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ERPs ASSOCIATED WITH FAMILIARITY AND DEGREE OF FAMILIARITY DURING FACE RECOGNITION

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Event-related potentials (ERPs) triggered by three different faces (unfamiliar, famous, and the subject's own) were analyzed during passive viewing. A familiarity effect was defined as a significant difference between the two familiar faces as opposed to the unfamiliar face. A degree of familiarity effect was defined as a significant difference between

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all three conditions. The results show a familiarity effect 170 ms after stimulus onset (NI70), with larger amplitudes seen for both familiar faces. Conversely, a degree of familiarity effect arose approximately 250 ms after stimulus onset (P2) in the form of progressively smaller amplitudes as a function of familiarity (subject's face < famous face < unfamiliar). These results demonstrate that the structural encoding of faces, as reflected by N170 activities, can be modulated by familiarity and that facial representations acquire specific properties as a result of experience. Moreover, these results confirm the hypothesis that N170 is sensitive to face vs. object discriminations and to the discrimination among faces.

Keywords ERPs, face, familiarity, N170, passive viewing, self-recognition

Visual evoked potentials studies have shown that faces give rise to a posterior negative wave approximately 170 ms after stimulus onset, called the "N170" (Bentin, Allison, Puce, Perez, & McCarthy, 1996; George, Evans, Fiori, Davidoff, & Renault, 1996; Botzel, Schulze, & Stodieck, 1995), with a frontocentral counterpart, the "P2 vertex" (Jeffreys, 1989). The wave activity appears to correspond to a structural face encoding stage, as proposed by Bruce and Young (1986). However, according to these authors, this stage corresponds not only to the analysis of traits necessary for a face to be recognized as a face, as such but also to the stage where one face is differentiated from another.

Using a same/different decision task on sequentially presented pairs of familiar/unfamiliar faces, Barrett, Rugg, and Perrett (1988) observed a more negative waveform at posterior electrodes not when the second face did not match the previous one 160 ms after stim- Q2
ulus onset, but only for familiar faces. This "match/non-match" Q3
effect persists and even spreads to unfamiliar faces on the following components. These authors suggest that the earliest component reflects the beginning of a specific processing for familiar faces. Other experimenters have since explored how different recognition stages are reflected by ERP modulations (Bentin & Deouell, 2000; Eimer, 2000). However, these authors do not report a familiarity effect on the N170, but rather greater activity for familiar versus non-familiar faces approximately 400 ms after stimulus onset.

Most studies in face recognition have only included two levels of familiarity (known-unknown). A recent study (Tong & Nakayama,

1999) using reaction time measurements demonstrated that the processing of the subject's own face is always faster than a stranger's, irrespective of their orientation and even after hundreds of presentations. The authors suggest that overlearned faces ("robust representations") may mediate rapid asymptotic processing, require extensive experience to develop, contain abstract or view-invariant information, facilitate a variety of visual and decisional processes across tasks and contexts, and demand less attentional resources. These hypotheses presuppose that the enrichment of facial representations modulates face processing, depending on their degree of familiarity.

The present study was designed to investigate which components of the waveform evoked by faces are modulated by familiarity, as well as the degree of familiarity. A passive viewing experimental design was used in order to permit face recognition in a condition that occurs as naturally as possible, and thereby be ecologically valid, without being subject to influences from task-related factors that are hard to control. Moreover, familiarity and degree of familiarity are controlled because of the repeated presentations of the same faces. This design avoids the use of different levels of familiarity of famous faces, which may be subject to intersubject variability, depending on their interest and exposure time. Three different faces were used during passive viewing: an unknown face, a famous face (the actual president of France, Jacques Chirac), and the subject's own face. It was predicted that some components would display a familiarity effect, while others would display a degree of familiarity effect. A familiarity effect was defined as a significant difference between the two familiar faces, as opposed to the unfamiliar face. A degree of familiarity effect was defined as a significant difference among all three conditions.

