Is sex categorization from faces really parallel to face recognition?

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According to a classical functional architecture of face processing (Bruce & Young, 1986), sex processing on faces is a parallel function to individual face recognition. One consequence of the model is thus that sex categorization on faces is not influenced by face familiarity. However, the behavioural and neuropsychological evidences supporting this dissociation are yet equivocal. To test the independence between sex processing on faces and familiar face recognition, familiar (learned) faces were morphed with new faces, generating facial continua of visual similarity to familiar faces. First, a pilot experiment shown that subjects familiarized with one extreme of the face continuum roughly perceive one half of the continuum (60 to 100% of visual similarity to familiar faces) as made of familiar faces and the other part as unfamiliar. In the experiment proper, subjects were familiarized with faces and tested in a sex decision task made on faces at the different steps of the continua. Subjects were significantly quicker at telling the sex of faces perceived as familiar (60−100%), and the effect was not observed in a control (untrained) group. These results indicate that familiar face representations are activated before sex categorization is completed, and can facilitate this processing. The nature of the interaction between sex categorization on faces and familiar face recognition is discussed.

Face processing is one of the most important social and biological function studied in cognitive neuroscience, not only because it is essential to distinguish familiar individuals to unfamiliar from their faces and to recall specific information about the familiar ones, but also because the face conveys a great deal of

other socially relevant information such as the sex of the person, his/her mood, overall age, and so on.

From the cognitive point of view, studies of face processing aim at clarifying the different operations involved in face processing and how they interact with each other, as well as describing what kinds of facial cues are used to perform these operations. Regarding the first objective, the field mainly rests on the cognitive architecture proposed by Bruce and Young (1986), describing the perceptual and cognitive processes involved in face processing. This model is largely modular since it proposes that the different sub-functions of face processing are computed independently. At the core of this architecture is the distinction between an individual face recognition pathway, aimed at identifying the person, and parallel pathways involved in processing facial expression, facial speech, and ''visually derived semantic information'' from the face such as the sex, the age, or race of the bearer (Bruce & Young, 1986). The processing of the cues leading to these latter categorization are considered to be independent of facial identity processing and face recognition (deciding whether the face has been previously seen or not). The independence of these two pathways has gained support from various evidences, including behavioural experiments (e.g., Bruce, 1986; Bruce, Ellis, Gibling, & Young, 1987; Campbell, Brooks, deHaart, & Roberts, 1996; Wild et al., 2000; Young et al., 1986), neuropsychological impairments (e.g., Campbell, Landis, & Regard, 1986, Tranel, Damasio, & Damasio, 1988), cellular recordings in monkeys (see Rolls, 1992), event-related potentials (e.g., Munte et al., 1998), and neuroimaging studies on humans (e.g., Sergent, Otha, MacDonald, & Zuck, 1994; see Haxby, Hoffman, & Gobbini, 2000). More precisely, behavioural studies conducted in the mid-1980s have shown that facial expression analysis (Young, McWeeny, Hay, & Ellis, 1986) and sex decisions (Bruce, 1986) were not influenced by face familiarity, and that subjects can selectively attend to either identity or emotion in sorting tasks (Etcoff, 1984). A double dissociation between facial expression processing and familiar face recognition has also been described: Prosopagnosic patients still able to recognize facial expressions (e.g., Bruyer et al., 1983; Tranel et al., 1988) and also patients impaired at facial expression analysis but still able to recognize familiar faces (Kurkucz & Feldmar, 1979; see Humphreys, Donnelly, & Riddoch, 1993). Dissociations between facial speech analysis and face recognition have also been described in the neuropsychological literature (Campbell et al., 1986). In the monkey brain, different cells have been described that respond to a face configuration with sensitivity to facial identity and facial expressions (Hasselmo, Rolls, & Baylis, 1989) and other cells have been found to be specifically sensitive to eye-gaze direction (Perrett et al., 1988). Recent ERPs studies have also provided various evidence suggesting that facial identity could be spatio-temporally dissociated from facial expression (Munte et al., 1998) and sex processing (Mouchetant-Rostaing et al., 2000). Finally, neuroimaging studies in the 1990s have enabled the drawing of the first intelligible map of the neural systems involved in face

processing in humans, with the different face functions associated with distinct cortical and subcortical regions (see Haxby et al., 2000).

However, if no one disputes that different face processing functions are not overlapping—both functionally and neurally—the functional architecture of Bruce and Young (1986) suggests the independence of visual face processing operations, while the recent review on neural systems devoted to face processing considers their interactive character as a main feature of these neural systems (Haxby et al., 2000).

