

## ERP evidence for task modulations on face perceptual processing at different spatial scales

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### Abstract

Does the perceptual processing of faces flexibly adapt to the requirements of the categorization task at hand, or does it operate independently of this cognitive context? Behavioral studies have shown that the fine and coarse spatial scales of a face are differentially processed depending on the categorization task performed, thus suggesting that the latter can influence stimulus perception. Here, we investigated the time course of these task influences on perceptual processing by examining the visual N170 face-sensitive Event-Related Potential (ERP), while observers categorized faces for their gender and familiarity. Stimuli were full spectrum, or filtered versions that preserved either coarse or fine scale information of the faces. Behavioral results replicated previous findings of a differential processing of coarse and fine spatial scales across tasks. In addition, the N170 amplitude was larger in the Gender task as compared to the Familiarity task for LSF faces exclusively, thus showing that task demands differentially modulated the spatial scale processing on faces. These results suggest that the diagnosticity of scale-specific cues in categorization tasks can modulate face processing.

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## 1. Introduction

Capacity limitations force the visual system to selectively process the outside world information impinging on the retina. In high level vision for instance, to categorize the gender of a face, the visual system can selectively attend to its smooth contours, its eyelashes, the shape of the eyes or the mouth and other similarly diagnostic information of the stimulus to deduce that it is a female. This raises the possibility that the categorization task itself (here, gender) can drive the selective search of information from the visual array, allowing the visual system to tune to the input features that are most useful for the task at hand. In this sense, a categorization task is a cognitive context that might modulate the encoding functions of vision (Schyns, 1998).

The statement that such cognitive factors influence visual processes remains a core issue in cognitive science (e.g., Pylyshyn, 1999). The advocates of the *cognitive impenetrability* of vision (Fodor, 1983; Pylyshyn, 1980, 1999) argue that perceptual analysis operates as an encapsulated system, independently of cognitive influences. However, there is evidence that categorization modifies the perception of the stimulus (e.g., Goldstone, 1994; Schyns & Oliva, 1999; Schyns & Rodet, 1997; Schyns, Bonnar, & Gosselin, 2002). For example, Schyns and Oliva (1999) showed that the perceptual cues most useful for determining the identity, gender and expression of a face may be associated with different spatial scales (technically, different spatial frequencies). The perception of an identical face could therefore depend on the categorization task being performed. Schyns and Oliva (1999) addressed this question using hybrids derived from the faces of unfamiliar people. For example, a happy male face at fine, High Spatial Frequencies (HSF) may be superimposed with an angry female face at coarser, Low Spatial Frequencies (LSF). In their first experiment, stimuli were presented for 50 ms, and the nature of the categorization was indeed found to modulate the perception of the stimulus. For example, when asked if the face was expressive or not, observers tended to report their decision based on the information contained in the fine scale face, whereas they used the information contained in the coarse scale when asked to pinpoint the expression as happy, angry or neutral. However, observers remained unaware of the presence of two faces in any one image. In short, the use of spatial scales was determined by the categorization task. This suggests that categorization processes tune into diagnostic information at specific spatial scales.

More recent investigations (Schyns et al., 2002) using a new technique called *Bubbles* (Gosselin & Schyns, 2001), precisely gauged which face information a categorization task requires. *Bubbles* localized the required information in both the  $x$ -,  $y$ -coordinates and the spatial scales of the face stimulus. In a gender task, the authors showed that decisions relied predominantly on the LSF cues of faces. Such LSF bias was less clear in an identification task, due to high involvement of HSF information, suggesting that a LSF bias characterizes gender classification, whereas face identification is not biased that way.

Spatial scale processing is known to be an early operation of the visual system (see De Valois & De Valois, 1990, for a review). If the results just discussed suggest that scale perception is cognitively penetrable, it must be noted that the evidence is indirect because reported biases of Schyns and co-workers (1999, 2002) compress many processing stages extending from the primary extraction of visual features (as computed in V1), to the post-decisional motor performance. A more direct measure than categorization behavior might be required to firmly establish a modulation of visual processing.