METHODS

Subjects

Eleven subjects participated in the experiment (6 men and 5 women). All subjects were right-handed, as defined by the Edinburgh scale

(Oldfield, 1971), and had normal or corrected-to-normal vision. Their mean age was 24.5 years (ranging between 20 and 31 years).

Stimuli

The stímuli consisted of an unknown face, a famous face (the French president), and the own subject's own face as viewed by another person. Comparisons were made between signals obtained during the first and the second half of the experiment (averaging of the first 50 as opposed to the last 50 ERPs) to ensure the absence of an habituation effect. No differences were found. The subjects' faces were obtained by a videocamera and converted into pcx format with an analog/numeric converting card. The other stimuli were scanned. All images were calibrated by a new software program in a gray scale with a 8 cm × 8 cm format. The images were also calibrated in luminance and contrast by Photoshop™ software.

Procedure

After electrode placement, each subject was comfortably seated in a sound-attenuated, dimly lighted room at a distance of 90 cm from an IBM-compatible computer monitor. The subjects were instructed to look carefully at each stimulus. Each stimulus was presented in random order one hundred times (duration: 1 s, interstimulus interval: 1 s). A rest period of approximately 1 min was given after the presentation of 20 stimuli, in addition to a 10 min rest period every 30 min.

EEG Recordings

Electrical activity was recorded from 32 surface electrodes, according to the 10–20 classification system, with respect to a reference electrode placed in a frontocentral position. A common average reference was recalculated off-line from the following 19 electrodes: F3, C3, P3, F7, T3, T5, F4, C4, P4, F8, T4, T6, FZ, PZ, CP3, TP7, CP4, TP8, and CPZ. The EEG was amplified (resolution: 0.16 µV; band-pass: high-pass with a 1 s time constant and low-pass equal to 100 Hz), digitized at a rate of 256 Hz, and stored on a Deltamed™

system. Electrode impedance was kept below 5 KΩ. The EEG was continuously recorded during the experiment and codes, synchronized to stimulus delivery, were used for averaging sample epochs offline. Sample epochs began 250 ms prior to stimulus onset and ended 1 s later. During the averaging procedure, artifacts were eliminated by means of software that rejected sequences with a peak amplitude above 100 μV. After grand averaging of the eleven subjects, the data were low-pass filtered (cut-off 48 Hz) and displayed off-line in the form of raw data and topographic maps.

Statistical Analyses

Each identified component was quantified as the mean amplitude in a temporal window centered on the component. Amplitudes were measured with respect to the 250 ms prestimulus baseline. The three face conditions were first compared by analyses of variance (ANOVAs). A familiarity effect was demonstrated when an electrode presented a significant ($p < .05$) difference on planned multiple comparisons with ANO VA between familiar faces (French president and subject's own) and an unfamiliar face. A degree of familiarity effect was demonstrated when both comparisons were significant.

RESULTS

Following stimulus onset, all three stimuli evoked in the posterior region a triphasic waveform, consisting of P1, N1, and P2 components (see Figure 1). Because the posterior Pi wave is well known to be sensitive to the physical features of stimuli, it does not present variations relevant to the factors manipulated in the present study. In contrast, the N1 and P2 waves present differences in amplitude depending on the nature of the stimuli. The stimulus that gave the maximum amplitude for these two waves is not the same, an indication of differential processing.

The posterior N1 was largest in the temporal region (see Figure 2) and culminated 170 ms after stimulus onset, corresponding to the N170 (Bentin et al., 1996; George et al., 1996). A positive counterpart (P170) was observable at the midline, corresponding to the P2-

