

Research report

Electrophysiological study of contextual variations in a short-term face recognition task

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Abstract

Event-related potentials (ERPs) were recorded during two short-term recognition tasks using unfamiliar faces. These experiments are based on the process dissociation procedure (PDP), whereby the exclusion criterion was an intrinsic context or extrinsic context, the facial expression (Experiment 1) or background (Experiment 2), respectively. The results indicate that retrieval orientation, in addition to extensive strategic control, affects both the frontal (N250) and temporoparietal (P3b) components. Furthermore, these data indicate that an early frontal modulation interacts between processing that bears on the face (interactive intrinsic context) and processing that bears on two objects at the same time (interactive extrinsic context), in which, in the latter case, that the background change led to an early modulation at the frontal sites in the left hemisphere. These results are consistent with the idea that frontal effects reflect differences in the nature of the information during retrieval and postretrieval processes involved. Furthermore, that the left posterior repetition effect appears to be a manifestation of the retrieval of relevant contextual information that perturbs the recognition decision, whereas the right posterior repetition effect reflects to be the outcome of the retrieval of the face as a whole. Finally, results are in concordance with the hypothesis that the difference during recognition with or without source memory may be in the strength of the relationship between the target and the contextual information to be retrieved. In essence, that automatic and controlled processes in a given context depends on both task-related and target-related constraints. © 2004 Elsevier B.V. All rights reserved.

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1. Introduction

Face perception and face recognition are extremely fast and automatic processes that enable us to identify a given person among a large group of individuals in everyday situations. These cognitive abilities depend on many different kinds of contextual, biographic and episodic information, such as the person's emotional expression, social status and the spatiotemporal context in which he/she has been encountered in the past. Dual-process theories of memory

posit that recognition judgments can be based on two distinct processes: familiarity and recollection [35,37,46,65]. Familiarity is generally thought to reflect an assessment of perceptual similarity between studied and tested items [29,49]. Recollection or search process entails the retrieval of specific information about studied items, e.g. physical attributes [35]. Face recognition provides a classical example of this distinction between recollection and familiarity because we have all had experience of knowing a face is familiar despite the inability to recollect details such as person's name or the circumstances in which we have seen him/her before [46]. These depictions raise the possibility that one may selectively orient attention towards different aspects of mnemonic information.

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From the visual standpoint alone, a distinction can be made between different kinds of perceptual context during recognition of a face: the intrinsic context that provides information that is an integral part of the face (e.g., facial expression) and the extrinsic context that provides information in a more or less arbitrary way (e.g., the place where the person was seen, which constitutes the “background”) [3,54,60]. The intrinsic context can be defined as the set of all visual characteristics that are automatically integrated onto the face into which, together with the face, form a unit. In contrast, the extrinsic context includes aspects of the environment independent of the face but may be visually associated with it. It is important to note that the perceptual context, as defined here, is relative to the information conveyed by the target event itself.

Another important distinction in context is that, in some cases, it does not involve the situational relationship between the context and the target but concerns the specific type of processing the subject performs on the target to accomplish a given task. Thus, “processing context” depends on the instructions given to the subject prior to the task rather than the information conveyed by the target event itself. The part of the context that is essential to perform a task is called “interactive,” whereas the part of the context that is not essential for execution of the task is called “independent” [3,4,16]. Interactive context determines how the participant encodes the information, and independent context refers to the environment surrounding the presentation of an item (external such as physical surrounds).

Although processing context and perceptual context can occur together in different combinations, they should not be confused with each other. For example, during face recognition, the specific type of processing that defines interactive contextual information may possibly be applied to intrinsic or extrinsic visual context. A dual role for contextual information in affecting recognition via influences on the evaluation of familiarity and the retrieval of an item has since been proposed [60]. That is, both the familiarity of the context and the item may contribute to the familiarity estimate, and contextual cues can also be used to guide the search process. Using the process dissociation procedure (PDP), Yonelinas and Jacoby [66,67] expressed a similar view that variations in context may affect memory for an event via both automatic and consciously controlled influences.

The PDP uses two tasks (inclusion and exclusion) wherein automatic and conscious processes either support or oppose each other. In the inclusion task, subjects accomplish an old/new judgment, whereas during the exclusion task, they have to recognize the item and the study list where the old item has been presented (recognize items which were presented in list A for example). If recollection fails, familiarity will cause the subject to respond incorrectly to lure items during the exclusion task (old item presented in list B). In the present experiment, a perceptual manipulation was conducted on face. Thus, the decision for rejecting responses to old faces is based on retrieval of information about the target per se rather

than list membership (PDP) during the exclusion tasks. This distinction may be important considering suggestions that different types of contextual features of an event may involve different memory processes [12].

It seems, crucial in attempting to understand the cognitive processes underlying face recognition, to take into account the exact nature of the task being performed on the target face and its perceptual context. Gaining insight into this problem was the goal of the present study. Dual-process dissociation procedure and different definition of context may allow us to approach more specifically (1) the impact of contextual information and (2) how this information is implemented and retrieved in terms of cognitive processes and brain mechanisms involved.

We know that, during the short-term recognition of unfamiliar faces, performance may be altered by variations in luminosity, point of view and/or facial expression and also differences in the objects surrounding the faces [33]. The foregoing findings are generally consistent with the idea that recognition can be attributable at least in part to the facilitation of perceptual processes (familiarity). The study of the impact of these contextual variations on behavioral indexes can be supplemented by the study of the associated event-related potentials (ERPs) in an attempt to uncover the electrophysiological correlates of face recognition in a temporally precise way.

During face recognition, temporoparietal N170, whose principal generator is thought to be the fusiform gyrus [40,47], is acknowledged as an indicator of face-specific categorization processes [27]. This early component (between 150 and 200 ms) seems to be related to the final steps of structural encoding stage of face processing described in the functional architecture of Bruce and Young model [11], when the configural representation of the face is generated for use during recognition [21,22]. This ERP component related to the detection/structural encoding of a face is likely to be mediated by posterior lateral occipito-temporal cortex. On the other hand, N170 is apparently not the best indicator of the processes at play in repetition priming and recognition [8,9]. It is more often on the later ERP components that the impact of memory processes has been demonstrated.

Numerous studies have investigated the neural correlates of the repetition of stimuli such as words or pictures in both direct and indirect memory test. Most of these studies employed event-related potentials to detect these correlates [for review, see Ref. [24]]. With few exceptions, these studies have investigated the neural correlates of recognition while holding constant the context in which the experimental items were experienced. Repetition effect, positive shift in ERP that occurs when stimuli are repeated, is classically observed on recognition tasks whether the items to be recognized are faces or verbal material [2,41]. During face recognition, old items as compared to new ones are associated with an increase in positivities at parietal sites after 300 ms [5,57,62]. This parietal repetition effect may

reflect changes in cortical activity brought about by cortico-hippocampal interactions thought to constitute the substrate of episodic information retrieval [48]. Repetition effect observed during picture matching or short-term recognition tasks is the functional equivalent of the so-called old/new effect in long-term recognition tasks, which reflects the reactivation of memory representation. It is therefore interpreted as an index of the activation of a (temporoparietal) working memory system under the influence of frontal structures [50]. These ERP memory effects also appear to be related to decision-making and/or response-related factors and contextual variations [2,26].

The trends in ERP studies of memory are now to investigate the cognitive and brain correlates of the various components identified during the last years, particularly over the frontal regions. During face recognition and face matching tasks, the frontal repetition effect is manifested by an increase in the amplitude of the early frontal negativity on new faces as compared to old ones [6]. The influence of strategic control on this early effect has already been demonstrated for short-term recognition of faces [55] and verbal material [63]. This early frontal negativity also appears to have higher amplitude when retrieval is conscious rather than automatic [45]. Moreover, it has become clear that these components are affected by contextual information. For example, contextual variations, even if they are irrelevant to the task at hand (context-independent), affect this component during the short-term recognition of unfamiliar faces [30].

A late frontal positive wave, which lasts longer than the parietal repetition effect, has also been reported to distinguish between old and new items during retrieval tasks [18,62]. Allan et al. [2] have interpreted these results in terms of retrieval and postretrieval processes, with the parietal effect representing the retrieval of episodic information and the frontal effect reflecting the evaluation or use of the retrieved information. This late positive component observed principally on the right fronto-central regions is particularly evident in tasks involving source retrieval [64]. It is thus thought to reflect strategic memory processes [2] or more specifically the goal-directed integration of the intrinsic attributes of items [32]. Two sources of evidence can be brought to bear on the question of the origin of this effect, which converge to suggest that it reflects neural activity originating from right prefrontal cortex [23].

The recent development of topographic ERP studies has made it possible to dissociate a fronto-central effect (FC) and an early bilateral frontopolar effect (FP) during recognition [13,17]. This topographical dissociation may be the key in the near future in reconciling the different interpretations by speaking of several rather than one frontal effect. Tasks involving explicit retrieval of extrinsic contextual information seem to trigger an FP effect but not an FC effect. Noteworthy, tasks involving the retrieval of extrinsic contextual information (e.g., recency) seem to elicit the FP effect but not the FC effect [59]. Thus, the FP

effect may depend more on the type of information retrieved than on the recognition processes implemented. This frontal ERP effect have been described during unfamiliar faces recognition [32]. On the other hand, the FC effect has been described in memory exclusion task [63]. In such tasks, a list context has been shown to affect both the perceptual identification and episodic retrieval [38]. Metabolic imagery studies reach to similar dissociation. Some authors have hypothesized that the right prefrontal cortex (PFC) supports judgments based on readily accessible information (familiarity and perceptual details), whereas the left PFC (or both) is (are) implicated in judgments requiring a finer analysis of stored information and the evaluation of additional information [42].

As a whole, the results obtained on ERPs suggest that the underlying processes are highly sensitive to the task being carried out [19]. The type of context to be retrieved and its relation with the target appear to be another critical variable for proposing a functional interpretation of the observed effects [see also [32]]. This would seem to imply that recognition is not uniform from the functional and neurophysiological standpoints and probably accounts for the observed discrepancies between the different functional interpretations. But above all, it points out the need to conduct more in-depth research into how context affects behavioral and neurophysiological measures of recognition. It will be of interest, since context is a crucial point in most models of recognition memory, to determine whether recognition employ qualitatively different retrieval processes or whether instead if they differ with respect to processes that act upon retrieved information.

The intrinsic/extrinsic opposition used in the present experiment describes the perceptual relationship between the context and the target. In the former case, contextual information is an integral part of the target (e.g., facial expression); in the latter, contextual information is associated with the target in an arbitrary way only (e.g., the background). The interactive/independent opposition applies to the context of the processing done by the subject in accordance with the specific instructions of the task. In the former case, contextual information must be taken into account to perform the task (e.g., recognizing a face with its expression or with its background); in the latter case, contextual information is not needed for processing and can be ignored (e.g., recognizing a face no matter what expression or background it has). Depending on the task defined in the instructions then, the context can be intrinsic and interactive, intrinsic and independent, extrinsic and interactive or extrinsic and independent. Repetition effects and retrieval orientation during face recognition should thus be affected by both of these types of context and by their interaction.