To support the interactive processing mode, recent behavioural evidence also suggests that facial identity exerts an influence on both expression analysis (Schweinberger, Burton, & Kelly, 1999; Schweinberger & Soukup, 1998) and speech reading (Schweinberger & Soukup, 1998). More precisely, Schweinberger and Soukup (1998) found that RTs for expression and facial speech judgements were influenced by variations on the identity of the face (even if this dimension was irrelevant to the task). Furthermore, speech judgements were faster on familiar than unfamiliar faces. Because the reverse influences were not found (changes in facial expression or facial speech did not influence facial identity judgements), the authors suggested that there exists non-independent but asymmetric relationships between facial identity processing on the one hand, and emotion and facial speech analysis on the other hand (see also Schweinberger et al., 1999).

Based on these findings and our own incidental observations (see later), the present study re-evaluates another kind of relationship between operations considered to be independent in the cognitive model of Bruce and Young (1986): That of familiar face recognition and sex processing of faces.

According to Bruce and Young (1986), sex is a kind of ''visually derived semantic information'', that can be extracted equally whether the face is familiar or not, and is thus thought to be processed in parallel to facial identity processing (see also Bruce, 1986; Bruce et al., 1987). There are several reasons for which the present study wished to re-evaluate this claim. First, there isn't any clear evidence in the neuropsychological literature of a double dissociation between sex processing and familiar face recognition. Some patients have been described who can still perform sex categorization without being able to recognize faces (e.g., Bruyer et al., 1983; Humphreys et al., 1993; Tranel et al., 1988) but the reverse dissociation has never been described. In neuroimaging studies, despite the frequent use of sex categorization tasks on faces (e.g., Dubois et al., 1999; Morris et al., 1998; Rossion, Schiltz, Robaye, Pirenne, & Crommelinck, 2001; Sergent et al., 1992, 1994) there isn't any clear indication that the brain regions activated by this task are different than the occipito-temporal regions involved in facial identity analysis (Haxby et al., 2000). The ERP evidences are not much clearer: Sex processing has been found to affect early and late processing stages in a recent ERP study (Mouchetant-Rostaing et al., 2000) but no test of the influence of facial identity processing has been performed on these electro-physiological differences. We also recently conducted a neuroimaging study in

our laboratory, in which we presented subjects with visually familiar and unfamiliar faces in a sex categorization task: Incidentally, subjects were significantly quicker at classifying familiar faces (see Dubois et al., 1999). Finally, a recent study using Principal Component Analysis (PCA) of face pixel intensities showed that sex and facial identity are coded by similar components to one another (Calder, Burton, Miller, Young, & Akamatsu, 2001), suggesting that human observers might use very similar cues and representations to process identity and sex on faces. Nevertheless, the current evidence so far from behavioural studies does not indicate any influence of face identity or familiarity on sex processing (Bruce, 1986; Bruce et al., 1987).

The present study's goal was to re-assess these evidences, using a more powerful design with several conditions, and a set of face stimuli that were, unlike previous studies, completely devoted of social and cultural cues to sex categorization (facial hair, external cues, etc.).

To do this, subjects were presented with a set of face photographs that was familiarized through intensive training, and then compared to novel faces in a sex recognition task. All face stimuli were cautiously cropped, and only photographs of well-shaved males and females without makeup and jewellery were included. More importantly, the study tested whether the *perception* of face familiarity—not only the *visual similarity* between stored and currently perceived faces—facilitated sex processing or not. That is, subjects were presented with a sex processing task on a large set of face stimuli: Completely novel faces (0% familiarity) and familiar faces (100% familiarity), and also face photographs saturated at different percentages of the familiar faces: 80% (20% of similarity to unfamiliar faces), 60% (40%), 40% (60%), and 20% (80%). In a pilot experiment, eight subjects were familiarized with a large set of faces during 3 days, and then presented with faces extracted from different steps of the continua made by morphing a familiarized face with an unfamiliar face. Their task was to decide whether the faces were familiar or not. After it was determined how subjects process morphed familiar and unfamiliar faces, the main experiment compared a group of trained subjects to a group of naive subjects on a sex categorization task on the morphed faces. If perception of a face as being familiar exerts an influence on sex categorization, faster response times were expected in the trained group for morphed faces that were classified as familiar by the trained group of the pilot experiment than for unfamiliar faces.

PILOT EXPERIMENT: CLASSIFYING FACES AS FAMILIAR OR UNFAMILIAR FROM A CONTINUUM

The aim of this pilot experiment was to test the learning procedure on faces and assess the percentage of familiarity decisions for different steps of the continua.[1]

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[1]For the same purpose, these pilot data were also used for training subjects in a PET study, comparing the activation patterns obtained for familiar and unfamiliar faces (Rossion et al., 2001).

Methods

Subjects.   Eight right-handed adult subjects (four males, age range: 20–26) took part in the pilot behavioural experiment.