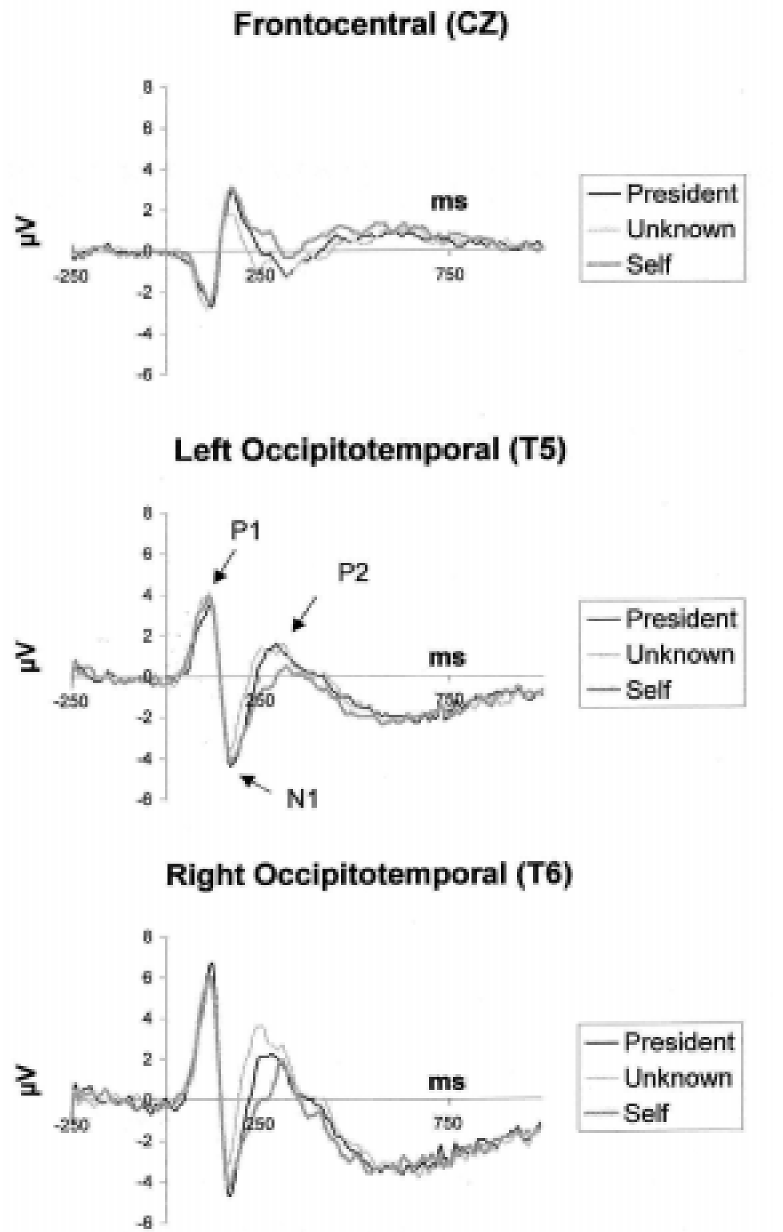

FIGURE 1. Event-related potentials obtained for the three faces after grand averaging of the 11 subjects. The N1 is larger for the familiar faces, while the P2 presents progressively larger amplitudes for less familiar faces.

vertex (Jeffrey, 1989). The analysis (see Table 1 and Figure 3) of the N170 component (time window: 150–200 ms, see Methods) revealed a familiarity effect, consisting of a larger amplitude for the two familiar faces (famous and self) than the unknown one. This difference was only significant at the right occipito-temporal region and at anterior midline sites.

The P2 wave (time window: 200–300 ms) showed a degree of familiarity effect (see Table l). Contrary to the N170, the amplitude