ERPs provide this direct measure (Rugg & Coles, 1995). The EEG/ERP method samples brain activity at a high temporal resolution so that the time course of brain activation related to visual processes can be tracked. Given the type of stimulation (i.e., faces) used in the reviewed experiments, we will examine the N170 component. The N170 is an electrophysiological response that is maximal at occipito-temporal sites following the presentation of faces (e.g., Bentin, Allison, Puce, Perez, & McCarthy, 1996), and which is also observed with a lower amplitude at the same sites for multiple non-face objects (e.g., Rossion et al., 2000). Elicited by faces, the N170 is considered as reflecting a stage of visual processing immune to background knowledge and task influences. For instance, the familiarity of the face does not influence the N170 (Bentin & Deouell, 2000; Eimer, 2000b; Rossion et al., 1999), nor does the type of categorization task performed (Carmel & Bentin, 2002; Cauquil, Edmonds, & Taylor, 2000; Rossion et al., 1999). Consequently, the N170 has been equated to the construction of the structural representation of a face configuration (Bentin et al., 1996; Eimer, 1998). The fact that previous knowledge of the face or the relevant information to extract does not appear to influence the N170 is in agreement with the cognitive impenetrability of visual processes since this hypothesis includes high-level visual processes (Pylyshyn, 1999).

To resolve the apparent contradiction between these ERP results and the behavioral evidence that categorization modifies the perception of face stimuli, we used a within-subject design to examine modulations of the N170 when observers performed two different categorization tasks (Gender and Familiarity) on identical sets of faces presented in their normal, coarse and fine scale versions. If the categorization task modifies the processing of spatial scales on faces when the face perceptual representation is extracted, we should observe corresponding modulations of the N170 component. Specifically, we expected to observe an increase of the N170 amplitude when the diagnostic information for the task at hand is contained in the stimulus (i.e., at either fine or coarse spatial scale). Since LSF faces contain the most diagnostic cues for Gender, they should produce better performance and larger N170 amplitude than HSF faces. On the other hand, the Familiarity task which requires the identification of a particular face should reduce such advantage, reflecting the increased contribution of HSF cues in this task (Schyns et al., 2002). These hypotheses were motivated by a related ERP literature showing increases of amplitude of the N170 component to non-face objects with visual expertise (Tanaka & Curran, 2001), and subordinate level of categorization (Tanaka, Luu, Weisbrod, & Kiefer, 1999) suggesting that the extraction of relevant visual information is indeed associated with increases in activation of occipito-temporal visual components. Such modulations of the electrophysiological markers of visual processes in response to cognitive demands would provide more direct support for the idea that categorization flexibly adjusts the perceptual encoding of the required diagnostic cues, thus confirming one implementation of cognitive penetrability.

## 2. Methods

### 2.1. Subjects

Twenty-one naive subjects, with normal or corrected to normal vision, took part in the experiment (mean age: 23.7; three were left-handed).

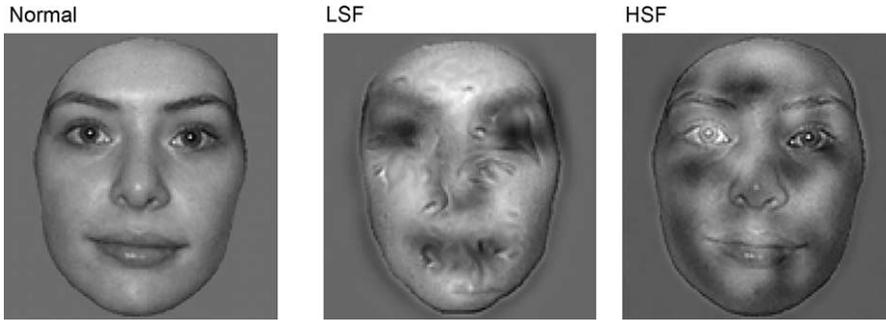


Fig. 1. Example of the face stimuli used in the experiment. From left to right, the pictures depict a Normal face and its corresponding coarse scale (LSF) and fine scale (HSF) versions. A LSF face comprised spatial frequencies below 8 cycles per image combined with fine scale noise (noise was jumbled face features). An HSF face depicted jumbled face features at coarse scale combined with fine scale face information (preserving frequencies over 16 cycles per image). Thus, the Normal, LSF and HSF stimuli were all full spectrum stimuli with a similar average spectral energy.

## 2.2. Stimuli

We used 20 unfamiliar gray-scale pictures of faces evenly distributed between males and females. The face pictures were trimmed to remove background, clothing and hairline and were fitted onto a gray square subtending  $3.7 \times 3.7^\circ$  of visual angle at a 100 cm viewing distance. For each of the 20 original face pictures, we computed a coarse scale and a fine scale version (see Fig. 1, from left to right, a Normal, coarse scale and fine scale version of the same face).