Stimuli.   Photographic face quality images of 90 students (45 males and 45 females, age 18–30), without glasses, facial hair, or make-up, were taken with a digital camera. These photographs were divided in three sets of 30 facial identities each: A, B, and C. Set A was divided in two parts: A1 and A2. A1 served for extensive training. There were three photographs (full front, and left and right three-quarters profiles) for each identity in set A1 (thus 90 photographs). Set A2 was made of another pool of full-front photographs of the same faces (30 faces). Set B was made of 30 unknown full-front faces that were used for the test of familiarity (third day, see later). Set C contained the unknown full-front faces that were morphed with the familiarized faces (A2). All sets and sub-sets of faces always contained half male and half female faces. All face photographs were edited in Adobe Photoshop 4.0 to remove backgrounds and haircut, and everything below the chin (see Figure 1). They were all of neutral facial expression The resolution of all face photographs was of 155 × 188 pixels at 72 dpi. Each of 30 full-front faces from set A2 was paired with one of the 30 full-front faces of set C, giving 30 pairs of faces (only male–male and female–female morphs were made). 30 continuums were generated from these pairs using a ''morph'' program (Morph^{TM}), which, given any two images as endpoints, can produce a linear continuum of images between the two end images (see Beale & Keil, 1995). Using this program, six images were
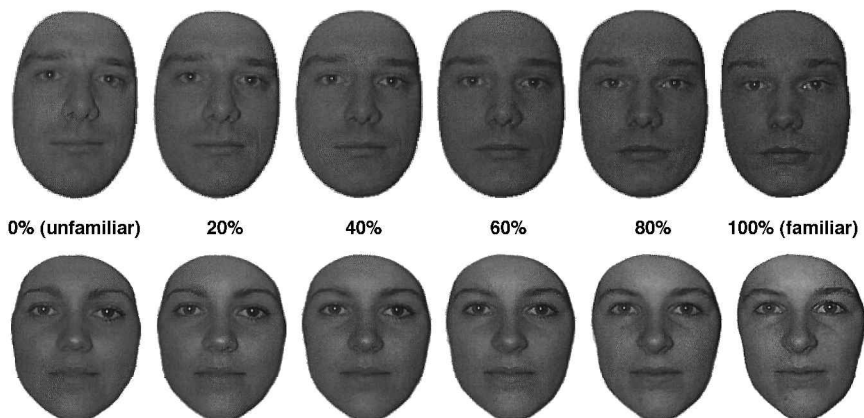

Figure 1.   Examples of the face stimuli used in this study. Two continuums are presented here, although 30 were used in the experiment (15 male continuums, 15 female continuums). Subjects are familiarized with the faces on the right (100%), which are morphed with completely unknown faces. Familiarity and sex decisions are performed on faces at six different steps of the continua.

extracted for each of the 30 face pairs, at 20% increments: 0% familiar, 20%, 40%, 60%, 80%, and 100%. All of these 180 images (extracted from sets A2 and C) were shown only after the training procedure (see later).

Procedure

Learning phase.   This phase took part two consecutive days before testing. On the first day, subjects were familiarized with the faces (set A1) over about 100 min, and the second day over 60 min. On each day of training, subjects were familiarized first with manually presented photographs, and then with computer exercises. On the first day, subjects were given 90 photographs of the 30 faces (A1): full front, three-quarters right profile, three-quarters left profile. All faces were mixed and subjects had to find the three faces belonging to the same person (making 30 triplets), with no time limit. On average, subjects completed the task in 51 min, with only two errors for four out of eight subjects. Then, subjects were familiarized again with the faces presented on the computer screen by means of various tasks (in the order they were presented): Checking for face repetition within a sequence (45 full-front faces—15 repeated; 8 males repeated, 7 females); passive viewing of the faces (full-front faces, three-quarters faces, original full-front photographs, 5000 ms, ISI: 2000 ms); judging whether full-front and three-quarters faces were ''nice'' or ''not so nice'' persons;[2] passive presentation of the 30 faces in the three viewpoints successively (left three-quarters, full front, right three-quarters); matching faces across viewpoint changes (60 same/different trials, delayed presentation: Central cross for 500 ms—three-quarters right view for 1000 ms—blank for 500 ms—full-front face view for 1000 ms—time out for 2000 ms); and passive viewing of the original photographic stimuli (not cropped but taken with a hat masking the external features) that they had to try to match to the cropped face photographs.

The second day, they had to do the ''photographs'' task and no errors were made. Then, they once again performed the repetition task (eight females and seven males repeated), the ''personality'' judgements on the three-quarters left profiles, passive presentation of the viewpoints, matching across viewpoint changes, and the viewing of the original pictures.

Testing.   On the third day, subjects performed a simple face recognition task, as a control to test that they had learned the faces properly. Sixty full-front faces were presented successively on the computer screen (2000 ms, ISI: 2000 ms): The 30 faces of set A1 and 30 novel faces of set B. Subjects had to press one of two keys depending on whether they knew the face or not. This

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[2]This task was used since such personality trait judgements on faces, such as likeability, yield high recognition rates of the faces (see Coin & Tiberghien, 1997).

testing of face familiarity was performed well by all subjects, with only four subjects responding ''unknown'' to one of the familiarized faces (different item for each subject).