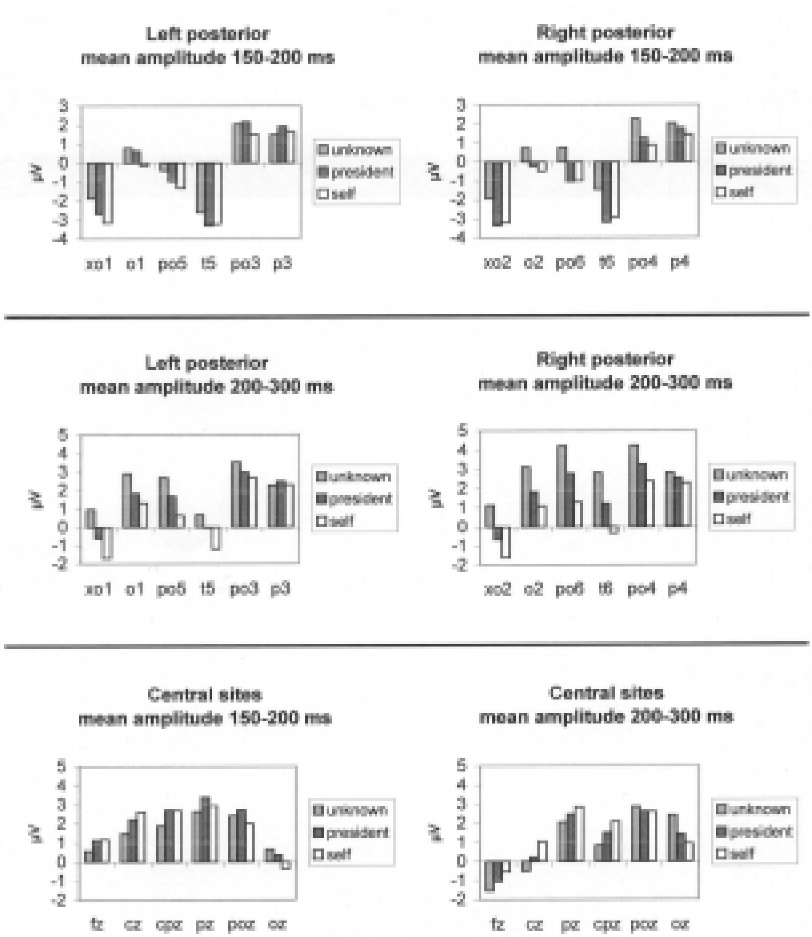

FIGURE 2. Mean amplitude for the N1 (window 150–200 ms) and the P2 (window 200–300 ms) for the three faces at left, right, and central sites.

TABLE 1. Statistical results for the comparisons of the three faces on the N1 and the P2

	N1 (140–200 ms)			*P2 (200–300 ms)*		
Electrode	*Unknown/ self*	*Unknown/ president*	*President/ self*	*Unknown/ self*	*Unknown/ president*	*President/ self*
fz	0.048	0.01	n.s.	0.005	0.016	n.s.
cz	0.007	0.02	n.s.	>.001	>.001	0.002
cpz	0.016	0.018	n.s.	>.001	>.001	0.036
pz	n.s.	0.046	n.s.	0.005	0.035	n.s.
poz	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
oz	0.038	n.s.	n.s.	>.001	0.022	n.s.
fp1	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
fp2	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
f7	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
f8	n.s.	n.s.	n.s.	n.s.	0.003	0.007
f3	n.s.	0.013	n.s.	n.s.	0.031	n.s.
f4	n.s.	n.s.	n.s.	0.008	n.s.	0.027
c3	0.011	0.03	n.s.	0.004	0.002	n.s.
c4	n.s.	n.s.	n.s.	0.002		n.s.
cp3	0.002	n.s.	n.s.	0.028	>.001	n.s.
cp4	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
p3	n.s.	n.s.	ns.	n.s.	n.s.	n.s.
p4	n.s.	n.s.	n.s.	0.038	n.s.	n.s.
po3	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
po4	0.011	0.027	n.s.	>.001	0.008	0.021
t3	n.s.	ns.	n.s.	0.008	n.s.	0.037
t4	n.s.	0.008	n.s.	n.s.	0.009	n.s.
tp7	n.s.	n.s.	n.s.	0.028	n.s.	0.006
tp8	0.008	0.002	n.s.	>.001	>.001	n.s.
t5	n.s.	n.s.	n.s.	0.001	0.027	0.004
t6	0.002	0.004	n.s.	>.001	>.001	0.002
po5	0.031	n.s.	n.s.	0.003	0.009	0.034
po6	0.016	0.002	n.s.	>.001	0.001	0.008
o1	0.042	n.s.	n.s.	0.001	0.015	n.s.
o2	0.024	0.009	n.s.	>.001	0.003	0.044
xo1	0.021	0.04	n.s.	>.001	>.001	0.041
xo2	0.021	0.003	n.s.	>.001	>.001	0.01

Note. Numbers in the table represent the *p* value of ANOVA. Nonsignificant (n.s.) effects were indicated for $p \geq .05$.