A coarse scale stimulus depicted a face at LSF (retaining only those spatial frequencies below 8 cycles per image) combined with fine scale noise (noise was composed of jumbled face features). A fine scale stimulus depicted coarse scale noise combined with a face at HSF (preserving frequencies over 16 cycles per image; to ensure clear separation, we left one octave between the low and high spatial frequency bandwidths). An important feature of this stimulus design is that the three stimulus conditions (Normal, LSF and HSF) were all (1) full spectrum and (2) equated for their average spectral energy. That is, the Normal, LSF and HSF versions of the same face had on average the same contrast energy because we replaced filtered face information with noisy face features of the same average contrast energy. Thus, the three stimulus conditions only differed with respect to the presented bandwidth of relevant face information (i.e., all spectrum vs. LSF vs. HSF), not their contrast energy. Behavioral or ERP differences arising between the Normal, LSF or HSF faces can only stem from differences in the face information available, an important control often neglected in studies of recognition at different spatial scales.

## 2.3. Design and procedure

In a within-subject design, all participants underwent a training phase before being tested in a gender and a familiarity categorization task. During testing, we recorded the observers' response accuracy and latency and EEG.

### 2.3.1. Training phase

Subjects were presented with the 20 original face pictures. In a given trial, two faces of the same gender appeared simultaneously on the screen, together with a written cue indicating their gender. In a self-paced presentation procedure, we instructed observers to study the gender of the face. We then randomly selected a subset of 10 faces from this set and asked observers to learn the name corresponding to each face. All subjects were trained with the same random set, which constituted the set of so-called “familiar” faces. Each name appeared at the center of the screen, immediately followed by one face. To test their knowledge of the face-name pairings, a face appeared and observers had to name it aloud. When the observers were able to name correctly all the faces twice, they entered the testing phase. On average, the training phase lasted for about 15 min, or eight repetitions of the pairs of face pictures.

### 2.3.2. Testing phase

Following training, observers were submitted to the Gender and Familiarity tasks on the Normal, the LSF and the HSF faces. Half of the observers began with Gender, the other half started with Familiarity. In each task, all observers saw the Normal faces first, followed by the LSF, and the HSF faces (the order of LSF and HSF conditions was counterbalanced across observers). The use of a block design for both the types of stimuli and the tasks was motivated by previous behavioral studies run in these conditions (Oliva & Schyns, 1997; Schyns & Oliva, 1999) and by a too low performance level observed with intermixed design during pilot experiments. A trial consisted of the presentation of a face stimulus (Normal, LSF or HSF) for 120 ms, followed by an average ISI of 1700 ms (randomized between 1600 and 1800 ms). Observers responded by pressing one of two response keys (associated with male vs. female in Gender, and familiar vs. unfamiliar in Familiarity). There were 600 trials in total (20 Normal + 20 LSF + 20 HSF faces, each repeated five times in both the Gender and Familiarity tasks). Every 25 trials, observers marked a pause. The experiment lasted for about 40 min.

## 2.4. EEG recordings

During the testing stage, we recorded EEG using 64 electrodes mounted in a Quickcap<sup>®</sup>. Electrode positions included the standard 10–20 system locations and additional intermediate positions (Fig. 2). Four facial bipolar electrodes placed on the outer canthi of the eyes and in the inferior and superior areas of the orbit monitored horizontal and vertical EOG (HEOG and VEOG), respectively. EEG was continuously recorded at a rate of 500 Hz with a left mastoid reference. The signal was amplified by Synamps<sup>®</sup> amplifiers and band-pass filtered online at 0.01–40 Hz. The raw EEG data was digitally filtered, using a 101-point digital 1–30 Hz band-pass FIR filter, with cut-off frequencies of 28.01 Hz (–3 dB point), and a stop-band attenuation of –65.6 dB (50 Hz and above). We performed signal epoching 200 ms prior to and 800 ms after stimulus onset, and the pre-stimulus interval was used for baseline correction. Prior to averaging, epochs were screened for eye blinks and other artifacts. The epochs were excluded from averaging if the standard deviation of the EEG within a sliding 200-ms time window exceeded 40  $\mu$ V. Incorrect trials were also excluded from the ERPs. ERPs were corrected for eye blinks by the subtraction of PCA-transformed EOG components for

each electrode, weighted according VEOG propagation factors (computed via linear regression; Nowagk & Pfeifer, 1996). After VEOG correction and rejection of artifacted ERPs, the number of sweeps was equalized across conditions for each subject, resulting in a mean of 57 sweeps averaged per condition per subject. Averaged ERPs were re-referenced using an average-reference.