Detection and categorization tasks. On the fourth day of the pilot experiment, subjects performed two tasks, a categorisation task and a detection task. In the categorisation task, 20 continua were used. Three stimuli were extracted from each continuum, in a way that 10 stimuli of each step (0%, 20%, 40%, 60%, 80%, and 100%) were presented to the subjects (60 stimuli). Each face was presented for 2000 ms as in the testing stage (day 3), and subjects had to decide whether the face presented was a known or an unknown face. The results indicated that subjects indeed perceived the continua in a categorical way, with a sharp difference in the percentage of the familiarity decisions between the 40% images (perceived as unknown) and the 60% images (perceived as known). The percentages of ''familiar'' decisions for each of the steps in the continuum were as follow: 0%, 12.5%, 26.5%, 78.75%, 91.25%, and 96.25% for the conditions 0%, 20%, 40%, 60%, 80%, and 100% respectively. These percentages are similar to what has been demonstrated in previous behavioural studies (e.g., Beale & Keil, 1995; Calder, Young, Perrett, Etcoff, & Rowland, 1996): There is a sudden change in the decisions made at the boundary (around 50%), although this is not as sharp as a complete categorical perception would be (see Figure 2). The *detection task* was similar to the discrimination task that was used with some variations in previous behavioural studies (Beale & Keil, 1995). That is, it aimed at showing a better discrimination of two faces crossing the perceptual boundary than two faces on the same side of this boundary (even if the physical distance between the pairs is kept equal). The remaining 10 continua (extracted from A2 and C) were used for this task, and 24 pairs were extracted from each continuum, giving a total amount of 240. Each trial was made of a consecutive presentation of two
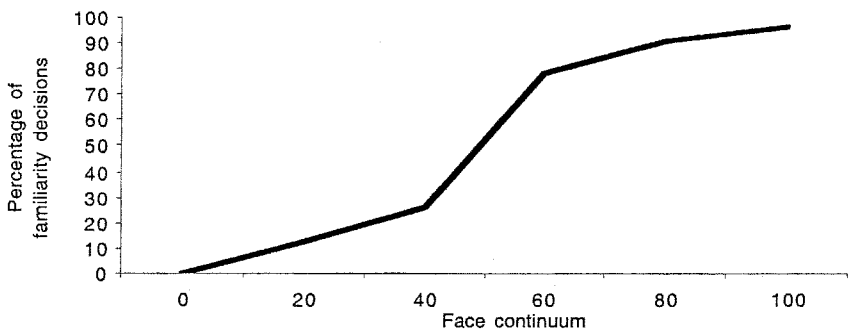

Figure 2. Proportions of familiarity decisions for the face continua presented to the control subjects.

faces, each presented for 400 ms (delay between pairs: 500 ms, ISI: 2000 ms). There were 120 identical trials, and all the other trials were pairs of very similar but different face photographs: 40 pairs of 5–25%; 40 pairs of 40–60%; and 40 pairs of 65–85%. The subjects' task was to press a key when they detected that the two faces were different. This task was very difficult since the two faces look very similar and subjects were asked only to press the key when they were sure of their response, but as expected subjects pressed the key more often when the two faces were of the 40–60% pairs than (5–25%) and (65–85%) pairs, although the number of difference detection was very low: 19.5/40 for 40%/60% pairs; 16/40 (65%/85%); 13.5/40 (5%/25%). Nevertheless, these differences were significant, one-way ANOVA for repeated measurements: $F(1, 7) = 15.414$. $p < .001$, and post hoc t-tests confirmed that the detection was better when the two faces of a pair were on different sides of the perceptual boundary: 40%/60% vs. 5%/25% ($p < .005$), 40%/60% vs. 65%/85% ($p < .005$), 65%/85% vs. 5%/25% (n.s.).

Discussion

This pilot experiment aimed at testing the learning procedure and at recording subject's responses to face continua made of morphed familiar and unfamiliar faces. The training procedure turned out to be efficient, as indicated by the testing (third day) and the categorization task (fourth day). The categorization task, which was the most important for our purpose, suggests that subjects roughly classify the faces in two groups (familiar and unfamiliar) with a large difference made between the faces that were 40% similar to the encoded faces, and the 60% faces. This pattern (Figure 2) is not unlike what has been described as categorical perception effects on faces (Beale & Keil, 1995; Etcoff & Magee, 1992). The detection task indicated that the difference between 40% and 60% faces was easier to make than the difference between faces suggesting indeed that a kind of perceptual boundary was made between 40% and 60% faces in the continua used.

SEX DECISIONS ON FAMILIAR AND UNFAMILIAR FACES

Method

Subjects

Two groups of 12 students (half female in each group) took part in this experiment.