The general hypothesis tested here is that the processing context (interactive vs. independent) defined by the task instructions should affect the explicit orientation of memory

retrieval, and that these explicit processes have a specific impact on the frontal and parietal repetition ERP effects described above. A change in an interactive context between the encoding phase and the test phase should always hinder recognition whether that context is intrinsic or extrinsic (e.g., increased reaction time). This change should therefore modulate the ERP repetition effect. Furthermore, interactive context and attentional demand should have a weighty influence on the early ERP components (parietal N170 and frontal N250) compared to the independent context, which is contingent to the task.

On the other hand, the nature of the perceptive contextual information that needs to be retrieved during recognition should affect these ERP effects and particularly their distributions. For example, it is possible that the nature of the perceptual information that needs to be retrieved (intrinsic vs. extrinsic context) influences the frontal N250. Considering the frontal and parietal repetition effects, controlled retrieval of contextual information extrinsic to or arbitrary associated with the face should be more lateralized on the left hemisphere due to the greater and more focal attention. When the context is intrinsic and interactive (experience 1), memory retrieval is necessarily directed at a contextual information that is part of the face and should therefore modulate both the frontal components of the ERPs—reflecting strategic control known to occur during exclusion tasks—and the temporoparietal repetition effect—known to be involved in face recognition. When the extrinsic context is the interactive one (experience 2), an additional left frontal effect should be observed—specific to the extrinsic context retrieval and the increased of attentional demands.

2. Materials and methods

The situation studied was a short-term recognition task on unfamiliar faces derived from the PDP [37]. The exclusion criterion was an intrinsic perceptual context, i.e., the facial expression (Experiment 1), or an extrinsic perceptual context, i.e., the background (Experiment 2). In the first experiment, the intrinsic context (expression) was interactive, whereas the extrinsic context (background) was independent. In the second experiment, the extrinsic context (background) was interactive, whereas the intrinsic context (expression) was independent.

Controlled memory retrieval processes (e.g., retrieval interactive information) should be implemented in different ways, depending on whether or not the target context is consciously retrieved and on whether it is or is not an integral part of the face. To test these hypotheses, all facets of the experimental procedure were held constant except the instructions that defined the target context (expression or background) in this exclusion type of recognition task.

2.1. Participants

Sixteen healthy, right-handed university students (seven females and nine males; mean age 26.3 years old, SD 4, 1) participated in the experiment. Data of two participants were discarded due to an excessive number of trials with artifacts (eye blinks). All subjects performed both exclusion tasks, and the testing order of the tasks was counterbalanced across participants.

2.2. Stimuli

The stimuli consisted of digitized black-and-white photographs of young adult Caucasians without distinctive facial features and carefully edited to maintain a standard brightness and contrast. Faces were superimposed on landscape scenes (32 different landscapes). In the foreground of each picture, there was an unknown face with a happy or neutral expression. The background was one of 32 different landscapes consisting of views of mountains, waterfalls, beaches, forests etc. of which none depicted buildings, people or animals. Landscapes were easily discriminated from each other. Different sets of stimuli vary in the allocation of faces to landscapes and face–landscape or face–expression combinations to experimental conditions. All were counterbalanced across subjects. Each set consisted on 64 faces repeated two times and 128 faces presented one time (distracters) for an average of 128 trials per experiment. For each participant, faces presented in one task were not presented again in the other task. The stimuli were presented on a black computer screen using a delayed matching paradigm. All images were presented in the middle of the screen with a visual angle of approximately $5.5 \times 4^\circ$.

2.3. Experimental design

Each trial began with a fixation point (lasting 1500 ms). Then the first picture (study) was presented in the center of the screen for a period of 200 ms followed by a mask (noise) for the 1000 ms that preceded the second picture (test) for 200 ms. After a 2500 response interval, the next trial began.

There were four successive blocks of 32 trials and eight categories: (1) same face, same expression, same background (physically identical picture); (2) same face, same expression, different background; (3) same face, different expression, same background; (4) same expression, different expression, different background; (5) different face, same expression, same background; (6) different face, same expression, different background; (7) different face, different expression, same background; and (8) different face, different expression, different background. A total of 128 trials were presented during each experiment (16 per condition): 64 repeated faces (32 with “same” or “new” expression; 32 with “same” or “new” background) and 64 nonrepeated faces (32 with “same” or “new” expression; 32

with “same” or “new” background). Each pair of pictures, presentation and task order was counterbalanced across participants.

During the two exclusion tasks, participants were instructed to make affirmative recognition judgments only for face tested with the same perceptual interactive context (expression or background; 32 trials) and to reject any face with new interactive perceptual features (32 trials) or completely new face (64 trials). In Experiment 1 (expression-based recognition), the subject’s task was to decide whether the test face was the same as the studied face and if the expression was the same while at the same time ignoring the background. In Experiment 2 (background-based recognition), the subjects had to decide whether the test face was the same as the study face and if the background was the same without paying attention to the expression. The responding hand was counterbalanced across participants. All participants were instructed to answer as quickly and accurately as possible and to blink after responding. Reaction time (RT) and frequency of the correct responses were calculated in each condition. Statistic analysis was carried out in a factorial analysis of variance with two types of face (old or new) \times 2 expressions (same or different) \times 2 types of background (same or different), ANOVA with repeated measures (all variables). All of the variables and the order of stimulus presentation were counterbalanced across participants.

2.4. EEG/ERP methods

High-density event-related potentials (ERPs) were recorded for each participant using a 64-channel Geodesic Sensor Net™ (GSN) [61] connected to AC-coupled, 64-channel, high-input impedance amplifier (200 M Ω , Net Amps™; Electrical Geodesics, Eugene, OR), allowing us to fully characterize the scalp topography over the frontal, temporal and parietal regions. Amplified analog voltages (0.01–100-Hz band-pass, –3 dB) were digitized at 500 Hz. Fig. 1 presents the approximately 10–20 International Classification System [39] equivalent on the 64-channel GSN, which has been calculated by EGI using the Fastrack hardware and Locator software. The nearest GSN position was used as an approximate equivalent to 10–20 position to facilitate comparison with results from other laboratories. EEG was continuously recorded and then segmented off-line into epochs of 1200-ms duration, time locked at the onset of the second face, which included a 200-ms prestimulus baseline. Individual sensors were adjusted until the impedances were less than 40 k Ω . EOG was recorded bipolarly from electrodes placed on the outer canthus of the left eye and above the supraorbital ridge of the right eye. Trials were discarded from analyses (4%) if they contained eye movements (vertical EOG channel differences greater than 70 μ V) or more than five bad channels (changing more than 100 μ V between samples or reaching amplitudes over

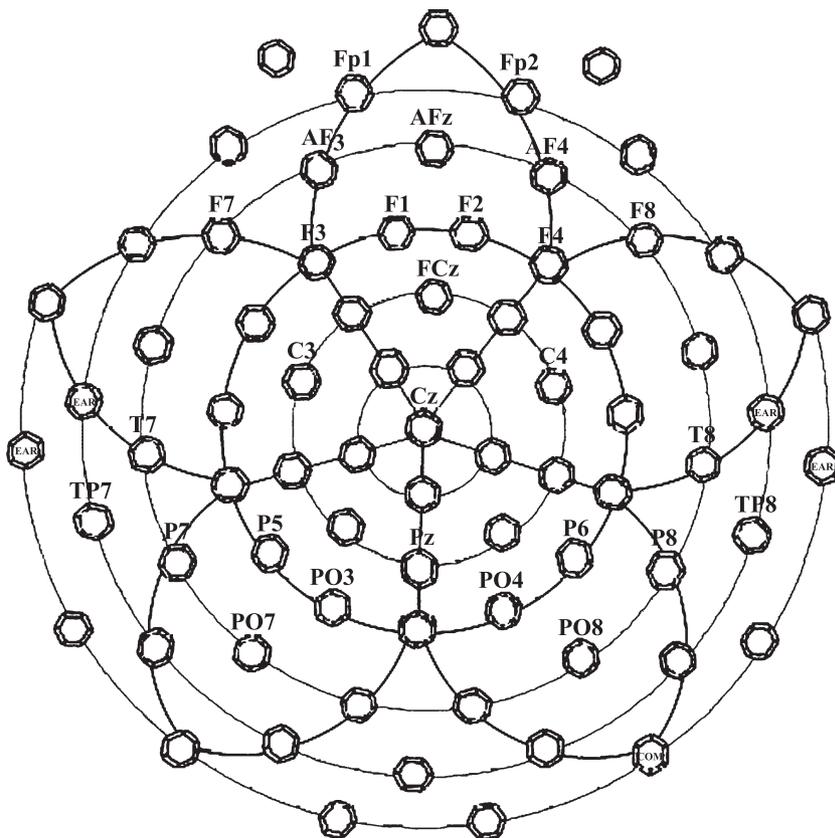


Fig. 1. Layout illustrating the approximate 10–20 equivalent on the 64-channel GSN (geodesic sensor net).

200 μV). ERPs from individual channels that were consistently of poor quality for a given participant were replaced using a spherical interpolation algorithm [58].

The ERPs were baseline corrected with respect to a 200-ms prestimulus recording interval and were digitally low-pass filtered at 30 Hz. EEG was measured with respect to a vertex reference (Cz), but an average-reference transformation was used to minimize the effects of reference-site activity and to accurately estimate the scalp topography of the measured electrical fields [15]. Average-reference ERPs were computed for each channel as the voltage difference between that channel and the average of all channels.

The results were obtained by cutting the EEG segment within several time windows starting at stimulus onset. ERP peaks were identified by visual inspection of the grand average waveforms. Statistical analyses for correct answers were carried out on the 20 electrodes (presented on Fig. 1) by comparing the mean voltage of averaged waveform components in three different time windows (150–200; 200–500 and 500–800 ms) using a repeated measurement ANOVA. To maintain an acceptable signal/noise ratio, only ERPs formed from 14 or more artifact free trials for a given category were accepted for analysis. Different ERP waveforms representing the interaction between face status and perceptual context variation were averaged and plotted in each experiment. These averaged ERPs represented a minimum of 28 trials per participant (after the rejection of incorrect responses) for each waveform plotted. The grand average of old and new face conditions were also computed and plotted in each experiment.

A topographical analysis was conducted on five regions: anterior frontal (Fp1/2, AF3/AF4), frontal (F3/4, F7/8), parietal (P5/6, P7/8), temporal (TP7/8, T7/8) and parietooccipital (P03/4, PO7/8). Separate test condition \times site \times hemisphere (left, right) analyses of variance were conducted on amplitudes averaged of each site. In topographical analyses, degrees of freedom were adjusted using the Geisser–Greenhouse procedure where appropriate to correct for violations of nonsphericity (uncorrected df are reported with epsilon, ϵ values and corrected p values). This analysis of ERPs scalp distribution was conducted in the three-time windows that correspond to specific components based on the peaks identified at visual inspection of ERPs (N170: 150–200 ms; frontal N250 and parietal P350: 200–500 ms and late components: 500–800 ms). Effects involving spatial factors were reported only if they interact with experimental conditions.

