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Sex differences in face processing: Are women less lateralized and faster than men?

Ornella Godard *, Nicole Fiori

Laboratoire de Psychologie et de Neuropsychologie Cognitives, Université Paris Descartes, CNRS, FRE 3292, France

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ABSTRACT

The aim of this study was to determine the influence of sex on hemispheric asymmetry and cooperation in a face recognition task. We used a masked priming paradigm in which the prime stimulus was centrally presented; it could be a bisymmetric face or a hemi-face in which facial information was presented in the left or the right visual field and projected to the right or the left hemisphere. The target stimulus was always a bisymmetric face presented centrally. Faces were selected from Minear and Park's (2004) database. Fifty-two right-handed students (26 men, 26 women) participated in this experiment, in which accuracy (percentage of correct responses) and reaction times (RTs in ms) were measured. Although accuracy data showed that the percentage of correct recognition – when prime and target matched – was equivalent in men and women, men's RTs were longer than women's in all conditions. Accuracy and RTs showed that men are more strongly lateralized than women, with right hemispheric dominance. These results suggest that men are as good at face recognition as women, but there are functional differences in the two sexes. The findings are discussed in terms of functional cerebral networks distributed over both hemispheres and of interhemispheric transmission.

1. Introduction

Numerous studies have revealed sex differences in the performance of various cognitive tasks. Women often outperform men on tasks requiring verbal-linguistic processing (verbal fluency, speed of articulation and grammar), while men appear to be more efficient on a variety of tasks calling on spatial abilities (labyrinths, Kohs cubes, manual precision, mental rotation and mechanic abilities; Kimura, 1999).

Several studies have proposed that sex differences in cognitive abilities originate in sex differences in brain organization. Sex differences in brain lateralization were first studied by examining the neuropsychological consequences of unilateral lesions. Lansdell (1962) observed that the consequences of unilateral brain damage were different in men and women: men only, presented spatial deficits after right-hemisphere damage and verbal deficits after left-hemisphere damage. McGlone (1978) showed that aphasia after unilateral left-brain damage was more frequent in men than in women and in a critical survey (McGlone, 1980), she highlighted that the male brain may be more asymmetrically organized than the female brain, both for verbal and nonverbal functions. Lansdell (1962) proposed that some neurophysiological mechanisms underlying spatial and verbal skills might overlap in the same hemisphere in women and be located in opposite hemispheres in men. More recently, Frith and Vargha-Khadem (2001) found that, in children (8–13 years old), reading and spelling impairment was related specifically to left-hemisphere damage in boys, whereas no specific effect was found for girls with left-hemisphere lesions.

Other studies, based on behavioral data or cerebral imaging, focused on sex differences in verbal and visuospatial processes by studying healthy subjects. In an fMRI examination of language processing, Kansaku, Yamaura, and Kitazawa (2000) observed a typical left temporal activation in men and bilateral temporal activation in women. In a meta-analysis of 266 studies, Voyer (1996) concluded that hemispheric lateralization of verbal and spatial skills was stronger in men than in women. In particular, certain visuospatial tasks tend to be right-hemisphere-lateralized in men, whereas they are more bilaterally distributed in women. These tasks include mental rotation (Gur et al., 2000; Johnson, McKenzie, & Hamm, 2002) and geometric illusions (Rasmjou, Hausmann, & Güntürkün, 1999). These results suggest that verbal and spatial information is processed more asymmetrically in men and more symmetrically by both hemispheres in women.

Neuroimaging studies have shown that face perception is mediated by a distributed bilateral neural system in the ventral occipito-temporal visual extrastriate cortex (Kanwisher, McDermott, & Chun, 1997; Maurer et al., 2007; Passarotti, Smith, DeLano, & Huang, 2006). Two main regions of the visual extrastriate cortex respond more to faces than objects; these regions are in the middle fusiform gyrus ("fusiform face area" (FFA); Kanwisher et al., 1997) and in the postero-inferior occipital cortex ("occipital face area" (OFA)). There is greater activation in the right hemisphere than

* Corresponding author. Address: 71, Avenue Edouard Vaillant, 92774 Boulogne-Billancourt Cedex, France.
E-mail address: ornella.godard@parisdescartes.fr (O. Godard).