2.5. Data analyses

ERP analyses of the present study were conducted on the mean N170 amplitude values, which were measured in a time interval centered on average N170 latency (e.g., 150–200-ms window). Occipito-temporal electrodes in the left and right hemispheres (PO7, PO5, P7, P5 and PO8, PO6, P8, P6, respectively) displayed maximal N170 amplitudes. Analyses were conducted on mean amplitude values averaged across these maximal electrodes (Fig. 2). We computed repeated-measure analyses of variance (ANOVAs) on the behavioral and mean N170 amplitudes with the factors of Task (Gender–Familiarity), Stimulus (Normal–LSF–HSF), and electrode Laterality (left–right). All effects with two or more degrees of freedom in the numerator were adjusted for violations of sphericity according to the Greenhouse–Geisser correction. Polynomial contrasts were used for *post hoc* comparisons.

To ascertain that modulations observed on N170 amplitude did not stem from earlier effects, i.e., P100 modulations, we performed complementary analyses on P100 amplitude. P100 amplitude was measured in a time interval centered on average P100 latency (e.g., 100–150-ms window). Results of P100 analyses are reported in note 1.

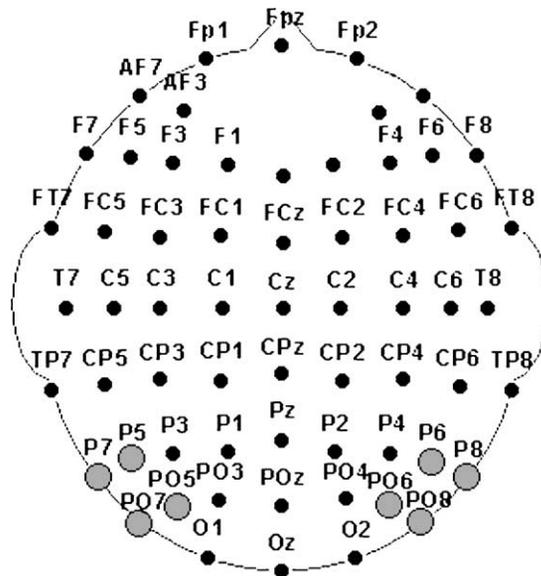


Fig. 2. Scalp locations of the 64 EEG electrodes distributed at the standard 10–20 system locations and additional intermediate positions. N170 mean amplitude was measured at left and right occipito-temporal electrodes (gray circles).