3. Results

3.1. Experiment 1: expression-based face recognition

3.1.1. Analysis of correct answers

Table 1 presents the correct answer percent and standard deviation (SD) averaged over the 14 participants for each

Table 1

Mean and standard deviation (SD) of correct answer percent and reaction time (ms) for old faces and new faces by expression (same or different) and background (same or different) in experiment 1 (expression-based face recognition)

Conditions			Correct response (%)	Reaction time (ms)
Face	Expression	Background		
Old	Same	Same	93.9 (8.6)	582 (164)
		Different	92.4 (5.8)	621 (187)
	Different	Same	77.7 (10.8)	666 (175)
		Different	78 (9)	657 (184)
New	Same	Same	98.9 (3.3)	502 (139)
		Different	98.9 (3.3)	499 (143)
	Different	Same	100 (0)	455 (135)
		Different	99.6 (1.5)	467 (130)

type of face (old or new), expression (same or different) and background (same or different). An ANOVA applied to the correct answer percent showed that the three-way face \times expression \times background interaction was not significant. There was a significant two-way interaction between face and expression ($F(1,13)=24.8$, $p<0.0005$), suggesting that the effect of the expression on the correct answer percentage was not the same for new and old faces. Further analysis reveals that a change in expression did not have a significant effect on performance when the face was “new”. In contrast, for “old” faces, the correct answer percentage was significantly lower when the expression was different rather than the same (77.8% vs. 92.6%, respectively; $F(1,13)=43.6$, $p<0.0001$). For the main effects, only the face factor was significant, with performance being superior for new faces than for old ones (99.4% vs. 85.3%, respectively; $F(1,13)=201.5$, $p<0.0001$).

3.1.2. Analysis of correct answer response time

Table 1 indicates that the correct answer response times (RTs) were slower for old faces than for new ones. An ANOVA on correct answer RT showed that the three-way face \times expression \times background interaction was nonsignificant. Only the two-way interaction between face and expression was significant ($F(1,13)=13.6$, $p<0.005$). If we break this interaction down, we find that (1) for an old face, the RT was significantly higher when the expression was different than when it remained unchanged (662 vs. 584 ms; $F(1,13)=8.2$, $p<0.01$), and (2) the RTs had a different pattern for new faces; this time, they were higher when the expression was the same rather than changed (501 vs. 461 ms; $F(1,13)=5.6$, $p<0.03$). As far as the main effects were concerned, the responses were significantly slower when the face was old rather than new (623 vs. 481 ms; $F(1,13)=55.5$, $p<0.0001$), whereas facial expression had no significant main effects.

3.1.3. Electrophysiological data

Regarding the ERPs, separate condition \times site \times hemisphere repeated measures ANOVAs were conducted to assess face repetition and contextual effects. For each

component, the dependent measure was mean voltage in each condition. ANOVA results obtained on the mean ERP amplitude in the expression-based recognition task are summarized in Table 2. Conditions×site×hemisphere interactions are reported only when significant. The global ANOVAs were then followed up by pairwise comparisons to elucidate the spatial distributions of the observed effects.

3.1.3.1. 150–200 ms. Fig. 2 presents the grand average ERPs obtained for old and new faces separately. The mean number of trials per participant used to form these waveforms was 56. Only one component was identified in this early temporal window. As shown in the figures, this negative component (N170) was clearly localized on the posterior regions. Confirmatory analysis on these regions of interest (P5/6, P7/8, T7/8, TP7/TP8, PO3/4 and PO7/8) was then conducted.

Temporoparietal N170. Considering the scalp distribution of the N170, the analysis on the posterior regions resulted in a face×site interaction ($F(5,65)=2.9, p<0.05, \epsilon=0.841$), a reliable expression×site×hemisphere interaction ($F(5,65)=4.3, p<0.01, \epsilon=0.729$) and a main effect of the face ($F(1,13)=9.2, p<0.01$). Contrast analysis of the face×site interaction resulted in a main effect of the change in face on the parietal electrodes (P5, P6, P8 and PO4). As shown in Fig. 2, the N170 amplitude was higher for a new face than for an old one at P5 ($F(1,13)=7.7, p<0.02$), P6 ($F(1,13)=22.6, p<0.001$), P8 ($F(1,13)=6.2, p<0.03$) and PO4 ($F(1,13)=17.4, p<0.002$).

Contrasts of the expression×site×hemisphere interaction resulted in a main effect of the expression change on the right parieto-occipital region (P6, PO4 and PO8). The amplitude of the N170 component was greater when the expression (interactive context) was different rather

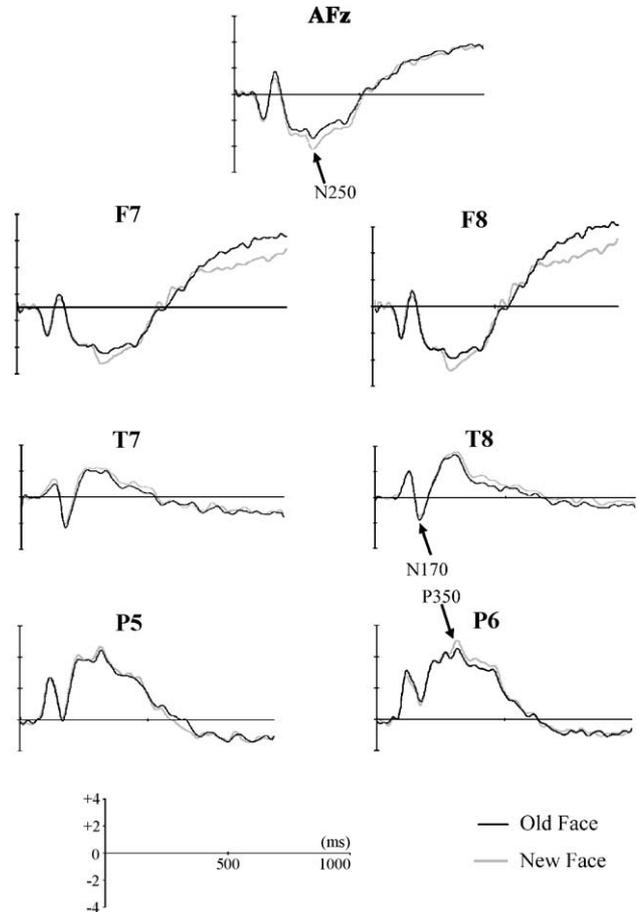


Fig. 2. Grand average ERP waveforms from selected anterior and posterior electrodes for old faces (black line) and new faces (gray line) in Experiment 1. Waveforms are shown from electrode sites on the anterior frontal (AFz) and over left and right frontal (F7, F8), temporal (T7, T8) and parietal (P5, P6).

Table 2
Anova results in the three consecutive time windows in the expression-based recognition

Latency windows (ms)	150–200		200–500		500–800	
	df	F	df	F	df	F
<i>Anterior sites</i>						
F×E×S			3 39	5.6**		
F×S			3 39	3.7*	3 39	5.9**
B×S					3 39	7.2***
<i>Posterior sites</i>						
F×E×S×H					5 65	4.5*
F×E×S			5 65	4.6**		
E×S×H	5 65	4.3**				
F×S	5 65	2.9*				
B					5 65	4.4**
F	1 13	9.2**				

Conditions×site×hemisphere interactions are reported only when significant. F=face; E=expression; B=background; S=electrode site; and H=hemisphere.

* $p<0.05$.

** $p<0.01$.

*** $p<0.001$.

than unchanged at P6 ($F(1,13)=9.7, p<0.01$), PO4 ($F(1,13)=9.4, p<0.01$) and PO8 ($F(1,13)=8.2, p<0.02$). These results reflect that the N170 is larger when change occurs in expression (interactive intrinsic context), as well as in face repetition, suggesting an attentional modulation of the N170 component relative to the face intrinsic modifications.

3.1.3.2. 200–500 ms. FN250 and the early part of the parietal repetition effect were analyzed within the 200–500 ms temporal window. Regions of interest were selected a priori based on previous results, suggesting that early frontal negativities are maximal over frontal regions [6,30,45,55], whereas parietal repetition effects are maximal over posterior regions [5,24,57,62]. This distinction between anterior and posterior components was also confirmed by visual inspection of the average waveforms (see Figs. 2 and 3). Thus, a separated analysis on the anterior (Fp1/2, AF3/4, F3/4, F7/8) and posterior (P5/6, P7/8, TP7/8, T7/8, PO3/4, PO7/8) regions was conducted to observe on these two distinct ERP components the contextual effects at stake.

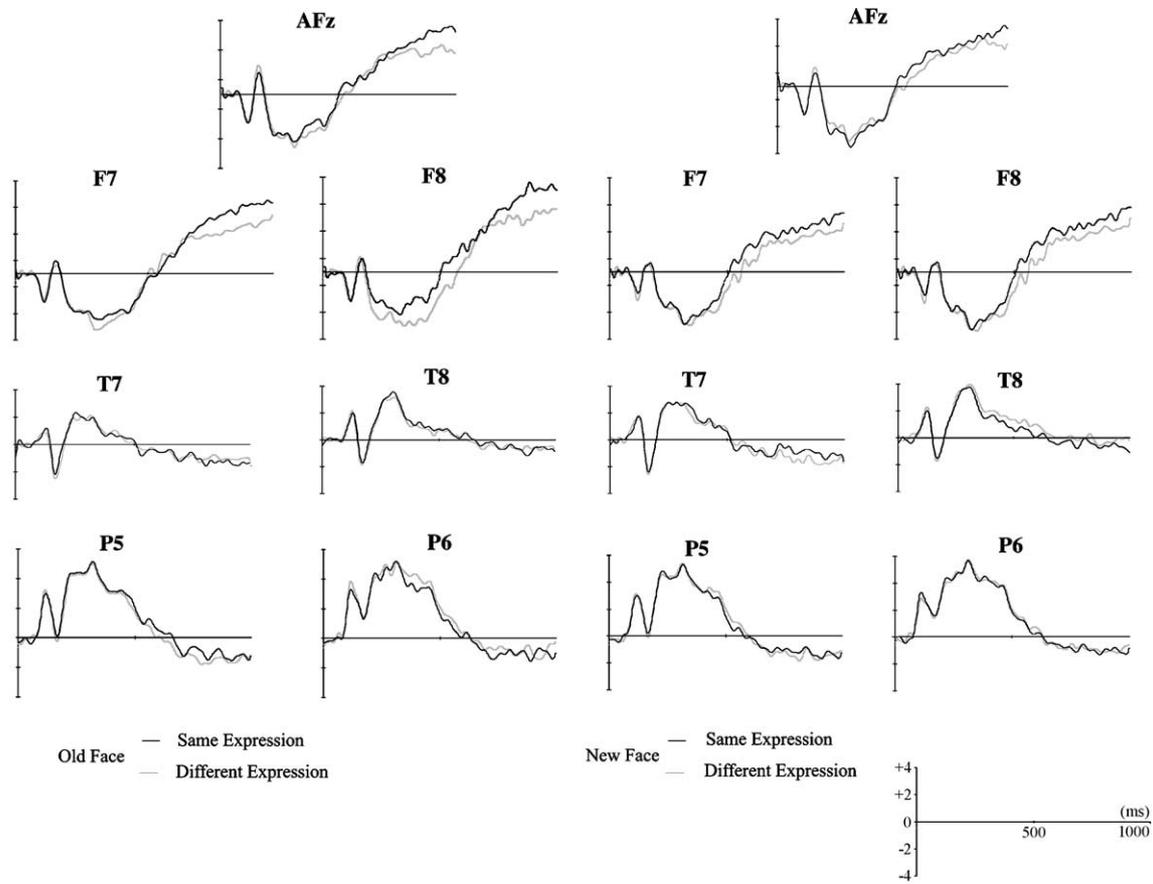


Fig. 3. Grand average ERP waveforms from selected anterior and posterior electrodes for old faces and new faces, depending on whether the expression (interactive context) was the same (black line) or different (gray line) in Experiment 1. Waveforms are shown from electrode sites on the anterior frontal (AFz) and over left and right frontal (F7, F8), temporal (T7, T8) and parietal (P5, P6).