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in the left hemisphere (Rossion et al., 2003; Rossion, Schiltz, & Crommelinck, 2003). Face perception is a type of visuospatial task that induces cerebral asymmetry. Electrophysiological studies (Yovel, Levy, Grabowecky, & Paller, 2003) provide support for right-hemisphere dominance (or left-visual-field superiority) in face processing. Other authors (Bentin, Allison, Puce, Perez, & McCarthy, 1996; George, Evans, Fiori, & Davidoff, 1996; George, Evans, Fiori, Davidoff, & Renault, 1994) have highlighted the presence of a negative wave in the infero-temporal regions, 170 ms (N170) after face onset, which is thought to reflect an early structural face encoding stage. It is important to note that the face-specific N170 is bilateral but is initiated, and is larger, in the right hemisphere (George et al., 1996). The amplitude of the N170 specific face component can be altered by several factors such as the configurational organization and familiarity of faces (Caharel, Fiori, Bernard, Lalonde, & Rebaï, 2006; George et al., 1996). Finally, in behavioral studies, using lateralized repetition priming, a prime effect was found in the RH for familiar faces (Bourne & Hole, 2006; Cooper, Harvey, Lavidor, & Schweinberger, 2007) and for unfamiliar faces (Martin, Nind, & Macrae, 2009), which indicating structural encoding operations residing in the RH.

Other data are not in line with the hypothesis that there is a right-sided brain asymmetry for decoding the structural properties of faces. A recent meta-analysis (Kampf, Babkoff, & Nachson, 2005), examining laterality in familiar face naming and also in face recognition highlighted no hemispheric lateralization which is consistent with the latest brain-imaging data. Indeed, some studies have indicated a bilateral activation of the FFA (Henson et al., 2003; Herrmann, Ehlis, Ellgring, & Fallgatter, 2005; Liu, Higuchi, Marantz, & Kanwisher, 2000). These findings are consistent with lesion studies demonstrating that most cases of prosopagnosia (i.e., the inability to recognize faces following a brain lesion) are followed by a bilateral damage to the occipito-temporal cortex, although there are several case descriptions of unilateral right-sided lesions (Michel, Poncet, & Signoret, 1989). In a PET study, Rossion et al. (2000) showed that the right middle fusiform gyrus was more activated when matching faces configurally than featurally. This pattern of activity was reversed in the homologous left region (Rossion et al., 2000). This finding is consistent with other data showing that configural processing is mediated by the right hemisphere and analytical processing by the left hemisphere (Bourne, Vladeanu, & Hole, 2009; Parkin & Williamson, 1987; Rhodes, 1993; Ross & Turkewitz, 1981). These results confirm that each hemisphere is differentially involved in processing distinct aspects or types of facial information.

Some studies suggest that the cerebral activation differences in face processing depend on sex. In an emotional judgment of chimerical faces, Bourne (2005) showed that hemispheric lateralization was stronger in men than in women, although the right hemisphere was more efficient in most of the subjects. In an electrophysiological study based on a judgment of facial expression task, using pictures of infants, Proverbio, Brignone, Matarazza, Del Zotto, and Zani (2006) found an asymmetrical activation of the visual cortex in men (with right-hemisphere predominance), and bilateral activity in women. In a facial judgment task, using the Mooney faces, Fiori, Chaby, and George (2001) found that the N170 component was larger in the right than in the left hemisphere in men and equivalent in both hemispheres in women. Then, sex differences were shown in facial expression processing and facial decision-making.

In addition, some behavioral studies showed that women presented an advantage in face recognition compared to men (Rehnman & Herlitz, 2007) and were more efficient at categorizing female faces (Cellerino, Borghetti, & Sartucci, 2004). Lewin and Herlitz (2002) did not observe a difference between men and women in a task of male face recognition, but they found that women recognized female faces better than men did. Thus, the sex of the subjects and the sex of the faces must be controlled in studies of hemispheric lateralization in face processing.