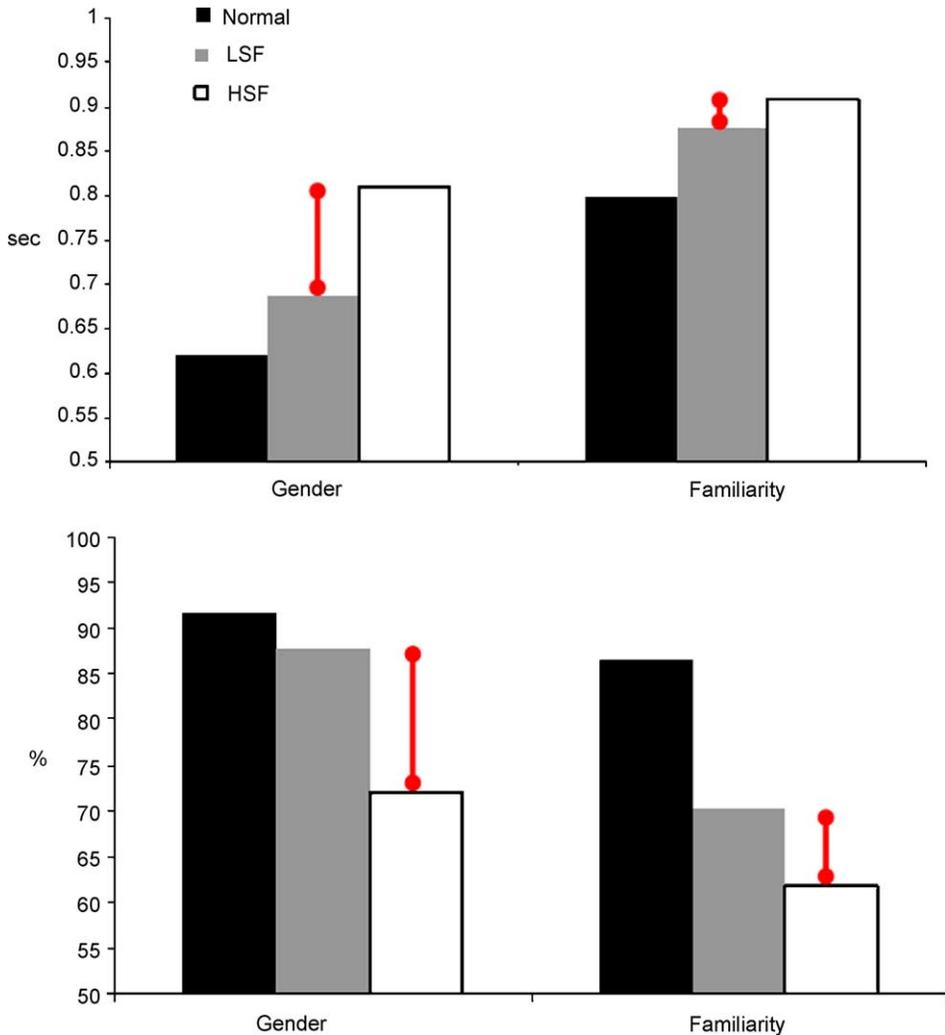


Fig. 3. Graphic illustration of mean response times (in seconds) and accuracy (in percent correct) across experimental conditions. The bars show the evolution of LSF–HSF performance difference across tasks.

### 3. Results

#### 3.1. Behavioral performance

Mean accuracy (percent correct) and response latencies (seconds) are shown in Fig. 3. Subjects were faster,  $F(1, 20) = 130, p < .0001$ , more accurate  $F(1, 20) = 90.53, p < .0001$ , in Gender than in Familiarity. Stimulus affected response accuracy,  $F(1.9, 37.8) = 88.12, p < .0001$ , and response latency,  $F(1.9, 38) = 39.4, p < .0001$ , with a linear decrease of accuracy and increase of latency from Normal to LSF to HSF faces. The interaction between the two factors was significant in accuracy,  $F(1.9, 37.7) = 13.4, p < .0001$ , and response latencies,

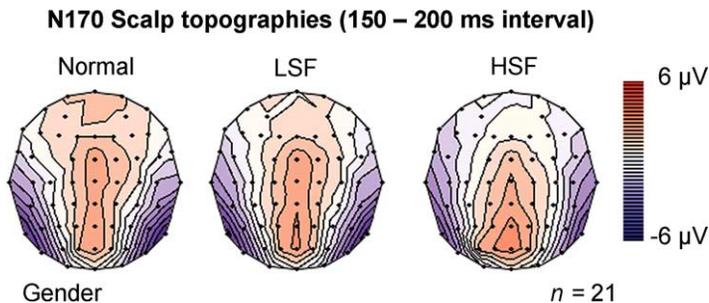


Fig. 4. Scalp topography of grand-average ERPs ( $n = 21$ ) recorded during 150–200-ms time interval for Normal, LSF and HSF faces in Gender. Note the N170 amplitude decrease for HSF as compared to Normal and LSF faces.

$F(1.4, 27.3) = 13.4, p < .017$ . In Gender, LSF faces were processed faster,  $p < .0001$  and better,  $p < .0001$  than HSF faces. In Familiarity, the LSF advantage in response latency was no longer significant,  $p = .095$ , whereas LSF advantage in accuracy was still present,  $p < .001$ , but significantly reduced as compared to Gender,  $p < .01$ .

The behavioral data revealed that subjects perceived LSF and HSF faces differently according to the task at hand. They performed better with LSF faces than HSF faces in Gender task, an advantage which was largely and significantly attenuated in the Familiarity task. This