Frontal N250. The analysis on the anterior regions showed two reliable face \times site ($F(3,39)=3.7$, $p<0.05$, $\epsilon=0.922$) and face \times expression \times site ($F(3,39)=5.6$, $p<0.01$, $\epsilon=0.873$) interactions. Subsidiary contrast analysis of the face \times site interaction resulted in a main effect of the face on the frontal N250. As shown in Fig. 2, a surface voltage decrease generated by the distracter faces was observed over to the frontal regions (at Fp1, Fp2, AF4, F4 and F8). Frontal N250 had a greater amplitude when the face was new at Fp1 ($F(1,13)=10.2$, $p<0.01$), Fp2 ($F(1,13)=13.2$, $p<0.01$), AF4 ($F(1,13)=6.9$, $p<0.03$), F4 ($F(1,13)=7.4$, $p<0.02$) and F8 ($F(1,13)=5.3$, $p<0.04$).

Considering the face \times expression \times site interaction, contrasts revealed a main effect of the expression change in the frontopolar electrodes (Fp1 and Fp2). Fig. 3 presents the ERPs average across old and new faces depending on the expression (same vs. different). Between 200 and 500 ms, contrasts revealed that the frontal N250 had greater amplitude when the expression has been changed rather than unchanged at Fp1 ($F(1,13)=5.2$, $p<0.05$) and at Fp2 ($F(1,13)=20.2$, $p<0.001$). Frontal N250 seems thus to be involved in the explicit processing of the face's intrinsic context. Moreover, contrasts analysis of the face \times expression \times site interaction

revealed, in the condition where the face was old, a significant difference of the expression change on the right frontal sites (AF4 and F8). As illustrated in Fig. 3, contrasts analysis of this interaction pointed out greater negativities, when the face was old, if the expression was different rather than unchanged at AF4 ($F(1,13)=6.1$, $p<0.03$) and F8 ($F(1,13)=11.7$, $p<0.005$).

Parietal repetition effect. The analysis on the posterior regions result in a reliable face \times expression \times site \times hemisphere interaction ($F(5,65)=4.6$, $p<0.01$, $\epsilon=0.613$). Subsidiary contrasts resulted in a significant main effect of the face status on the parietal sites (P5, P6, P8 and PO8). As it is typical for such old/new or repetition effects, posterior amplitudes were more positive for old than for new face on the right occipito-parietal region. The amplitude of the parietal repetition effect was greater when the face was old rather than new at P8 ($F(1,13)=8.5$, $p<0.02$) and PO8 ($F(1,13)=7.3$, $p<0.02$). On the other hand, result observed at P5 and P6 is atypical. As illustrated in Fig. 2, the amplitude of the parietal repetition effect was greater when the face was new rather than old at P5 ($F(1,13)=8.3$, $p<0.02$) and at P6 ($F(1,13)=15.1$, $p<0.002$).

In addition, contrasts analysis of this interaction revealed that the repetition effect was dependent of the intrinsic context change. This effect of intrinsic context observed on this component account for the atypical face repetition effect observed on the parietal regions (P5 and P6). As shown in Fig. 3, contrasts focused on posterior sites revealed a decreased amplitude of the P350, in the conditions where the face was old, if the expression has been changed rather than unchanged at P5 ($F(1,13)=5$, $p<0.05$) and PO3 ($F(1,13)=4.7$, $p<0.05$). These results revealed that the repetition effect observed on the left parietal sites might be dependent in the same time of the face and its interactive perceptual context.

3.1.3.3. 500–800 ms. Late components were analyzed within the 500–800-ms temporal window. Two distinct components on the temporoparietal and frontal regions were again identified (see Figs. 2 and 3) in this late temporal window. A separated analysis on the anterior (Fp1/2, AF3/4, F3/4 and F7/8) and posterior (P3/4, P7/8, TP7/8, T7/8, PO3/4 and PO7/8) regions was then conducted.

Late frontal component. In the late temporal window, the analysis on the anterior regions showed two significant face \times site ($F(3,39)=5.9$, $p<0.01$, $\epsilon=0.728$) and background \times site ($F(3,39)=7.2$, $p<0.01$, $\epsilon=0.691$) interaction. As illustrated in Fig. 3, contrasts of the face \times site interaction revealed that the amplitude of the late positive component was higher when the face was old rather than new at F3 ($F(1,13)=5.2$, $p<0.05$), F4 ($F(1,13)=6.1$, $p<0.03$), F7 ($F(1,13)=4.9$, $p<0.05$) and F8 ($F(1,13)=6.3$, $p<0.03$). Contrasts analysis of the background \times site interaction revealed that the amplitude of the late positive component was higher when the background was modified rather than unchanged. This voltage increase was significant and persisted after the behavioral response at AF4 ($F(1,13)=6.1$, $p<0.03$) and at F4 ($F(1,13)=5.5$, $p<0.04$).

Late parietal component. The analysis on the posterior regions resulted again in a significant face \times expression \times site \times hemisphere interaction ($F(5,65)=4.5$, $p<0.02$, $\epsilon=0.537$). Subsidiary contrasts revealed a significant difference between old and new face localized on temporal and temporoparietal sites in the right hemisphere (T8, P8 and TP8). ERPs for old face condition were more positive than for new face at T8 ($F(1,13)=7.2$, $p<0.02$), P8 ($F(1,13)=11.5$, $p<0.005$) and TP8 ($F(1,13)=10.7$, $p<0.01$). In this late temporal window, ANOVA revealed also in a significant difference, when the face was old, of the expression change between right and left posterior sites ($F(5,65)=4.9$, $p<0.005$, $\epsilon=0.778$). Contrasts resulted in the increased negativities when the old face's expression was different rather than unchanged on the left parietal sites ($F(1,13)=12.4$, $p<0.004$ at P5 and $F(1,13)=9.1$, $p<0.01$ at PO3). This effect was not found again on the right parietal sites. If the background was irrelevant for the recognition decision, a significant background \times site interaction ($F(5,65)=4.4$, $p<0.01$, $\epsilon=0.625$) was found on the posterior regions.

Subsidiary contrasts resulted in a main effect of the background at the left parietal posterior sites (P5, P7 and PO7). The surface voltages were lower, between 500 and 800 ms, if the background was different rather than unchanged at P5 ($F(1,13)=16.1$, $p<0.002$), P7 ($F(1,13)=10.4$, $p<0.01$) and PO7 ($F(1,13)=9.4$, $p<0.01$).

In summary, ERP analysis of the first experiment shows various contextual and face repetition effects. If the temporoparietal N170 (150–200 ms) is modulated by the face status (old vs. new), results also show an effect of the face intrinsic context on this component. This increased amplitude of the N170 relative to the expression modifications is predominant on the right posterior sites (P6, P8, PO4). This intrinsic context effect is found again on the frontal N250 (200–500 ms) where the amplitude is higher when interactive context changes occurred on a repeated face. This increased amplitude relative to the interactive modifications is predominant on both the right frontal (AF4, F4 and F8) and the anterior frontal sites (Fp1, Fp2). If the posterior ERPs (200–800 ms) appear globally larger for old face compared to new one, results further showed dissociation between the effects observed bilaterally over the left parietal regions (P5 and PO3) and the right temporoparietal regions (T8, TP8 and P8). The first simultaneously depends on the face status (old vs. new) and on its interactive intrinsic context manipulation (different expression), whereas the second depends mainly on the face status independently of the contextual manipulations. A late positivity (500–800 ms) related to the face repetition is also elicited out in the bilaterally fronto-central regions (F3, F4, F7 and F8). Finally, independent extrinsic perceptual (background) modification has opposite effects on the late components over the left parietal (P5, P7 and PO7) and the right frontal sites (AF4, F4). Changing background decreased the amplitude of the left parietal component but increased, at the same time, the amplitude of the late positivity observed at right frontal sites.

3.1.4. Discussion of Experiment 1

In the first experiment, the participants identify the face along with its expression. All participants had to decide whether it was the same face and whether the expression was unchanged between the study and test phases. Under such conditions, attention was immediately directed in an intentional and interactive way towards the intrinsic characteristics of the face; as such, simply identifying the face was not enough to be correct. The lack of extrinsic-context effect on the behavioral measures clearly demonstrates that attention and memory retrieval processes were directed solely at the face. Furthermore, there were stronger negativities for a new face in both the temporoparietal N170 and the frontal N250. The change in expression (interactive perceptual context) also led to early modulation of the frontal and parietal components. Greater negativities at the anterior and right frontal sites were found if the intrinsic interactive context was modified. This effect observed on

the frontal N250 seems to reflect the detection and the controlled retrieval of relevant contextual information.

Contrary to the repetition effect observed in the right parietal region, which was specific to face repetition, the effect observed in the left parietal region was modulated by both the face repetition and its expression. The amplitude of the left parietal repetition effect was the lowest when participants correctly recognized an old face and also identified the exclusion criteria (correct response to lures: old face with different expression). This modulation, specific to lure faces, indicates the implication of a memory retrieval process specific to the exclusion of lures and may reflect processes that monitor for certain kinds of retrieval: conscious search process on perceptual and specific information of the encoding episode. Although the extrinsic context change did not have an impact on the behavioral response, it did, however, modulate the late components in the right frontal and left parietal ERPs. Subsequent to the behavioral response (after 500 ms), these late modulations, due to the changed independent extrinsic context, are most likely due to a response checking process. The purpose of the second experiment was to look at whether these different measures were affected by a change in the “status” of the perceptual context, i.e., when the intrinsic context became independent and the extrinsic context became interactive to the recognition task.