Even if the hemispheres differ in specialization, for cognitive and emotional functioning, they are in constant communication with each other in performing most tasks. Mohr, Landgrebe, and Schweinberger (2002) obtained a bilateral gain for familiar faces but not for unfamiliar faces in a familiarity decision task in which one copy of familiar and unfamiliar faces was presented tachistoscopically to the right visual hemifield (RVF), the left visual hemifield (LVF) or simultaneously to both visual hemifields (bilateral condition, BVF). They concluded that interhemispheric cooperation occurs only for meaningful material. In contrast to this study, Compton (2002) found that interhemispheric interaction facilitated emotional and facial identity processing of unfamiliar faces, using matching tasks in which subjects were required to indicate when a target face matched one of two probe faces in with-in hemisphere condition and in across hemispheres condition. Given these conflicting results, bilateral gain and sex differences have to be investigated again.

The aim of the present research is to study sex differences in hemispheric lateralization and in interhemispheric cooperation during a face recognition task using a masked priming paradigm. The main hypothesis is that men will present a stronger hemispheric asymmetry than women. To conduct this study, we used three types of centrally presented primes: bisymmetric faces, which present facial information in both hemispheres; right hemi-faces, which present facial information in the right visual field only; and left hemi-faces, which present facial information in the left visual field only. The target stimulus was always a centrally presented bisymmetric face. This design allows us to study hemispheric asymmetry, when the primes are hemi-faces (right or left), and interhemispheric cooperation in all priming conditions (Yovel et al., 2003), particularly in the condition where prime is a bisymmetric face. The faces used were selected from a recent database (Minear & Park, 2004). A forced-choice procedure was used in which both accuracy and reaction times were recorded.

We hypothesized that both men and women would be more accurate and faster when the prime was a bisymmetric face (facial information projected to both hemispheres) compared to the conditions where the prime was a hemi-face. But only men should be more accurate and faster when the prime was a left hemi-face (facial information projected to the right hemisphere), rather than a right hemi-face condition (facial information is projected to the left hemisphere). Women should present similar performance whatever the hemi-face prime type. If women have more efficient hemispheric cooperation, they should be faster and more accurate than men in all conditions. An additional hypothesis was that women should be better than men at recognizing female faces.

2. Methods

2.1. Participants

Twenty-six right-handed women (mean age 20.7; SD = 4.13) and 26 right-handed men (mean age 21.7; SD = 2.78) participated in the study after giving informed consent. All participants were undergraduate students of psychology at the Henri Pieron Center. Handedness was assessed by a 12-item questionnaire adapted from the Edinburgh Inventory (Oldfield, 1971). The handedness score was .88 (SD = .16) for women and .82 (SD = .17) for men. No effect of sex on handedness score was found ($F(1, 50) = 1.85$, $p = .18$).

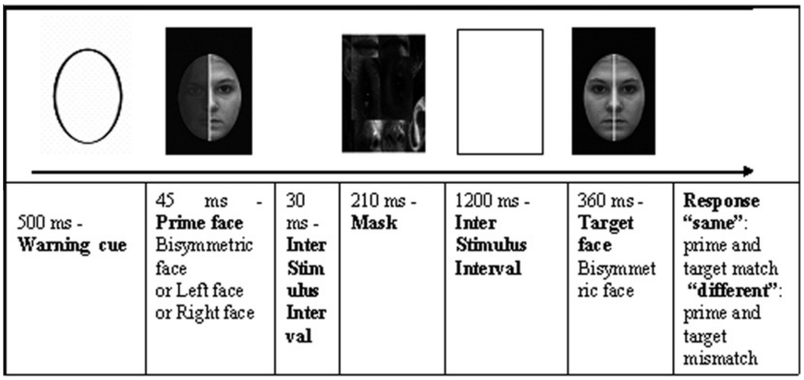

Fig. 1. Timeline of the stimulus sequence.

2.2. Materials and stimuli

Stimuli were presented on a Dell UltraSharp computer running E-prime1 software (Psychology Software Tools Inc., Pittsburgh, USA). Screen resolution was 1024 × 768 pixels.