Stimuli

The stimuli were exactly identical as those used in the pilot experiment.

Procedure

One group of subjects was trained exactly the same way as the subjects in the pilot experiment: 2 days of familiarization, a recognition test on the third day, and then the sex categorization experiment on the fourth day. The untrained group only underwent the sex decision task.

During this task, subjects of both groups were presented with two consecutive blocks of 90 stimuli. Each block contained 15 stimuli of each step on the continuum (0%, 20%, 40%, 60%, 80%, and 100%). Each face was presented for 1500 ms (ISI: 3000 ms) and the subject's task was to press the ''m'' key if the face was of a male person, or the ''q'' key if the face was of a female person. Subjects were required to be as accurate and as quick as possible in their judgements.

Results

As in the pilot experiment, all subjects of the trained group learned the faces and recognized them without any hesitation (one subject pressed the wrong key on two occasions; seven other subjects made one mistake).

Sex categorisation. Sex categorization was measured by A', a sensitivity (response-bias-free) measure of discrimination accuracy based on signal theory (Green & Swets, 1966),[3] and mean response times (correct responses). These values are given in Tables 1 and 2, respectively. As indicated by A' values, both

TABLE 1
Sensitivity measures for the two groups
of subjects in the sex classification task

Continuum	Sensitivity (A')	
	Trained	Untrained
0%	0.958	0.956
20%	0.979	0.968
40%	0.987	0.973
60%	0.990	0.975
80%	0.992	0.980
100%	0.990	0.972

[3] In the context of a sex classification experiment, response bias refer to the tendency of participants to guess ''male'' more than ''female'' when they are unsure (e.g., see Wild et al., 2000), and A' is used to control for this kind of bias. In the present study, such response bias was indeed observed although it was relatively small: On average, for the whole experiment, ''male'' responses were given for 52.4% of the stimuli.

TABLE 2
Mean correct response times (ms) for the
two groups of subjects in the sex
classification task

| | Mean response times (RTs) | |
Continuum	Trained	Untrained
0%	772	777
20%	756	756
40%	742	752
60%	699	768
80%	690	764
100%	694	754

groups of subjects were very efficient at this task. Differences were tested in a two-way ANOVA with *group* (trained vs. untrained) and *condition* (0–100% similarity with familiar faces) as factors: There was a significant effect of group, $F(1, 22) = 6.18$, $p = .02$, and a significant main effect of condition, $F(5, 110) = 8.67$, $p < .001$, but no interaction, $F(5, 110) = 0.56$, $p = .160$. Observation of the sensitivity values in Table 1 shows that subjects were slightly less accurate in their decisions for the 0% faces, and there was also a trend for subjects of the trained group to be more accurate overall, probably because they had substantial practice at categorizing photographs of faces by means of response keys. However, given the high values observed in all conditions for all subjects and the absence of significant interaction between group and conditions, no strong conclusion was extracted from these analyses on sensitivity.

The observations on response times were particularly interesting (see Table 2; Figure 3). The two-way ANOVA revealed no significant main effect of the group factor, $F(1, 22) = 1.374$, $p = .254$, but a significant effect of condition, $F(1, 22) = 6.845$, $p < .001$. This last effect was qualified by a significant interaction between group and condition, $F(1, 22) = 5.841$, $p < .001$. As indicated by Table 2 and Figure 3, mean RTs appear to be similar for both groups for faces considered as unfamiliar. However, RTs are largely decreased for faces considered as familiar, only in the trained group (mean decrease = 68 ms). Pairwise comparisons for identical level of condition between groups (e.g., 40% untrained vs. 40% trained, corrected for multiple tests using Tukey's HSD) showed highly significant differences at 60% ($p < .01$), 80% ($p < .01$), and 100% ($p < .01$). There was no significant difference or trend between groups for conditions 0%, 20%, and 40%.

Since the interaction between group and condition was significant in the main ANOVA, separate one-way ANOVAs testing the effect of condition were conducted for each group of subjects. While there was no effect of condition for
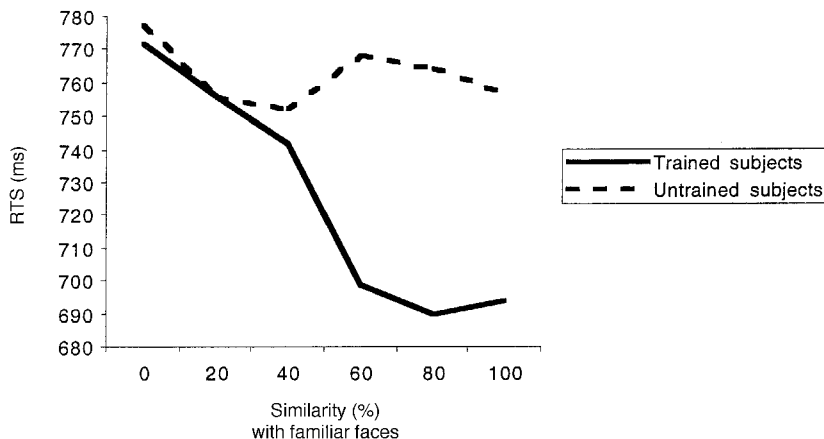
Figure 3.   Mean response times for trained and untrained subjects in the sex categorization task. Note the large decrease of RTs for faces recognized as familiar in the pilot experiment (60%–80%–100%). The slight differences between 0–20% and 40% faces was non-significant, and observed for both groups of subjects, and cannot be related to face familiarity.

