condition compared to the old one, but the old/new recognition effect was spared between different and new faces on this task. These results are in line with the proposal that the FN400 old/new effect reflects a continuous recognition signal with respect to the degree of matching between study and test (Finnigan, Humphreys, Dennis, & Geffen, 2002; Groh-Bordin et al., 2006; Münte et al., 1998; Yovel & Paller, 2004; Zimmer & Ecker, 2010). Similarly, a significant difference was observed on the parietal old/new effect in the old as compared to the different condition. It is as if, in the inclusion situation, the parietal old/new effect—like the FN400—reflects the matching level between the faces. This finding is consistent with recent studies showing that the parietal old/new effect reflects familiarity in the face-recognition domain (MacKenzie & Donaldson, 2007, 2009).

On the other hand, when the expression had to be "diagnosed" to achieve correct performance (exclusion task), the FN400 old/new effect was no longer found in the different condition despite equivalent familiarity strength. In the exclusion task, the modulations obtained on FN400 no longer reflected the degree of matching between the memory trace and the picture presented. In this situation, the FN400 elicited on correctly rejected faces with a new expression (different) were not significantly different from the FN400 elicited on correct rejections of new faces, despite the preservation of the face's identity. It seems that by indicating what information is relevant, the processing context pre-determines the FN400 old/new effect by setting a different criterion for face matching in each task: physically identical pictures (exclusion) vs. face identity (inclusion). When the slightest perceptual change on the face was a criterion for exclusion, modulations of the FN400 old/new effect no longer reflected familiarity as a continuous signal but rather as an absolute, all-or-none signal, proper to the exclusion task. The processing context thus seems to constitute a variable that adjusts the neurophysiological processes of recognition. Here too, the parietal old/new effect indexed both a continuous and an all-or-none process, depending on the task at hand. This was not the case for the late frontal old/new effect, for which all correctly recognized faces involved more positive amplitudes than did new faces, to an equal extent in both tasks. The larger LPC observed in the exclusion task than in the inclusion task, and the absence of a significant difference between the old and different conditions in each task, support the view that the late frontal old/new effect reflects decisional processes common to both experimental situations rather than corresponding to processing dedicated to the evaluation of the products of an episodic retrieval attempt (e.g., Hayama et al., 2008).

As stated in the introduction, multiple groups of investigators agree that amplitude reductions in FN400 potentials occur in conjunction with the memory experience of familiarity (Düzel, Yonelinas, Mangun, Heinze, & Tulving, 1997; Rugg & Curran, 2007; Tsivillis et al., 2001). However, there appear to be inconsistencies in the different authors' conceptions of familiarity. An intuitively appealing conception of familiarity experiences is that they are supported by the same sort of unconscious processes that support priming in implicit memory tests (e.g., fluent perception, conceptual priming). Familiarity is thus generally thought to be an automatic context-independent process and a continuous signal that is proportional to the number of features shared by the target and the memory trace. Paller et al. (2007) contend that conflicting results come from the fact that unfamiliar face stimuli provide a richer facial meaning of a conceptual nature (with, for example, associations to concepts like class, race, and personality), thus engaging more conceptual activation for repeated faces as compared to new ones. On the other hand, in line with the idea that the FN400 old/new effect is dependent on the nature of the representations that underlie the stimuli, diverging results with previous face recognition studies may be due to the nature of the face-context association. In the Curran and Hancock study (2007), retrieval was not oriented toward perceptual features but rather toward conceptual information associated with the face (occupation). Moreover, the associated occupation was not reintroduced on the test, making it difficult to assess the study-test mismatch effect. The present results are in line with a previous study showing that when subjects were told to accept as "old" only the exact exemplar studied—and one that thus focused on the perceptual study-test match—"same" exemplars elicited an FN400 old/new effect but "different" exemplars did not (Ecker & Zimmer, 2009). A single-strength continuum cannot alone explain the differential mismatched-expression effect observed in the two tasks carried out here. Correct recognition required inhibiting the expression change on the inclusion task, which called for a ternary decision (recognize repeated faces with the same expression, recognize repeated faces despite a mismatched expression, and reject new faces), whereas on the exclusion task, all perceptual differences induced the same behavioral response (accept perfect study-test match, reject any perceptual change), which called for a binary decision. The task-processing context thus appears critical in determining which unit is attended to and is used as a memory cue. This evidence indicates that the early neurophysiological correlates of retrieval processing depend on voluntarily task-related control. While the FN400 old/new effect reflects perceptual congruity (e.g., Curran & Hancock, 2007; Groh-Bordin et al., 2006), this matching effect appears to be dependent on the task being performed.

The present findings add to the body of evidence questioning the hypothesis that the FN400 old/new effect is related to conceptual priming (Paller et al., 2007; Voss et al., 2012) or familiarity defined as an automatic process related to study-test matching. They suggest that one way to reconcile the findings of FN400 old/new effects is to conclude that task demands can promote reliance on assessments of either relative or absolute familiarity. Indeed, early recognition processes reflected by the FN400 were modulated by the task-processing context and the diagnostic vs. non-diagnostic nature of the mismatched expression, yet conceptual as well as perceptual priming is theoretically unaffected by the task demands. In line with recent work showing that FN400 is functionally distinct from the N400 (Bridger, Bader, Kriukova, Unger, & Mecklinger, 2012), this finding challenges the position that the FN400 indexes only automatic memory processes such as conceptual priming. A similar interpretation may be advanced in the light of the proposal that the parietal old/new effect reflects a recollection or recall-like process. While our findings support the idea that recollective experience is associated with widespread, maximum parietal positivity, they cast serious doubt on the position that this recollective experience and the corresponding ERPs are homogeneous in every situation. The expression change did not modulate the parietal old/new effect in the exclusion task either, but the old/new effect was still found for the set of all correctly recognized faces. On the exclusion task, the absence of modulations linked to the expression change can be explained by the fact that diagnosing the status of the expression was necessary in every condition where the face was recognized, regardless of what that status was. Hence, if both FN400 and parietal old/new effects reflect study-test matching and familiarity as a continuous signal in the inclusion task, there is no ERP old/new effect that reflects face familiarity as a global matching signal in the exclusion task.

5. Conclusions

According to global matching models of memory (e.g., Norman & O'Reilly, 2003), familiarity is an assessment of the overall similarity between a test item and all study-list information in memory. By manipulating the similarity of the studied and tested faces, we obtained clearly different results across situations for the condition where old faces had a new expression. However, the task-processing context did not change the perceptual or conceptual characteristics of the material, only the relevance of the study-test match in the memory judgment. In the critical comparison between the FN400 old/new effect for different faces in the inclusion and the exclusion conditions, familiarity was constant. Thus, the present results show that the FN400 old/new effect does not reflect familiarity as a continuously varying signal in all situations. Modulation of the FN400 old/new effect by the task instructions, while perceptual and conceptual priming were kept constant, suggests that this early ERP component is related not only to automatic memory processes, as suggested by global matching models, but also to the task-processing context. The extent to which the FN400 discriminates between conditions depends on retrieval orientation at test. Further investigations are needed to find out whether this task instruction effect can be generalized to other types of material with different binding properties.

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