3.2. Experiment 2: background-based face recognition

3.2.1. Analysis of correct answers

Table 3 presents the correct answer percent, reaction time and associated standard deviation (SD) averaged over the 14 participants for each type of face (old or new), expression (same or different) and background (same or different). An ANOVA applied to the correct answer percent yielded a significant three-way face×expression×background interaction ($F(1,13)=10.5$, $p<0.01$) reflecting the fact that the expression×background interaction was nonsignificant for new faces but significant for old faces ($F(1,13)=6.3$, $p<0.03$).

Table 3

Mean and standard deviation (SD) of the correct answer percent and reaction time (ms) for old faces and new faces by expression (same or different) and background (same or different) in Experiment 2 (background-based face recognition)

Conditions			Correct response (%)	Reaction time (ms)
Face	Background	Expression		
Old	Same	Same	91.6 (9.3)	680 (215)
		Different	90.3 (10.4)	704 (165)
	Different	Same	75.8 (15.9)	737 (212)
		Different	79.4 (12.7)	739 (186)
New	Same	Same	87.6 (10.5)	642 (186)
		Different	94.9 (7.4)	554 (154)
	Different	Same	97.3 (5.5)	597 (153)
		Different	98.9 (2.4)	523 (138)

Contrasts analysis of the expression×background interaction for old faces alone showed that, when the expression was the same, the background change significantly decreased the correct answer percent (93% vs. 76%; $F(1,13)=30.7$, $p<0.0001$). Likewise, when the expression was different, changing the background led to a significant performance decline (89% vs. 80%; $F(1,13)=7.9$, $p<0.02$). Changing expression had no effect on the correct answer percent, however, whether the background was the same or different.

There was only one significant two-way interaction for face×background ($F(1,13)=11$, $p<0.01$), indicating that a change in background did not have a significant effect for new faces, whereas for old faces, the correct answer percent was significantly lower when the background was different (77.5%) rather than the same (91%; $F(1,13)=9.1$, $p<0.01$). ANOVA revealed a significant main effect for face that influenced the percentage of correct recognitions, where it was lower for old faces (84.3%) compared to new (94.8%; $F(1,13)=17.7$, $p<0.001$).

3.2.2. Analysis of correct answer response time

An ANOVA on correct answer RTs showed no significant interaction among face×expression×background. The two-way interactions face×expression ($F(1,13)=10.5$, $p<0.01$) and face×background ($F(1,13)=8.8$, $p<0.01$) were significant, however. Contrast analysis of the face×expression interaction revealed that, (1) for old faces, RTs were slower for changed expressions (738 ms) than for unchanged ones (692 ms), $F(1,13)=6.8$; $p<0.03$, and (2) for new faces, RTs were not significantly faster when the expression was different (560 ms) than when it was the same (598 ms).

The breakdown of the face×background interaction yielded the following: (1) for new faces, RTs were significantly slower when the background was the same (619.5 ms) than when it was different (538.5 ms; $F(1,13)=9.9$, $p<0.01$), and (2) for old faces, RTs did not differ significantly as a function of variations in the background. As far as the main effects are concerned, correct answers were made significantly more slowly if the face was old (715 ms) rather than new (579 ms; $F(1,13)=35.6$, $p<0.0001$). Neither the background nor the expression had a significant effect.

3.2.3. Electrophysiological data

Regarding the ERPs, separate condition×site×hemisphere repeated measures ANOVAs were conducted to assess face repetition and contextual effects. ANOVA results obtained on the mean ERP voltage in the background-based recognition task are summarized in Table 4. Conditions×site×hemisphere interactions are reported only when significant.

3.2.3.1. 150–200 ms. Fig. 4 presents the potentials obtained by taking the grand average of the 14 participants

Table 4

Anova results in the three consecutive time windows in the background-based recognition

Latency windows (ms)	150–200		200–500		500–800	
	df	F	df	F	df	F
<i>Anterior sites</i>						
B×S×H			3 39	7.4**		
F×S			3 39	3.7*		
B×S					3 39	8.5***
<i>Posterior sites</i>						
E×B×S×H			5 65	6.7***		
E×B×S					5 65	5.8**
F×S	5 65	4.3**	5 65	3.7*	5 65	7.2***

Conditions×site×hemisphere interactions are reported only when significant. F=face; E=expression; B=background; S=electrode site; and H=hemisphere.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

for old and new faces separately. The mean number of trials per participants used to form these waveforms was 57. As shown in Fig. 4, the only one component identified in this time window was again clearly localized on the posterior regions. Confirmatory analysis on these regions of interest (P3/4, P7/8, TP7/8, T7/8, PO3/4 and PO7/8) was conducted.

Temporoparietal N170. Considering the temporoparietal distribution of the N170, a separated analysis on the posterior regions showed a significant face×site interaction ($F(5,65)=4.3$, $p < 0.01$, $\epsilon=0.516$). Contrasts resulted in a significant main effect of the face repetition on parietal and parietooccipital electrodes. As illustrated in Fig. 4, contrasts revealed that the amplitude of the N170 component was higher for an old face compared to a new one at PO3 ($F(1,13)=18.6$, $p < 0.001$), PO4 ($F(1,13)=14.1$, $p < 0.003$), P08 ($F(1,13)=5.3$, $p < 0.04$), P6 ($F(1,13)=14.2$, $p < 0.003$) and P8 ($F(1,13)=15.3$, $p < 0.002$). No perceptual context effect (expression or background) was found on this component.

3.2.3.2. 200–500 ms. Similarly to the first experience, two distinct components on the temporoparietal and frontal regions were identified in the 200–500 and 500–800 ms temporal windows (see Figs. 4 and 5). A separated analysis on anterior (Fp1/2, AF3/4, F3/4 and F7/8) and posterior (P5/6, P7/8, T7/8, TP7/8, PO3/4 and PO7/8) regions was then conducted.

Frontal N250. In the 200–500-ms temporal window, the analysis on the anterior sites resulted of two significant face×site ($F(3,39)=3.7$, $p < 0.04$, $\epsilon=0.784$) and background×site×hemisphere ($F(3,39)=7.4$, $p < 0.01$, $\epsilon=0.751$) interactions. A contrast analysis of the face×site interaction revealed a significant increased of the N250 amplitude for distracter faces on various frontal sites, including Fp1 ($F(1,13)=9.5$, $p < 0.01$), Fp2 ($F(1,13)=9.2$, $p < 0.01$), AF4 ($F(1,13)=5.9$, $p < 0.04$) and F4 ($F(1,13)=5.6$, $p < 0.04$).

The background×site×hemisphere interaction indicated that the background change effect was larger over the left

frontal regions. Contrasts resulted in a significant main effect of the background change at left frontopolar and left frontal electrodes (Fp1, AF3, F3 and F7). In these regions, N250 was always larger when the background was changed as opposed to unchanged ($F(1,13)=10$, $p < 0.01$ for Fp1; $F(1,13)=9.2$, $p < 0.01$ for AF3; $F(1,13)=6.3$, $p < 0.03$ for F3 and $F(1,13)=14.8$, $p < 0.005$ for F7). This effect of the interactive extrinsic context was not found again on the right frontal regions (Fp2, AF4, F4 and F8). Fig. 5 presents the ERPs averaged across old and new items depending on the background. The mean number of trials per participant used to form these waveforms was 29.

Parietal repetition effect. Considering the parietal repetition effect (P350), the analysis on the posterior sites in the 200–500-ms time window revealed two significant interactions: expression×background×site×hemisphere ($F(5,65)=6.7$, $p < 0.001$, $\epsilon=0.719$) and face×site ($F(5,65)=3.7$, $p < 0.02$, $\epsilon=0.742$) interaction. Contrasts analysis of the face×site interaction revealed a significant difference of the face change in the right temporoparietal region (T8, TP8 and P8). The amplitude of the P350 was greater when the face

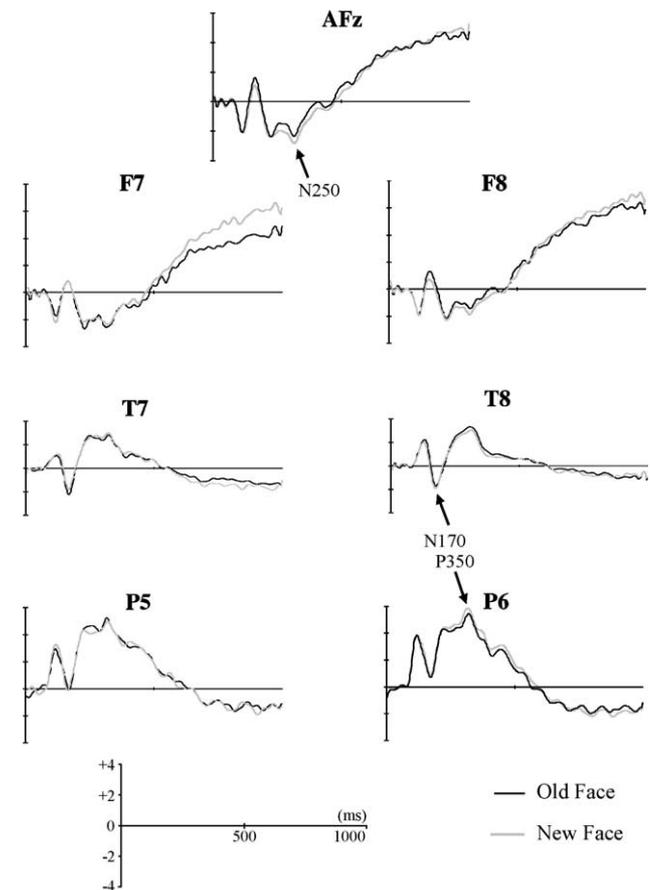


Fig. 4. Grand average of the ERP waveforms from selected anterior and posterior electrodes for old faces (black line) and new faces (gray line) in Experiment 2. Waveforms are shown from electrode sites on the anterior frontal (AFz) and over left and right frontal (F7, F8), temporal (T7, T8) and parietal (P5, P6).