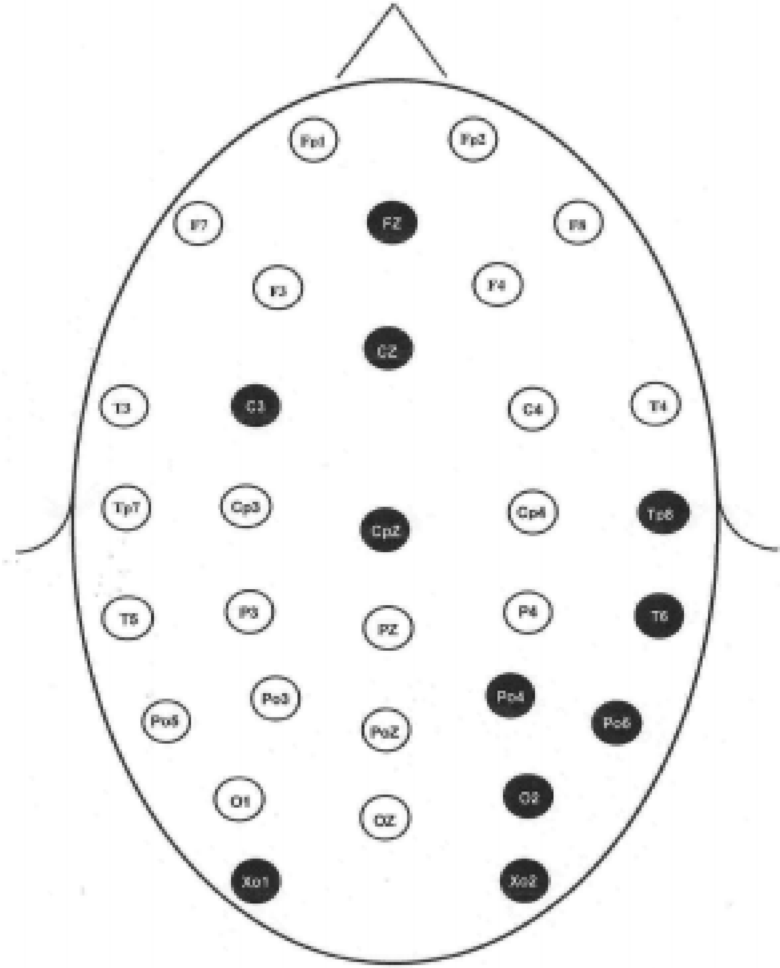

FIGURE 3. Mapping of the familiarity effect at the N170. The sites filled in black correspond to the electrodes presenting significant differences for both comparisons unknown/president and unknown/self.

of the P2 wave was larger when the face was less familiar. The scalp distribution of this effect concerns temporal (T5, PO5, T6, PO6), occipital (O1, O2, XO1, XO2), and central (FZ, CZ, CPZ, PZ, OZ) sites (see Figure 4).