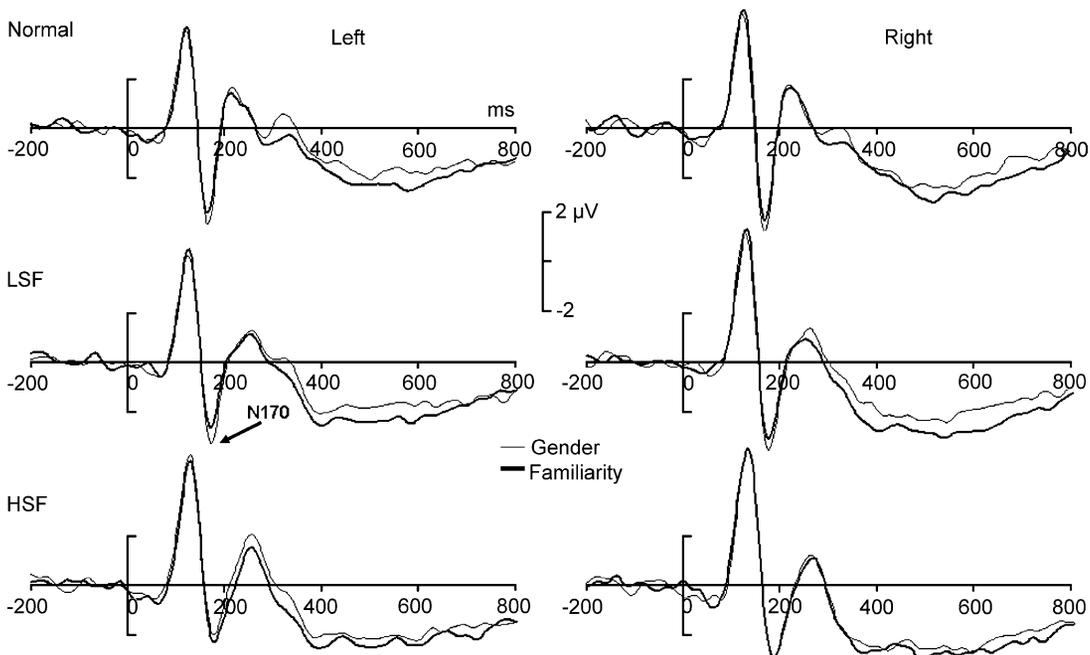


Fig. 5. Grand-average ERPs ( $n = 21$ ) recorded on left and right hemispheres at occipito-temporal electrodes are presented for Gender (thin line) and Familiarity (thick line) in Normal, LSF and HSF conditions. The N170 amplitude decreases in Familiarity task for LSF faces only.

pattern of results suggests that LSF faces were more diagnostic than HSF faces in Gender, an advantage which disappeared or was at the least consistently reduced in the Familiarity task.

### 3.2. Event-related potentials

Fig. 4 shows the scalp topographic distribution of the grand-average ERPs ( $n = 21$ ) recorded in the 150–200 ms interval after the presentation of Normal, LSF and HSF faces (for Gender). The N170 was observed bilaterally on occipito-temporal electrodes.

The N170 mean amplitude significantly differed across stimulus types,  $F(1.4, 27.5) = 4.08, p < .042$ . It was maximal for Normal faces and decreased for LSF faces, though not significantly,  $p = .6$ . It was minimal for HSF faces, which evoked a significantly smaller N170 as compared to Normal,  $p < .05$ , and LSF faces,  $p < .01$ . Importantly, the Task  $\times$  Stimulus interaction was significant,  $F(1.6, 31.7) = 4.08, p < .027$ . We observed a significant increase of the N170 amplitude during the Gender as compared to the Familiarity task for LSF faces exclusively,  $p < .04$  (Fig. 5). No task modulation was observed for Normal and HSF faces