Frontal views of six grey-scale faces with neutral expression were used (three female faces and three male faces), randomly selected from Minear and Park's (2004) face database. Only the left or the right hemi-face of each face was used.

Six bisymmetric faces (B face) were made by combining a hemi-face and its mirror image (three right–right faces and three left–left faces). This kind of stimulus construction is like the method used in the Yovel et al. (2003) study.

Six right (R face) and six left (L face) hemi-face stimuli were made by using a half face or its mirror image. These hemi-face stimuli were completed with a task-irrelevant female or male half face, which was reduced in contrast so that it would not be recognized, as in the Yovel et al. (2003) study. The role of this "irrelevant attached hemi-face" was to complete the hemi-face prime in order to avoid a "blank" and to produce the impression of a "whole-face" feeling but had no particular interest for the study.

The R and L faces presented the hemi-face information in the right visual field (RVF) and in the left visual field (LVF), respectively. Prime faces were one of the 18 B, L or R faces. Targets were always one of the six B faces. A thin white stripe (0.17° wide) covered the vertical midline of all stimuli. All faces were equated for luminance, length, and width (242 × 318 pixels). Faces subtended on average 11.4° vertically and 8° horizontally. Thus, L faces subtended 4° from the vertical midline in the LVF, and R faces subtended 4° in the RVF. Between prime and target, a pattern mask, subtended 16° vertically and 10° horizontally, was made with scrambled facial features. Prime face and target face matched in half of the trials and mismatched in the other half.

2.3. Procedure

2.3.1. The task was a face recognition task using a masked priming paradigm

Subjects were comfortably seated on a chair in a dimly lit room, at a viewing-distance of 60 cm from the screen. They were instructed to centrally fixate a small cross and to limit eye and head movements during the experimental session.

For each subject, an experimental session included 360 trials, divided into 10 blocks of 36. These 360 trials were carried out in pseudo-random order. A "same"/"different" judgment procedure was used. There were 10 repetitions for each prime–target pair across the 10 blocks. Half of the subjects had to press, as accurately as quickly as possible, a right key with the right index finger (M on an AZERTY keyboard) when prime and target matched and a left key with the left index finger (Q on an AZERTY keyboard) when they did not match. This order was counterbalanced for the other half of the subjects. Subjects were not informed that some of the stimuli were hemi-faces. After each block, a feedback period, in which the subject was informed of the percentage of correct responses, was used as a resting time. Subjects were instructed to try to improve their score during the course of the experiment.

A trial sequence began with the appearance of a central fixation cross for 1000 ms followed by a circle for 500 ms (warning cue), a 30 ms interstimulus interval, a central prime face for 45 ms, and a symmetrical rectangular pattern mask of scrambled facial features for 210 ms. The mask was used in order to avoid retinal and screen persistence. The target face was presented for 360 ms after an interval of 1200 ms (see Fig. 1).

Before the experimental session, subjects completed eight practice trials (in which the primes were only B faces) to make sure that they understood the task.

2.4. Data and statistical analysis

Reaction times (RT, in ms) and accuracy (correct responses, in %) were recorded. Accuracy refers to correct responses: when prime and target matched ("same" trials) and when prime and target mismatched ("different" trials). Reaction time refers to the time between the target's appearance on the screen and pressing the button. Only RTs for correct responses were analyzed.

A 2 (Sex: men or women) × 3 (Prime type: Bisymmetric face or Left face or Right face) × 2 (Condition: match or mismatch) × 10 (Block: from 1 to 10) repeated measures ANOVA was conducted on each dependent variable (accuracy in % and RT in ms). The analyses of the factor Block allow us to evaluate if subjects made a well progression on both dependent variables along the task.

The Greenhouse–Geisser (GG) epsilon correction was applied to adjust the degrees of freedom of the *F*-ratios. Post hoc comparisons were made to determine the significance of pairwise contrasts, using Tukey's one-factor HSD procedure ($\alpha = 0.05$). Partial η^2 were provided as a measure of effect size in ANOVA models, it corresponds to the proportion of the effect and error variance that is attributable to a variable ($\eta_p^2 = SS_{effect}/(SS_{effect} + SS_{error})$).