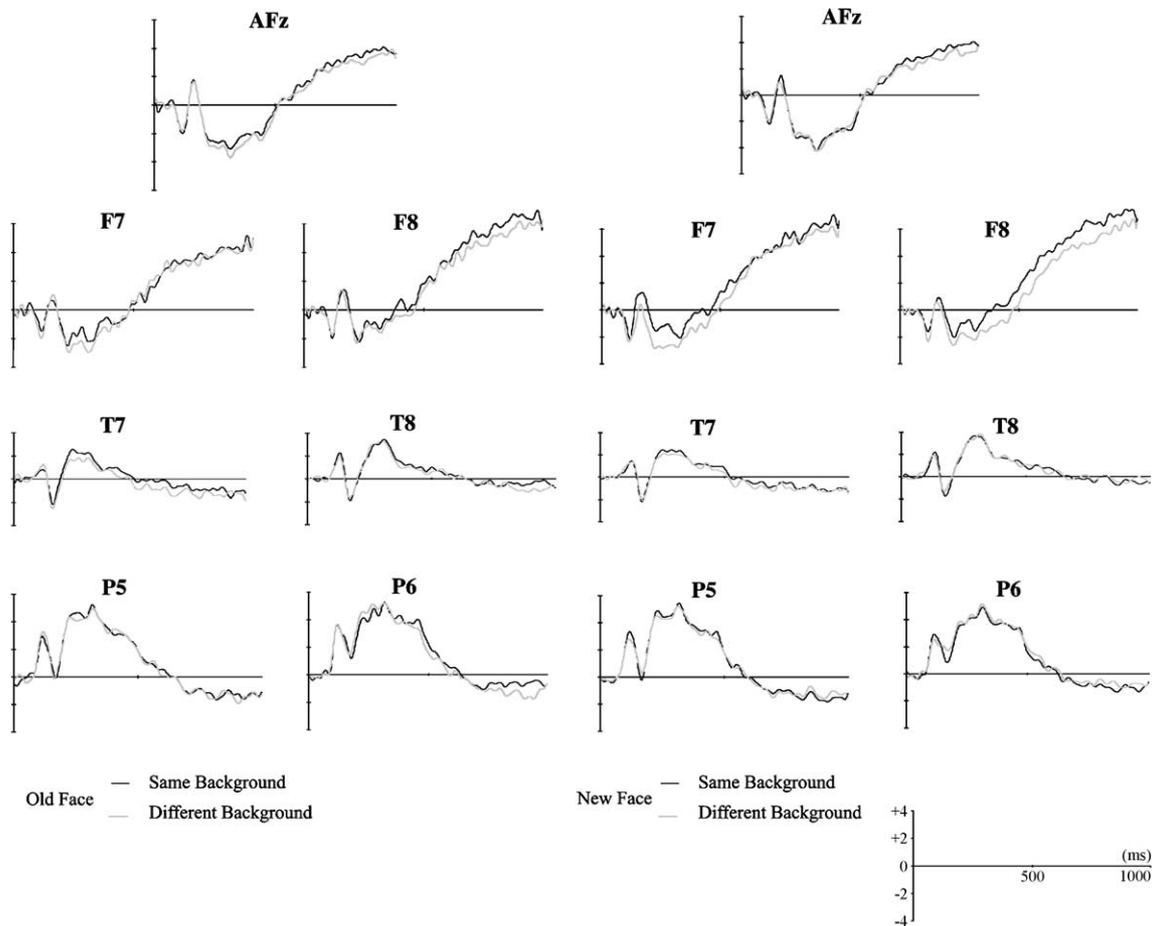


Fig. 5. Grand average of the ERP waveforms from selected anterior and posterior electrodes for old faces and new faces, depending on whether the background (interactive context) was the same (black line) or different (gray line) in Experiment 2. Waveforms are shown from electrode sites on the anterior frontal (AFz) and over left and right frontal (F7, F8), temporal (T7, T8) and parietal (P5, P6).

was old compared to new one at T8, ($F(1,13)=9.3, p<0.01$), TP8 ($F(1,13)=15.4, p<0.002$) and P8 ($F(1,13)=17.9, p<0.001$). As illustrated in Fig. 4, the result observed on P6 was different. The amplitude of the P350 was greater when the face was new at this electrode ($F(1,13)=7.1, p<0.02$). No significant background \times site interaction was found on the posterior sites.

Subsidiary contrasts of the expression \times background \times site \times hemisphere interaction revealed significant results on the left posterior region (P5, P7 and TP7). At these, the amplitude of the repetition effect was larger when a perceptual context change occurred (see Fig. 5). For the left parietal site (P5), contrasts revealed a significant difference (1) of background change when the expression was unchanged ($F(1,13)=21.5, p<0.001$) and (2) of expression change when the background was unchanged ($F(1,13)=11.6, p<0.005$). Contrasts analysis yielded comparable results in left parietal and temporoparietal regions (P7 and TP7). Contrasts revealed a significant difference (1) of background change when the expression was unchanged at P7 ($F(1,13)=6.1, p<0.03$) and TP7 ($F(1,13)=18.9, p<0.001$) and (2) of expression change when the back-

ground was different at P7 ($F(1,13)=9.8, p<0.01$) and TP7 ($F(1,13)=31.8, p<0.0001$).

3.2.3.3. 500–800 ms

Late frontal component. If no background \times site interaction was observed on the posterior regions, the analysis on the anterior regions resulted in a significant background \times site interaction ($F(3,39)=12.8, p<0.0001, \epsilon=0.813$). Subsidiary contrasts resulted in a significant effect of the extrinsic context on fronto-central regions in each hemisphere. As illustrated in Fig. 5, a decreased amplitude was observed on the late frontal positive component when the background has been modified rather than unchanged at F3 ($F(1,13)=5.5, p<0.04$), F4 ($F(1,13)=6.1, p<0.03$) and F8 ($F(1,13)=4.7, p<0.05$). No face \times expression \times site or expression \times background \times site interaction was observed on the anterior regions.

Late parietal component. The analysis on the posterior regions resulted in two significant face \times site ($F(5,65)=7.2, p<0.001, \epsilon=0.654$) and expression \times background \times site ($F(5,65)=5.8, p<0.01, \epsilon=0.448$) interactions. Contrast anal-

ysis of the face \times site interaction resulted in a main effect of the face in a diffuse way on posterior regions. Contrasts revealed again a surface voltage decrease generated by new face on the right temporoparietal region ($F(1,13)=24.2$, $p<0.001$ at T8, $F(1,13)=12.9$, $p<0.004$ at TP8 and $F(1,13)=16.1$, $p<0.002$ at P8). On the other hand, contrasts revealed a surface voltage decrease in the condition where the face was old rather than new at P5 ($F(1,13)=19.6$, $p<0.001$) and P6 ($F(1,13)=15.7$, $p<0.002$).

Contrasts analysis of the expression \times background \times site interaction revealed, on the left posterior sites, a significant difference (1) of background change when the expression was unchanged at P7 ($F(1,13)=17.1$, $p<0.005$) and TP7 ($F(1,13)=13.8$, $p<0.005$) and (2) of expression change when the background was different at P7 ($F(1,13)=9.9$, $p<0.01$) and TP7 ($F(1,13)=31.6$, $p<0.0001$).

In summary, ERP analysis of the background-based recognition shows numerous contextual effects. If the face repetition effect is found again on the temporoparietal N170 (150–200 ms), this component is now modulated in the opposite direction than in the first experiment and in a more diffuse manner on the posterior regions. Furthermore, contrarily to the interactive intrinsic context, the interactive extrinsic context has no effect on the N170 component. In the meantime, the amplitude of the frontal N250 is larger in the conditions where the face was new and where the background has changed, showing again a prevalent attentional effect of the task interactive information on this ERP component (e.g., face and background). Contrary to the first experiment, this N250 interactive context effect was more lateralized on the left frontal sites (Fp1, AF3, F3 and F7) in the second experiment. Considering late components, the parietal repetition effects (200–800 ms) present larger amplitude for old faces compared to new ones in the right temporoparietal region, showing again a classical repetition effect. Results also show that P350 is modulated by perceptual context changes whatever these changes were extrinsic or intrinsic to the face. These perceptual changes (expression and background) appear more lateralized in the left hemisphere than the face repetition effect. Finally, interactive extrinsic context modification has an effect on the late positive component (500–800 ms) observed over the fronto-central sites (F3, F4 and F8).

3.2.4. Discussion of Experiment 2

In this second experiment, the participants had to identify a face and decide simultaneously if the background had been changed or unchanged. Thus, it was a matter of making an identity judgment on the face and also of retrieving the extrinsic perceptual context which, unlike in the preceding experiment, was now an interactive context. Here again, once the face was identified, an additional decision had to be made, one which was obviously not necessary if the face was correctly rejected as new. This dual decision elucidates that behavioral indexes were then affected by both types of context (extrinsic interactive and

intrinsic independent) in interaction with the face. The three-way face \times expression \times background interaction shows that, when the subjects had to take the background into account, they were unable to ignore the change of expression. This means that there is an important difference between intrinsic and extrinsic perceptual contexts during face recognition. Even if the intrinsic context did not have to be considered to recognize the face, its change could nevertheless perturb the recognition judgment. In other words, unlike the independent extrinsic context in the first experiment, the independent intrinsic context was obligatorily processed in the second experience, thus perturbing the recognition judgment.

Considering ERPs, N170 exhibited the opposite pattern to that found in the first experiment, since during this time, early negativities were larger for repeated face than for a new one at parietal sites. The spread over the entire parietal region shows that the effect observed on this component did not reflect a face-specific processing as observed in Experiment 1. The frontal N250 in the first experiment was noted again in the second experiment and appeared again modulated by all relevant information: face and background. Changing background had a substantial and extensive effect between 200 and 500 ms at left frontal electrodes in the background-based recognition. This specific contextual effect may reflect the early orientation of memory retrieval toward the face's extrinsic context. Face repetition effect was found again at the posterior electrode sites. Like in the first experiment, the parietal repetition effect observed in the right hemisphere was specific to the face, whereas the effect observed in the left hemisphere was modulated by both the face repetition and the perceptual context manipulated. Nevertheless, the contextual effects observed here differed from those found in Experiment 1. The left parietal P350 had greater amplitude when there was a change in the perceptual context whether intrinsic or extrinsic to the face. The left parietal repetition effect observed in the present study may thus reflect the use of analytic strategies based relatively to the task. It appears as if these posterior regions (P5, P7 and TP7) were involved in resolving conflicts between any detected perceptual changes and face identity. Finally, a main effect of the background was found on the late frontal positive component, but in contrast with the first experiment, this effect was bilaterally distributed in the second experience.

4. Discussion

In these experiments, two types of contextual variations (perceptual context and processing context) were combined to study their impact on behavioral and electrophysiological parameters during a short-term face recognition. The experiments involved changes in the perceptual context (intrinsic/expression and extrinsic/background) and processing context (interactive/relevant and independent/irrelevant)

between acquisition and recognition in a crossed manner. By doing so, it made possible to observe the specific effects of each context and gain insight into the functional role of the ERPs observed on the surface of the scalp. Analyses on the mean ERPs amplitude measures revealed that, in the two experiments, there were significant differences between correctly recognized old items and correctly rejected new items in the different temporal windows. In both experiments, the conditions in which the face was old required additional processing to retrieve specific information. It was therefore not a mere question of a repetition effect solely reflecting the face identification process. This involvement of different and/or additional processes as a function of the face's status accounts for the topographic diversity of the modulations found for the face repetition effect. As [Tables 2 and 4](#) show, the electrophysiological modulations depended at the same time upon the task the participants had to perform and upon the nature of perceptual information that had to be retrieved.