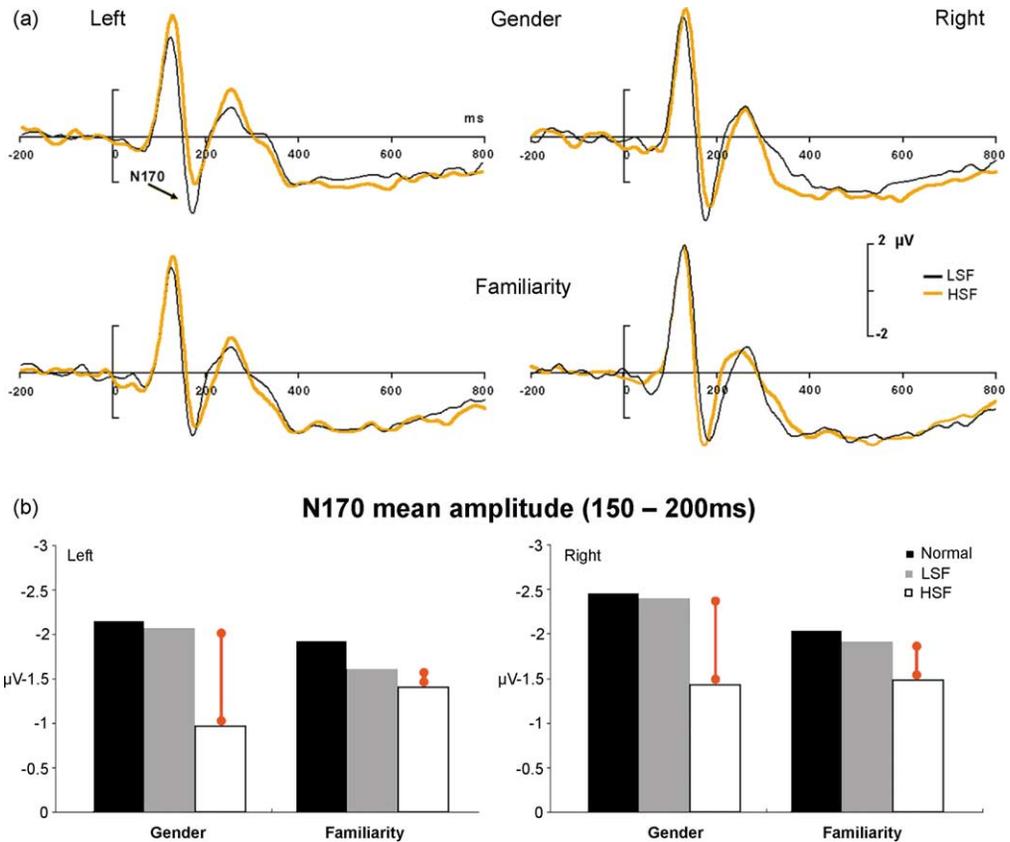


Fig. 6. (a) Grand-average ERPs ( $n = 21$ ) recorded for LSF and HSF faces are compared across tasks. (b) Graphic illustration of mean N170 amplitude across task and stimulus conditions, over left and right occipito-temporal electrodes. One observes that LSF faces evoke larger N170 amplitude than HSF faces in Gender, but not in Familiarity.

( $p = .31$  and  $p = .39$ , respectively). In the Gender task, the N170 amplitude recorded for LSF faces was larger than for HSF faces,  $p < .002$  (Fig. 6). In the Familiarity task, there was no significant amplitude difference between the two stimulus types,  $p = .2$ .

The analyses conducted on P100 amplitude did not reveal any Task  $\times$  Stimulus interaction,<sup>1</sup> thus circumscribing the interaction of interest to the N170 stage of processing.

In sum, the N170 amplitude was larger in the Gender task as compared to the Familiarity task for LSF faces exclusively, thus showing that task demands differentially modulated the spatial scale processing on faces. In Gender, we observed a significantly larger N170 amplitude to LSF as compared to HSF faces. This LSF–HSF amplitude difference was abolished in the Familiarity task.

#### 4. Discussion

Behavioral studies have established that the categorization task can modulate the use of spatial scales in recognition (Schyns & Oliva, 1999; Schyns et al., 2002). However, the temporal locus of the task modulation (i.e., early vs. late) has so far remained unsettled. According to the cognitive impenetrability hypothesis (Fodor, 1983; Pylyshyn, 1980, 1999), the extraction of spatial scales information during the construction of a face representation should be immune to task influences, which would take place outside of the visual system. In a related vein, previous ERP studies using full-scale stimuli have failed to report any task modulations of the N170 to faces (Carmel & Bentin, 2002; Cauquil et al., 2000; Rossion et al., 1999).

The behavioral data reported here replicated the differential, categorization-specific use of spatial scale analogous of Schyns and co-workers (Schyns & Oliva, 1999; Schyns et al., 2002; see also Oliva & Schyns, 1997). While cues represented at a coarse scale allowed better performance in Gender as compared to fine scale cues, this advantage vanished in Familiarity task. Given that our procedure strictly equated the stimuli presented in both tasks, a difference in the statistics of low-level image cues cannot account for the reported differences. Instead, the conclusion is that visual cues associated with LSF were differently involved in Familiarity and Gender.

Examination of the N170 confirmed that the LSF features were differentially encoded according to the task required. The N170 amplitude for LSF faces was larger than for HSF faces in the Gender task only, reflecting the diagnosticity of LSF cues in this peculiar task. A recent study has also shown an advantage of LSF cues on the N170 response to faces, but not objects, in a very simple orientation decision task (Goffaux, Gauthier, & Rossion, *in press*). Here, we show for the first time that this larger N170 to LSF faces is dependant on the task at hand. In the Familiarity task, the N170 amplitudes recorded for the two stimulus conditions were no more distinguishable, because the N170 amplitude was reduced in the Familiarity task for LSF faces. N170 amplitude modulations thus mirrored behavioral data and previous studies showing that LSF advantage in a gender decision is greatly reduced in tasks involving face identification.