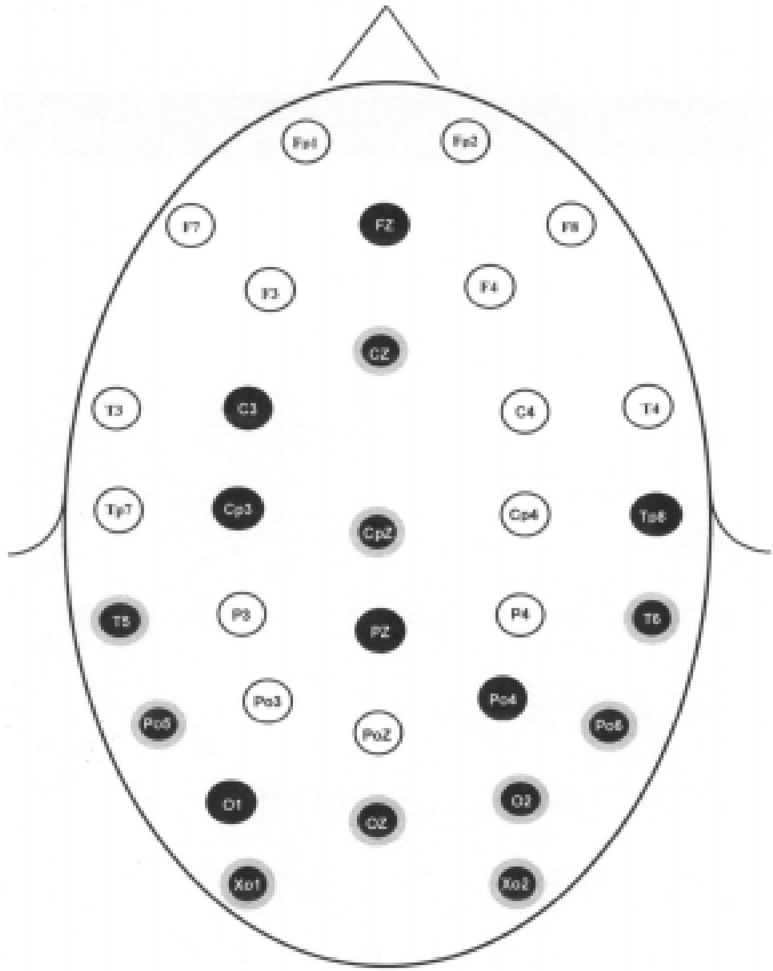

FIGURE 4. Mapping of both familiarity and degree of familiarity effects on the P2. The sites filled in black correspond to the electrodes presenting a significant differences for both comparisons (unknown/president and unknown/self). The sites circled in gray correspond to the electrodes presenting significant differences for the three comparisons (unknown/president, unknown/self and president/self).

DISCUSSION

One of the main results of the present study was the demonstration of a familiarity effect, as revealed by a higher amplitude of the N170 component for either familiar face in comparison to an unfamiliar face. This result is a possible indication that the structural encoding stage can be modulated by familiarity, explainable by the visual memory essential for the structural encoding of familiar faces. A similar result was described by Barrett et al. (1988), who observed a more negative waveform approximately 160 ms after stimulus onset for non-matching familiar faces. According to these authors, this effect reflects a modulation rather than the outcome of recognition processes, perhaps corresponding to the start of the accumulated information necessary for face discriminations. This interpretation is supported by our data because of the occurrence of the familiarity effect for the N170 without a degree of familiarity effect. We propose that at this stage of processing individual identification is not yet fully realized, but sufficient information is available for categorizing faces at an individual level. Many results in the literature support this interpretation. For example, Tanaka and Curran (2001) showed that the Nl70 may be modulated by the subject's level of expertise for other objects than faces. This component seems to reflect not only a category detection process, but also a stage where intra-category discriminations occur (see the review by Rossion and Gauthier (2002) Although this effect appears very early, such data agree with recordings of cells responsive to faces in the macaque temporal cortex. Indeed, Perrett et al. (1984) observed different firing rates between familiar as opposed to unfamiliar faces at 100 ms after stimulus onset. Thus, the structural encoding reflected by the N170 could mobilize representations linked to familiar faces. Jemel, George, Chaby, Fiori, and Renault (1999) found evidence supporting the hypothesis that the processing of the entire face and its component parts involves distinct functional mechanisms. Their results are suggestive of the existence of distributed neural networks in the inferior temporal cortex, where partial and complete facial representations may be stored. The larger negativity observed for the familiar faces may result from the activation of a larger network of representations, or else reflects the involvement of a different functional mechanism for the structural encoding of these faces.