It could be argued that repetition effect observed in this study is related to the differential probability of the two types of stimuli responses (yes/no). Although a probability effect cannot be completely discarded from the present experiment, it is unlikely to account for the observed effects for two reasons. First, the proportion of old and new faces was the same, and this experimental factor shows an important influence on the ERP repetition effect. Second, the differential probability (yes/no responses) was exactly the same for each experiment, whereas the ERP effects observed are different in the expression-based recognition and in the background-based recognition task.

4.1. Temporoparietal N170: processing context effects on the structural analysis of the face

The memory retrieval orientation effect observed on the temporoparietal N170 reveals that this specific component may be influenced, in certain conditions, by top-down processes relative to the task-processing context. In addition to being spread over a greater topographic area in the second experiment, the polarity of the face repetition effect observed differed according to whether the interactive context was intrinsic or extrinsic to the face. While showing up in its classical form (N170 amplitude was larger when the face was new) when the interactive context was intrinsic, N170 exhibited reversed pattern when the extrinsic context was relevant to the task (N170 amplitude was greater when the face was repeated). If we agree with the idea that this component is include in the structural encoding of faces [\[20\]](#), then new faces should require more structural encoding than old ones. How then can we account for the opposite polarity of the face repetition effect observed in the first and in the second experiments? One possible interpretation is that, in the second experiment, participants did not have to dwell on the detailed physiognomy of the old faces and quickly turn away from

them to process the background scene. The amplitude of the N170 being then larger when the face was new compared to old one.

The difference triggered by the interactive context suggests that temporoparietal N170 is controlled by early top-down influences related to the task execution strategy and specific demands. This interpretation is also in line with the idea that this component is not an indicator of face recognition per se but rather of the specific processing of physiognomy and low-level recognition of structural information [\[21,22\]](#). Facial expression may thus process in the early stage of face processing in the posterior temporal region, depending essentially of the processing context. If the N170 reflects the early visual stage of face processing, present results highlight the cognitive penetrability of this early visual process and contradict the idea that face recognition is not influenced by facial emotion.

4.2. Frontal N250: strategic demands and processing context

Present results provide evidence of early mobilization of frontal structures during these exclusion tasks. Between 200 and 500 ms, frontal N250 was of lower amplitude for old than for new faces. This component seems to correspond to the visual memory potential (VMP) described by Begleiter et al. [\[8\]](#) and thought to reflect short-term visual memory processes. These authors showed that VMP was smaller when unfamiliar faces were repeated. They also showed that this decrease affected only the temporo-occipital regions in priming task but occurred additionally in the frontal regions on a recognition task with greater explicit memory demands. Our results confirm that N250 early modulations occurred when the task to be accomplished demanded the reactivation of specific information taken (1) from the face and facial expression when the interactive context was intrinsic (experience 1) and (2) from the face and its background when the interactive context was extrinsic (experience 2).

Taken together, these results show that the frontal N250 has greater amplitude when relevant information is modified. This modulation relative to the processing of relevant and interactive information has been already described [\[14\]](#). ERP recordings of patients with frontal lesions have provided evidence of an orbital and ventral medial origin for this ERP component [\[31\]](#). Our results are thus in line with the idea that the orbital and dorsolateral regions of the frontal lobe are involved in processing target specifications [\[23,34\]](#) or in maintaining new information in memory during interference [\[17,56\]](#). If the frontal N250 is modulated by the change of interactive information, this increase in the amplitude appears, in the meantime, independent of the nature (intrinsic or extrinsic) of the interactive information.

4.3. *Left/right frontal N250: specificity of the interactive extrinsic context*

The influence of the nature of the interactive information on the frontal N250 is observed, on the other hand, through its topographic distribution. Nolde et al. [51] suggested that the right prefrontal regions are the locus of “holistic processing,” when judgments are based on a single dimension. In contrast, they argued that the left prefrontal regions are the locus of “analytic processing,” when multiple characteristics must be evaluated in memory for a judgment to be made (cortical asymmetry of reflective activity [CARA]). Our results support this idea of differences in the frontal activity between processing that bears on the face (as in the case of an interactive intrinsic context) and processing that bears on two objects at the same time (as in the case of an interactive extrinsic context). Only in the latter case, which requires an additional attentional effort, that an early longer modulation of the frontal N250 is observed in the left hemisphere. In cases wherein, in these two tasks, individuals had to take two perceptual characteristics into account (face and expression or face and background), the perceptual relationship between the face and the type of interactive context (intrinsic vs. extrinsic) seemed to best explain the lateralization of the observed effects. Thus, the early left frontal effect seems to be specific of interactive extrinsic information processing, independent of face identity. If the impact of the content of the to-be-retrieved information has already been demonstrated [44], it is interesting to note that these early left frontal negativities were not observed when the extrinsic context was independent to the task (Experiment 1). This result is in line with previous study showing that the left anterior prefrontal cortex is recruited when the demands for retrieval and specific perceptual evaluation increase [52].

If the frontal ERP effects reflect the use of information retrieved for the particular task [2], then the present results are also consistent with the recent idea that frontal effects reflect differences in the nature of the information to retrieve in the postretrieval processes involved or in the evaluation that follows retrieval [45,53]. Effort is known to be an essential determinant of performance in unfamiliar face recognition [36], and frontal activity seems to be a manifestation of it. There thus appears to be a link here between the perceptual context and the amount of effort during memory retrieval. The experimental situation used here falls between these two cases. Perceptual details had to be retrieved, but during the second experiment, additional associative information (background scene) also had to be processed. The results point out that the critical feature for left PFC involvement is having the to-be-retrieved perceptual information external, arbitrarily associated to the target face and, consequently, more sensitive to the interference. It was less the fine analyses of information stored in memory (that is common to both tasks) than the need to retrieve

external but relevant details that necessitated the implementation of both the right and left PFC.

4.4. *Left/right parietal repetition effect: retrieval of elements affecting the decision*

Given the short RTs and the high number of correct answers on these two exclusion tasks, it seems clear that the subjects’ attention and controlled memory retrieval processes were directed immediately on the interactive contextual information. The influence of the processing context (interactive vs. independent) seems to be manifested on both the early components (e.g., N170, N250) and the parietal repetition effect, particularly in the left hemisphere. However, the magnitude of the parietal repetition effect observed here is large relative to the right parietal repetition effect observed in an earlier study using a short-term unfamiliar face recognition task, in which contextual information was unnecessary [30]. Did the ERP repetition effect that showed up on the left parietal component also occur when the recognition involved contextual elements that are irrelevant to the task at hand? In fact, it seems to depend on the target/context relationship and on the perceptual characteristics at play. The results of the second experiment showed that an independent intrinsic context, although irrelevant to the task, had an impact on the left parietal repetition effect, unlike the independent extrinsic context in the first experiment. It therefore seems that it is not possible to disregard a facial expression—i.e., an intrinsic context—when making a face identity judgment [see Ref. [7]]. Thus, even if retrieval of the context is not explicitly requested in the task instructions, it may be necessary to the recognition decision. This was the case when the intrinsic face context was independent and had to be deliberately ignored.

Our results are thus in line with the idea that this left parietal component is critical to context retrieval, a finding which was also obtained in a study using an exclusion type of word recognition task [63]. In contrast, the right parietal repetition effect appears to be more involved in overall face identification than the left temporoparietal effect, the latter being relatively contingent upon contextual variations that disrupt the decision-making process. This distinction between right and left posterior repetition effect can be observed in the two exclusion tasks. The correspondence between the behavioral results and the ERPs shed additional light on the functional interpretation of parietal positivities and permit a direct insight into the various mechanisms underlying classical behavioral observations. The influence of a strategic criterion on left temporoparietal P350 points out that the processing context has a stronger effect than the perceptual context. This finding raises also that contextual information may have a dual role in affecting recognition via influences on both the evaluation of face perceptual familiarity and the conscious retrieval of a specific and interactive information. Indeed, although it reflects the retrieval of

contextual and specific information in memory, this component is first influenced by the contextual elements that enter into the decision. In this sense, perceptual and processing context interact together on the parietal repetition effect. In other words, the results obtained here show that left parietal repetition effect reflects the processing of contextual modifications solely if they perturb the decision. Indeed, when the modifications had no effect on the behavioral indexes (e.g., background in the first experience), they had no effect on the parietal repetition effect either.

5. Conclusion

As a whole, the present results support the idea that two major classes of processes are at play in a recognition task. The first class serves to specify the target information and the second class to carry out contextual information retrieval. The first is more dependent upon frontal structures and the second upon temporal and parietal structures. The present study shows that cascade interactions between frontal and posterior regions are also observed in the short-term recognition of unfamiliar faces when the retrieval of contextual elements is required. Our results show that context exclusion on a face recognition task recruits both hemispheres [10], and they are consistent with the proposal that the potentials elicited in explicit retrieval are contingent upon the task being performed [1,19,25,26,28,63]. Finally, the present results are in line with the hypothesis according to which an essential difference during recognition with or without memory of the source can be obtained by manipulating the strength of the relationship between the target and the contextual (or source) information to be retrieved [43]. Hence, the expression of automatic and controlled processes in a given context and their corresponding neurophysiological substrates depends on both task-related and target-related constraints—these influences being clearly in interaction during recognition.