the untrained group, $F(1, 22) = 1.163$, $p = .339$, a significant effect was observed in the group of subjects trained with the faces: $F(1, 22) = 10.840$, $p < .001$. Post hoc t-tests clearly indicated that this effect was related to the variable manipulated: Faces perceived as familiar were classified quickly than faces perceived as unfamiliar $\{(0 + 20 + 40) - (60 + 80 + 100): p < .001\}$. Pairwise comparisons (corrected for multiple tests using Tukey's HSD) showed significant differences between the following conditions: 0–60% ($p < .01$); 0–80% ($p < .01$); 0–100% ($p < .01$); 20–60% ($p < .01$); 20–80% ($p < .01$); 20–100% ($p < 0.01$); 40–80% ($p < .01$), and 40–100% ($p < .05$), Thus, all but two[4] pairwise comparisons between faces largely perceived as familiar on the one hand, and faces perceived as unfamiliar on the other hand, were significant. There wasn't any significant difference, not even a trend for the comparisons within the conditions of faces either perceived as unfamiliar (0–20–40) or familiar (60–80–100).

Finally, a whole analysis by items was conducted. The two-way ANOVA (repeated measures) on items revealed a significant main effect of the group factor, $F(1, 29) = 32.05$, $p < .001$, and a significant effect of condition, $F(5, 145) = 5.37$, $p = .0015$, these effects being qualified by a significant interaction between group and condition, $F(5, 145) = 5.70$, $p < .001$. Again, pairwise

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[4] The only comparison that failed to reach significance at the corrected threshold was 40–60%, for a 2 ms difference on average. Note however that the difference between 40% and 60% conditions is shown indirectly when groups are compared at the same level of condition in the pairwise comparison of the global ANOVA (40%/40% vs. 60%/60%).

comparisons for identical level of condition between groups (corrected for multiple tests using Tukey's HSD) showed highly significant differences at 60% ($p < .01$), 80% ($p < .01$), and 100% ($p < .01$). There was no significant difference or trend between groups for conditions 0%, 20%, and 40%.

Separate one-way ANOVAs testing for the effect of condition were conducted for each group of subjects. There was no effect of condition for the untrained group, $F(5, 145) = 0.81$, $p = .54$, but a highly significant effect was observed in the group of subjects trained with the faces, $F(5, 145) = 10.82$, $p < .001$. As for the analysis by subjects, post hoc t-tests clearly indicated that this effect was related to the variable manipulated: faces perceived as familiar were classified quickly than faces perceived as unfamiliar $\{(0 + 20 + 40) - (60 + 80 + 100): p < .001\}$. Pairwise comparisons (corrected for multiple tests using Tukey's HSD) showed significant differences between the following conditions: 0–60% ($p < .01$); 0–80% ($p < .01$); 0–100% ($p < .01$); 20–60% ($p < .01$); 20–80% ($p < .01$); 20–100% ($p < .01$), and 40–80% ($p < .01$).[5] There wasn't any significant difference for the comparisons within the conditions of faces perceived as either unfamiliar (0–20–40) or familiar (60–80–100). The item analysis thus largely confirmed the analysis by subjects, showing that the RTs differences observed between the trained and untrained group for the faces perceived as familiar were unlikely to be due to a few sexually ambiguous stimuli.

DISCUSSION

The main conclusion of this study is that face familiarity facilitates sex processing on faces: Faces that are perceived as familiar are categorized as male or female more quickly than faces perceived as unfamiliar. Moreover, this effect does not appear to depend strictly on the visual similarity with previously encoded face representations, but rather on the subject's *perception* of familiarity. That is, faces saturated at 40% from familiar faces were not classified more quickly than faces saturated at 20% or 0%. However, there was a sharp drop of RTs for faces saturated at 60%, i.e., faces mainly perceived as familiar. These observations suggest that the familiar and unfamiliar faces were already discriminated by the cognitive system before the sex decisions were taken.