A second hypothesis can be formulated by Yantis (1998) who suggests that face familiarity may act as an exogenous, data-driven cue attracting attention to the face. In other terms, the familiarity effect observed for the N170 could be explained by the modulation of attention.

The second main result of this study concerns the P2, N170/VPP has been suggested to be involved in the structural encoding of faces, the P2 may represent a component of explicit or implicit memory, as this wave is sensitive not only to recognition but also to priming tasks (Begleiter, Porjesz, Wang, and Zhang, 1993; Hertz, Porjesz, Begleiter, & Chorlian, 1994; Rossion et al., 1999). Moreover, Hertz et al. (1994) reported slowing of this component during a matching-to-sample task of scrambled as opposed to normal faces. Thus, this component could reflect the stage of the matching of the percept with face recognition units described by Bruce and Young (1986).

The degree of familiarity effect on the P2 consists of a larger positivity for less familiar faces, in particular at frontocentral and temporal sites. These results are consistent with the hypothesis that learning of face attributes continues over a long period and that extensive visual experience shapes the facial representations and their processing to an endpoint that reflects the development of a "robust representation" (Tong & Nakayama, 1999). The smaller amplitude observed for the subject's own face relative to the famous one may correspond to a lesser demand of attentional resources, as described by Tong and Nakayama (1999). In a similar vein, the larger amplitude for the unknown face than the familiar ones could reflect a more extensive search in memory. In a control experiment (unpublished results), we have tested the inversion effect for these three faces. In the inverted condition, we obtained for the P2 the same pattern of amplitude variation (i.e., subject < famous <unknown, in line with the idea that the representations change with experience, facilitating the information processing of familiar faces) (Tong & Nakayama, 1999). According to the latter authors, the subject's own face is always processed more rapidly irrespective of experimental conditions. This advantage persists even after hundreds of trials with the unknown face and whether or not the profile is atypical or inverted.

In contrast to the above-cited results, other experimenters (Bentin & Deouell, 2000; Eimer, 2000) have used two familiarity levels (known and unknown) and found an effect on the N400 (more negative for the familiar faces) but not on the N 170. Methodological factors may explain these different results. The different types of tasks used, such as match/non-match decisions, discrimination, recognition, counting the appearance of an infrequently appearing item, could lead to different strategies, depending on which dimension of the face is relevant to the mental task. For example, an "identify the profes- Q4 sion" task may not require the same encoding process and the be- fore the same facial representation as a "match/non-match" task. Q5 The absence of a N400 effect in the present study could be due to the use of the passive viewing condition, leading subjects to recognition in the absence of the retrieval of semantic information, as is more likely to occur in tasks requiring the ability of detecting the subject's identity or profession. Moreover, Bentin and Deouell (2000, 3rd experiment) suggest that different strategies may be employed for categorizing familiar as opposed to unfamiliar faces. One strategy consists in performing a familiarity judgement and another consists in identifying faces in a more complete way. The latter strategy may initiate N400 activity.

The choice of the electrical reference may also account for discrepancies in outcome. The choice of the reference has substantial effects on the observation of temporal negativities (Botzel et al., 1996; Dien, 1998; Seek & Grusser, 1992). While Eimer (2000) and Bentin and Deouell (2000) used as reference the tip of the nose, Barrett et al. (1988) used a mastoid reference, and we used an average reference from 19 electrodes.

Three conclusions of the present report are presented. First, we observed a familiarity effect for the N 170, perhaps indicating that the internal face representations at the perceptual and non-semantic level interact with the structural encoding of faces. Second, a degree of familiarity effect occurred approximately 250 ms after stimulus onset, compatible with the idea that face representations are enriched with extensive visual experience. Third, relative to previous studies, the exact nature of the task appears to be an important modulator of the structural encoding of faces in a way that remains to be determined.

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