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References

- [1] K. Allan, M.D. Rugg, An event-related potential study of explicit memory on tests of cued recall and recognition, *Neuropsychologia* 35 (1997) 387–397.
- [2] K. Allan, E.L. Wilding, M.D. Rugg, Electrophysiological evidence for dissociable processes contributing to recollection, *Acta Psychol.* 98 (1998) 231–252.
- [3] A.D. Baddeley, Domains of recollection, *Psychol. Rev.* 89 (1982) 708–729.
- [4] A.D. Baddeley, Implications of neuropsychological evidence for theories of normal memory, *Philos. Trans. R. Soc. Lond., B Biol. Sci.* 298 (1982) 59–72.
- [5] S.E. Barrett, M.D. Rugg, Event-related potentials and the semantic matching of faces, *Neuropsychologia* 27 (7) (1989) 913–922.
- [6] S.E. Barrett, M.D. Rugg, D.I. Perrett, Event-related potentials and the matching of familiar and unfamiliar faces, *Neuropsychologia* 26 (1998) 105–117.
- [7] J.-Y. Baudouin, D. Gilibert, S. Sansone, G. Tiberghien, When the smile is a cue to familiarity, *Memory* 8 (2000) 285–292.
- [8] H. Begleiter, B. Porjesz, W. Wang, Event-related potentials differentiate priming and recognition to familiar and unfamiliar faces, *Electroencephalogr. Clin. Neurophysiol.* 94 (1995) 41–49.
- [9] S. Bentin, L.Y. Deouell, Structural encoding and identification in face processing: ERP evidence for separate mechanisms, *Cogn. Neuropsychol.* 17 (2000) 35–54.
- [10] C. Braun, C. Denault, H. Cohen, I. Rouleau, Discrimination of facial identity and facial affect by temporal and frontal lobectomy patients, *Brain and Cogn.* 24 (1994) 198–212.
- [11] V. Bruce, A. Young, Understanding face recognition, *Br. J. Psychol.* 77 (1986) 305–327.
- [12] S.E. Clark, S.D. Gronlund, Global matching models of recognition memory: how the models match the data, *Psychon. Bull. Rev.* 3 (1) (1996) 37–60.
- [13] T. Curran, The electrophysiology of incidental and intentional retrieval: ERP old/new effects in lexical decision and recognition memory, *Neuropsychologia* 37 (1999) 771–785.
- [14] T. Curran, Brain potentials of recollection and familiarity, *Mem. Cogn.* 28 (2000) 923–938.
- [15] T. Curran, D.M. Tucker, M. Kutas, M.I. Posner, Topography of the N400: brain electrical activity reflecting semantic expectancy, *Electroencephalogr. Clin. Neurophysiol.* 88 (3) (1993) 188–209.
- [16] G.M. Davies, A. Milne, Recognising faces in and out of context, *Curr. Psychol. Res.* 2 (1982) 235–246.
- [17] M. D'Esposito, B.R. Postle, D. Ballard, J. Lease, Maintenance versus manipulation of information held in working memory: an event-related fMRI study, *Brain Cogn.* 41 (1999) 66–86.
- [18] D.I. Donaldson, M.D. Rugg, Event-related potential studies of associative recognition and recall: electrophysiological evidence for context dependent retrieval processes, *Brain Res. Cogn. Brain Res.* 8 (1999) 1–16.
- [19] M.C. Doyle, M.D. Rugg, T. Wells, A comparison of the electrophysiological effects of formal and repetition priming, *Psychophysiology* 33 (1996) 132–147.
- [20] M. Eimer, Does the face-specific N170 component reflect the activity of a specialized eye processor? *NeuroReport* 9 (1998) 2945–2948.
- [21] M. Eimer, The face-specific N170 component reflects late stages in the structural encoding of faces, *NeuroReport* 11 (2000) 2319–2324.
- [22] M. Eimer, Event-related brain potentials distinguish processing stages involved in face perception and recognition, *Clin. Neurophysiol.* 111 (2000) 694–705.
- [23] P.C. Fletcher, T. Shallice, C.D. Frith, R.S. Frackowiak, R.J. Dolan, The functional roles of prefrontal cortex in episodic memory: II. Retrieval *Brain; A, J. Neurol.* 121 (1998) 1249–1256.
- [24] D. Friedman, J.R. Johnson, Event-related potential (ERP) studies of memory encoding and retrieval: a selective review, *Microsc. Res. Tech.* 51 (2000) 6–28.
- [25] J.M. Fuster, Memory and planning. Two temporal perspectives of frontal lobe function, *Adv. Neurol.* 66 (1995) 9–20.
- [26] L. García-Larrea, G. Cézanne-Bert, P3, positive slow wave and working memory load: a study on the functional correlates of slow wave activity, *Electroencephalogr. Clin. Neurophysiol.* 108 (1998) 260–273.
- [27] N. George, J. Evans, N. Fiori, J. Davidoff, B. Renault, Brain events related to normal and moderated scrambles faces, *Cogn. Brain Res.* 4 (1996) 65–76.

- [28] A. Gevins, M.E. Smith, J. Le, H. Leong, J. Bennett, L. Martin, L. McEvoy, R. Du, S. Whitfield, High resolution evoked potential imaging of the cortical dynamics of human working memory, *Electroencephalogr. Clin. Neurophysiol.* 98 (1996) 327–348.
- [29] G. Gillund, R.M. Shiffrin, A retrieval mode for both recognition and recall, *Psychol. Rev.* 91 (1) (1984) 1–67.
- [30] F. Guillaume, G. Tiberghien, An event-related potential study of contextual modifications in a face recognition task, *NeuroReport* 12 (2001) 1209–1216.
- [31] F. Guillem, A. Rougier, B. Claverie, Short- and long-delay intracranial ERP repetition effects dissociate memory systems in the human brain, *J. Cogn. Neurosci.* 11 (1999) 437–458.
- [32] F. Guillem, M. Bicu, B. Debrulle, Dissociating memory processes involved in direct and indirect tests with ERPs to unfamiliar faces, *Cogn. Brain Res.* 11 (2001) 113–125.
- [33] J.B. Hancock, V. Bruce, M. Burton, Recognition of unfamiliar faces, *Trends Cogn. Sci.* 4 (2000) 330–337.
- [34] R.N. Henson, M.D. Rugg, T. Shallice, O. Josephs, R.J. Dolan, Recollection and familiarity in recognition memory: an event-related functional magnetic resonance imaging study, *J. Neurosci.* 19 (1999) 3962–3972.
- [35] D.L. Hintzman, T. Curran, Retrieval dynamics of recognition and frequency judgments: evidence for separate processes of familiarity and recall, *J. Mem. Lang.* 33 (1994) 1–18.
- [36] C. Hong Liu, A. Chaudhuri, Recognition of unfamiliar faces: three kinds of effects, *Trends Cogn. Sci.* 4 (2000) 445–446.
- [37] L.L. Jacoby, A process dissociation framework: separating automatic from intentional uses of memory, *J. Mem. Lang.* 30 (1991) 513–541.
- [38] L.L. Jacoby, J.P. Toth, A.P. Yonelinas, Separating conscious and unconscious influences of memory: measuring recollection, *J. Exp. Psychol. Gen.* 122 (1993) 139–154.
- [39] H.A. Jasper, The ten–twenty system of the international federation, *Electroencephalogr. Clin. Neurophysiol.* 10 (1958) 371–375.
- [40] D.A. Jeffreys, Visual evoked potential evidence for parallel processing of depth- and form-related information in human visual cortex, *Exp. Brain Res.* 111 (1) (1996) 79–99.
- [41] B. Jemel, N. George, L. Chaby, N. Fiori, B. Renault, Differential processing of part-to-whole and part-to-part face priming: an ERP study, *NeuroReport* 10 (1999) 1069–1075.
- [42] M.K. Johnson, C.L. Raye, False memories and confabulation, *Trends Cogn. Sci.* 2 (1998) 137–145.
- [43] M.K. Johnson, S. Hashtroudi, D.S. Lindsay, Source monitoring, *Psychol. Bull.* 114 (1993) 3–28.
- [44] M.K. Johnson, J. Kounios, S.F. Nolde, Electrophysiological brain activity and memory source monitoring, *NeuroReport* 7 (1996) 2929–2932.
- [45] K.A. Kane, T. Picton, W.M. Moscovitch, G. Winocur, Event-related potentials during conscious and automatic memory retrieval, *Cogn. Brain Res.* 10 (2000) 19–35.
- [46] G. Mandler, Recognising: the judgement of previous occurrence, *Psychol. Rev.* 87 (1980) 252–271.
- [47] G. McCarthy, A. Puce, A. Belger, T. Allison, Electrophysiological studies of human face perception: II. Response properties of face-specific potentials generated in occipitotemporal cortex, *Cereb. Cortex* 9 (5) (1999) 431–444.
- [48] J.C. McClelland, B.C. McNaughton, R.C. O'Reilly, Why are there complementary learning systems in the hippocampus and neocortex: insights from the successes and failures of connectionist models of learning and memory, *Psychol. Rev.* 102 (1995) 419–457.
- [49] J.B.B. Murdock, A theory for the storage and retrieval of item and associative information, *Psychol. Rev.* 89 (6) (1982) 609–626.
- [50] L. Nielsen-Bohlm, R.T. Knight, Electrophysiological dissociation of rapid memory mechanisms in humans, *NeuroReport* 5 (1994) 1517–1521.
- [51] S.F. Nolde, M. Johnson, C.L. Raye, The role of prefrontal cortex during tests of episodic memory, *Trends Cogn. Sci.* 2 (1998) 399–406.
- [52] C. Ranganath, M.K. Johnson, M. D'Esposito, Left anterior prefrontal activation increases with demands to recall specific perceptual information, *J. Neurosci.* 20 (2000) RC108.
- [53] M.D. Rugg, E.L. Wilding, Retrieval processing and episodic memory, *Trends Cogn. Sci.* 4 (2000) 108–115.
- [54] M. Schweich, A.-C. Schreiber, S. Rousset, R. Bruyer, G. Tiberghien, Effects of the meaning of visual context on semantic processing of famous faces, *CPC: Eur. Bull. Cogn. Psychol.* 11 (1) (1991) 55–71.
- [55] S.R. Schweinberger, E.M. Pfütze, W. Somer, Repetition priming of face recognition: evidence from ERP, *J. Exp. Psychol., Learn., Mem., Cogn.* 21 (1995) 722–736.
- [56] T. Shallice, 'Theory of mind' and the prefrontal cortex, *Brain* 124 (2001) 247–248.
- [57] M.E. Smith, Neuropsychological manifestations of recollective experience during recognition memory judgements, *J. Cogn. Neurosci.* 5 (1993) 1–13.
- [58] R. Srinivasan, P.L. Numez, R.B. Silberstein, D.M. Tucker, P.J. Cadusch, Spatial sampling and filtering of EEG with spline-Laplacians to estimate cortical potentials, *Brain Topogr.* 8 (1996) 355–366.
- [59] I. Tendolkar, M.D. Rugg, Electrophysiological dissociation of recency and recognition memory, *Neuropsychologia* 36 (1998) 477–490.
- [60] G. Tiberghien, Context and cognition: introduction, *CPC: Eur. Bull. Cogn. Psychol.* 6 (1986) 105–121.
- [61] D.M. Tucker, Spatial sampling of head electrical fields: the geodesic sensor net, *Electroencephalogr. Clin. Neurophysiol.* 87 (1993) 154–163.
- [62] E.L. Wilding, M.D. Rugg, An event-related potential study of recognition memory with and without retrieval of source, *Brain* 119 (1996) 889–905.
- [63] E.L. Wilding, M.D. Rugg, Event-related potentials and the recognition memory exclusion task, *Neuropsychologia* 35 (1997) 119–128.
- [64] E.L. Wilding, M.C. Doyle, M.D. Rugg, Recognition memory with and without retrieval context on ERP study, *Neuropsychologia* 33 (1995) 743–767.
- [65] A.P. Yonelinas, Receiver-operating characteristics in recognition memory: evidence for a dual-process model, *J. Exp. Psychol., Learn., Mem., Cogn.* 20 (6) (1994) 1341–1354.
- [66] A.P. Yonelinas, L.L. Jacoby, Response bias and the process-dissociation procedure, *J. Exp. Psychol. Gen.* 125 (1996) 422–434.
- [67] A.P. Yonelinas, L.L. Jacoby, Noncriterial recollection: familiarity as automatic irrelevant recollection, *Conscious. Cogn.* 5 (1/2) (1996) 131–141.