A previous behavioural study contrasted familiar and unfamiliar faces in a sex categorization task (Bruce, 1986) and actually reported a small effect of familiarity (quicker judgements) on a sex decision task: ''Familiar'' faces were more difficult to classify for the control group (for which all faces were actually unfamiliar). This difference disappeared in the group of subjects who knew the faces, suggesting a facilitation of familiarity on sex judgements. However, an item analysis indicated that this effect was due to two ambiguous items only, for which latencies dropped by over 200 ms. Removing these items cancelled the

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[5]Comparisons that failed to reach significance at the corrected threshold were 40–60%, for a 5 ms difference on average, and 40–100% (3 ms). See previous note.

effect, leading to the conclusion that face familiarity does not modulate sex processing under normal conditions (Bruce, 1986). In the present experiment, the drop of response times was observed for nearly all items, and the item analysis showed a strong effect of familiarity on sex categorization. It is difficult to clarify why the present study reported an effect that was absent in Bruce's (1986) experiment. Quality of the photographs might simply be responsible of the effects. For instance, faces of the present experiment were completely cropped, with no sex cues at all, whereas external cues (hair, facial accessories such as spectacles) from this previous study were minimal but still available for sex processing. These cues may have facilitated the processing of unknown faces in the sex task, which was impossible in the present study. In support of these explanations, behavioural studies have shown that different face features are used to process familiar and unfamiliar faces (Ellis, Sheperd, & Davies, 1979; Young, Hay, McWeeny, Flude, & Ellis, 1985): People rely more on internal features (nose, mouth, eyes) for familiar faces and more on external features (shape, hair) for unfamiliar faces (see also Campbell, Coleman, et al., 1999; Hosie, Ellis, & Haig, 1988). Since these external features were removed here, subjects had to rely on internal traits alone to categorize faces according to their sex.

What type of functional model can account for the result described here? Clearly, the early proposal by Ellis (1981) of sequential face processing stages during which sex categorization would be necessarily completed before fami- liarity decisions is further rejected by the present account (see mainly Bruce et al., 1987). The proposal by Bruce and Young (1986) of a parallel and independent processing for sex and facial identity is also difficult to reconcile with the quicker sex decisions made on familiar faces. At the very least, the present results support a modification of the relationship between sex categorization and facial identity recognition, such that the latter does influence the former processes.

Such influences could be implemented in a kind of cascade model, in which later processes may be initiated before earlier ones are completed, and distant stages may inhibit or facilitate adjacent or more distant ones (cf., McClelland & Rumelhart, 1981). According to this view, sex processing on faces and individual face recognition could be processed separately, but recognition of the individual face might facilitate and speed up sex categorization, despite the fact that sex categorization is performed quicker on average than familiarity or identity decisions (Bruyer, Galvez, & Prairial, 1993). The opposite influence—knowing the sex of a face helping recognizing that face—has not been considered because of the independence between performance at the two tasks (e.g., Bruce et al., 1987; Wild et al., 2000). However, a recent study has shown a modulation of face recognition by sex in a target recognition task: subjects were quicker to reject unknown—distractor—faces when their sex was different than to recognize the target face (independently of the visual similarity between the target and the distractor; Baudouin & Tiberghien, 2000). Even if additional evidence has to be gathered to draw strong conclusions on this issue, the proposed independence between sex categorization and familiar face recognition (Bruce & Young, 1986)

has to be re-examined. In a cascade processing system, there could either be an asymmetric interaction between two distinct processes, as already described for facial identity and face emotion processing (Schweinberger et al., 1999; Schweinberger & Soukup, 1998) or a two-way interaction. According to this type of account for the results reported here, the influence of face familiarity can be described as purely ''knowledge-based'': Rapid activation of the knowledge about a face, in a separate store, may influence the sex *decision*, even if the latter can be performed quicker than the former.

Going a step further, another possible account for the results reported here would be that (1) the perceptual face representation extracted during face processing is identical or overlapping for sex and face identity judgements, and (2) face familiarity modulates such perceptual processing. Two recent original studies strongly support the first point. First, in a PCA analysis based on the pixel intensities of faces, Calder and colleagues (2001) have shown that face identity and sex were coded by similar components to one another (but by different components to facial expression). They found that the components explaining most of the variance for both identity and sex show structural changes in rigid elements of the face that change slowly across a number of years, such as head size and nose shape. From different behavioural studies, it is also known that sex processing depends on several rigid face features such as the shape of the nose (Bruce et al., 1993; Chronicle et al., 1995; Roberts & Bruce, 1988; but see Brown & Perrett, 1993) and the eyes and the brows (Brown & Perrett, 1993; Bruce et al., 1993; Burton, Bruce, & Dench, 1993; Campbell, Benson, Wallace, Doesbergh, & Coleman, 1999), the skin texture, and 3-D shape information (Bruce et al., 1993). Several studies have arrived at the conclusion that sex categorization is multiply determined by a combination of these features, and that the configural relationships between features are particularly relevant (Brown & Perrett, 1993; Bruce et al., 1993). From behavioural studies, the facial features that are particularly salient for face identity discrimination are less known, although the importance of configural cues is well known from many studies (e.g., Leder & Bruce, 1998; Rhodes, 1993; Tanaka & Farah, 1993). The second support for an overlapping of visual representations used for face recognition and sex decision comes from the recent application of the Bubbles technique (Gosselin & Schyns, 2001)[6] to three different face categorization tasks (Schyns, Bonnar, & Gosselin, in press): Sex categorization, facial identification (among 10 possibilities), and expression decision. Interestingly, most if not all of the information used for the sex categorization task (the shape of the upper part of the head and the eyes region with the eyebrows) is