Since the contribution of HSF information was probably higher in face identification (Familiarity) than in gender classification (Schyns et al., 2002), one might have expected a N170 amplitude increase for HSF faces in Familiarity as compared to Gender. Several reasons may account for the absence of such effect (although a slight trend was observed, see Fig. 5). First,

Schyns et al. (2002) showed that even though the use of HSF cues increases in face identification, LSF processing is still largely involved in this task. The latter could thus have masked the subtle modulations of HSF processing. Second, modulations in HSF involvement might be reflected at later stages of visual processing than the N170.

We interpret the top-down influence observed on the N170 as reflecting the differential processing of scale information in faces across tasks. Yet, one may argue that they could result from sustained and non-specific factors such as task difficulty or arousal. However, several aspects suggest that this interpretation cannot account for the results reported here. First, the level of task difficulty does not seem to modulate the N170 in response to faces (Rossion et al., 1999). Secondly, the face familiarity task being more difficult, a simple sustained attentional effect should have led to a general increase of all the components in that particular task, especially for HSF stimuli, which was not the case (Fig. 5). Such a simple effect of task difficulty has indeed been reported at the level of occipital P100 for faces (Rossion et al., 1999). However, here the absence of any Task by Stimulus interaction on the preceding P100 precludes that the N170 modulations of interest might result from sustained and non-specific factors such as task difficulty or arousal. It rather suggests that the modulations observed are selectively related to the differential processing of scale information in faces across tasks at the level of N170.

In his influential article, Pylyshyn concedes that cognition can, in some cases, affect the content of visual perception when attention is allocated to particular stimulus sub-regions. The effects of attention to early visual processing stages to which Pylyshyn (1999) refers have been extremely well-documented in ERP studies (for a review, see Hillyard & Anllo-Vento, 1998). They are observed usually for peripheral targets, and always when targets are explicitly (through task instructions) attended versus non-attended, or when targets are cued by peripheral cues. Attentional allocation generally affects the amplitude of both visual P100 and N100 components. By contrast, the present experiment shows that the cognitive context, derived from specific task constraints, can bias the processing of stimulus cues (LSF vs. HSF) according to their task diagnosticity. Related ERP modulations were selectively observed at the level of the N170<sup>2</sup> and not on the P100. Our results thus show that the cognitive intervention in visual processing is not limited to the attentional selection of spatial portions of a stimulus array, as Pylyshyn thought. Rather, the specific N170 effects suggest that the cognitive modulations are selectively related to the differential processing of face scales across tasks.

Our findings may be related to two recent ERP studies also suggesting a cognitive penetrability of the structural encoding stage of faces at the level of the N170 (Bentin & Golland, 2002; Bentin, Sagiv, Mecklinger, Friederici, & von Cramon, 2002). In these, it was shown that schematic stimuli, either a pair of small line-shapes presented in isolation (Bentin et al., 2002) or scrambled schematic faces, elicited a conspicuous N170 only after subjects were presented with schematic face stimuli. In other words, the subjects had to “know” that these schematic pictures were somewhat related to faces in order to elicit a N170 visual response. Both this type of data and what is reported here support the cognitive penetrability of early face visual processing. In the present study, the top-down influences arise from changing the task constraint rather than the meaning of the stimulus. Such modulations of the N170 are of great interest in face processing since many ERP studies have assumed that the N170 reflects an automatic perceptual encoding stage of faces that is impervious to cognitive context (Bentin & Deouell, 2000; Carmel & Bentin, 2002; Cauquil et al., 2000; Eimer, 2000b). Nevertheless, our results

show that subtle differences of task demands can modulate face processing as early as a visual structural encoding stage of faces takes place, thus questioning the idea that it operates as an encapsulated processing system.

## 5. Concluding remarks

Our behavioral results confirmed a selective, task-dependent use of spatial scale cues, which was correlated with task modulations of the N170 visual component. The importance of our contribution is that the reported modulation arises from task differences, given that all other factors under experimental control (notably the stimuli) were identical across the two categorization tasks. These results demonstrate that visual perception is flexible and adapts to subtle modulations of cognitive context, even in the case of highly expert processes as those implicated in face perception.

## Notes

1. When computed on P100 amplitude values, the three-way ANOVA revealed a significant effect of Stimulus,  $F(1.6, 33) = 15.93$ ,  $p < .001$ . P100 amplitude increased linearly from Normal to LSF,  $p < .006$ , and from LSF to HSF faces,  $p < .003$ . Neither effect of Task, nor Task  $\times$  Stimulus interaction was significant,  $p > .4$ .
2. Note that Eimer (2000a) found an effect of selective attention on the N170 but only when the N170 responses were compared between faces and objects, and one category or the other had to be explicitly processed or ignored, which is quite different than the task modulations reported here within the face domain.

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