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[6]''Bubbles'' is a recent technique developed to identify which visual information in an image is used to perform a categorization task. It is based on the classification of the subject's responses during the categorization task made on images masked by gaussian windows (''Bubbles''). Randomly masked images correctly categorized will serve to extract the most salient or diagnostic information used for the task at hand (for details see Gosselin & Schyns, 2001).

contained in the diagnostic information also used for facial identity judgements (see Figure 2 in Schyns et al., in press). In other words, a sex categorization task on faces relies on extracting information that is also particularly salient for facial identification (whereas facial expression judgements appear to rely more on the lower part of the face and the mouth region).

Finally, the idea of overlapping visual representations for sex and identity processing is also supported by neuroimaging data. In their recent neuro-functional model of face processing, Haxby et al. (2000) proposed that the invariant properties of the face needed to code facial identity are processed in the occipito-temporal ventral pathway (including the middle fusiform gyrus), whereas changeable aspects of the face, such as facial expressions or eye-gaze direction, would rely on the superior temporal sulcus (STS). As also pointed out by Calder et al. (2001), this framework would place sex processing at the same level as facial identity processing. Although this has not been tested directly, the current data indicate a large recruitment of the middle and posterior fusiform gyrus of the ventral pathway, especially in the right hemisphere, during sex processing on faces (e.g., Dubois et al., 1999; Rossion et al., 2001; Sergent, Otha, & MacDonald, 1992; Sergent et al., 1994), similarly to the regions acti-vated by passive viewing of identity matching of faces (e.g., Haxby et al., 1996; Kanwisher, McDermott, & Chun, 1997; Rossion et al., 2000).

Yet, even if sex and identity from faces share similar perceptual repre-sentations, a second factor is necessary to explain the results reported here: Previous knowledge of the perceptual representation of the face must facilitate the extraction of visual information important to take sex and identity decisions. Again, there exists both behavioural and neuroimaging data supporting this possibility. First, perceptual tasks on faces such as matching faces from different viewpoint (Young et al., 1986) and face sex processing (the present study) are performed quicker for familiar than unfamiliar faces. Second, when subjects have to match different photographs of the same face (differing or not in expression and viewpoint) on internal features, they are quicker for familiar faces (Ellis et al., 1979; Young et al., 1985), suggesting that familiar and unfamiliar faces may not be *perceived* the same way. From the neuroanatomical point of view, there is currently no evidence that familiar and unfamiliar visual face representations rely on different brain structures (Haxby et al., 2000) if task factors are controlled and if familiar faces do not recruit additional regions for semantic and lexical (name activation) processing. In a recent PET study, we have actually collected evidence that familiar and unfamiliar faces recruit identical regions of the right occipito-temporal pathway if task factors are carefully controlled (Rossion et al., 2001; see also Dubois et al., 1999), the difference being reflected by a decrease of brain activation for familiar faces in right occipital and occipito-temporal cortex, much like perceptual priming studies have demonstrated for words and objects (see Wiggs & Martin, 1998 for a review). It is thus highly plausible that previous visual knowledge of the face facilitates its visual processing and the activation of overlapping perceptual representations for identity and sex judgements, in

occipito-temporal regions of the human brain. Whether being familiar with a face helps taking sex *decisions* on-line through knowledge-based influences from separate representations, or whether visual familiarity of the face modulates the *perceptual* processes important for accurate sex decisions will have to be further clarified, perhaps using electrophysiological measurements of brain activity, capturing the time course of interference between these processes (e.g., Van-Rullen & Thorpe, 2001).

CONCLUSION

Contrary to previous reports, this study has demonstrated that face sex categorization is clearly influenced by face familiarity. The quickest sex judgements were observed for faces that were consciously recognized as familiar by an independent group, and this effect was not linearly correlated to the visual similarity between the faces to be categorized and the familiar face representations. These results suggest that facial identity and sex categorization are not parallel and independent functions, as proposed by the cognitive archi-tecture of Bruce and Young (1986). Alternative explanations are either a kind of (a)symmetric influence of face familiarity on face sex processing, the two depending on distinct processing systems, or that facial identity and sex categorization depend on an overlapping perceptual representation, activated more easily and more quickly for familiar faces.

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