A Beta-test for statistical bias (Burton & Levy, 1989) was calculated to investigate any potential bias on responses as a function of prime type and sex.

3. Results

3.1. Accuracy (%)

The data on all trials, on trials when prime and target matched and on trials when prime and target mismatched are presented in

Table 1, as a function of sex and prime type. All the results of the ANOVA are presented in Table 3.

The effect of Sex was not significant ($F < 1$). Main effect of the factor Block was significant [$F(6.824, 341.225) = 38.79$, $GG_\varepsilon = .76$, $p < .001$; $\eta_p^2 = .44$] and did not interacted with Sex [$F(6.824, 341.225) = 1.99$, $GG_\varepsilon = .76$, $p = .057$; see Fig. 2]. Percentage of correct responses increased along the blocks (61.5% for the first block and 79.6% for the last one).

Effect of Condition was significant [$F(1, 50) = 10.72$, $p = .0019$; $\eta_p^2 = .17$]: subjects performed better on "mismatch" trials (77%) than on "match" trials (72%).

Prime type had a significant effect [$F(1.988, 99.420) = 76.81$, $GG_\varepsilon = .99$, $p < .001$; $\eta_p^2 = .60$]: accuracy was better on B face trials (81%) than on L face trials (73%) [$F(1, 50) = 107.4$, $p < .001$; $\eta_p^2 = .68$], and better on L than on R face trials (70%) [$F(1, 50) = 7.40$, $p = .009$; $\eta_p^2 = .13$].

The interaction between Prime and Condition effects was significant [$F(1, 100) = 16.98$, $p = .001$; $\eta_p^2 = .25$]. When the prime was a B face, accuracy was similar when the target matched (82%) and mismatched (79.5%) the prime [$F(1, 50) = 1.18$, $p = .283$]. When the prime was an L or an R hemi-face, accuracy was better for "mismatch" condition than for "match" condition (respectively, 76.5% and 69% for L face prime, $F(1, 50) = 18.69$, $p < .001$; 75% and 66% for R face prime, $F(1, 50) = 17.92$, $p = .000$; $\eta_p^2 = .26$).

Even if Prime by Sex interaction was not significant ($F < 1$), further analyses were conducted, using planned comparisons, by reason of our strong hypothesis relative to the influence of Sex on hemispheric differences. Accuracy was significantly better when the prime was an L face (72%) than when it was an R face (69%), in men only [$F(1, 50) = 7.16$, $p = .01$; $\eta_p^2 = .12$]. In women, there was no significant difference between the L face (73%) and R face (72%) prime conditions [$F(1, 50) = 1.38$, $p = .25$].

Table 1
Mean correct response rates (% of correct responses; ±SD) for All trials, for the "Matching" condition (when prime and target matched) and for the "Mismatching" condition, as a function of prime type and sex.

Condition	Prime	Men	Women
All trials	B face	79 (±14)	83 (±11)
	L face	72 (±13)	73 (±12)
	R face	69 (±13)	72 (±12)
Condition "Match"	B face	80 (±13)	84 (±10)
	L face	68 (±13)	70 (±13)
	R face	63 (±15)	69 (±14)
Condition "Mismatch"	B face	78 (±15)	81 (±13)
	L face	76 (±14)	77 (±13)
	R face	75 (±11)	75 (±10)

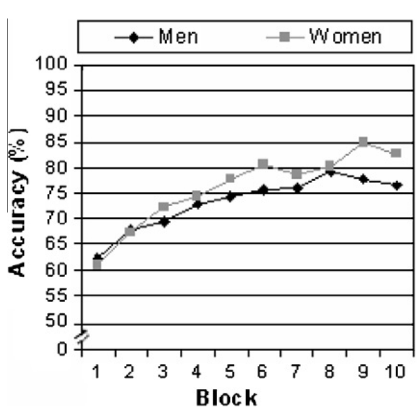

Fig. 2. Mean of accuracies (% of correct responses) for all trials, as a function of the Blocks in men (black diamond) and in women (grey square).

As the effect of Condition is significant, two separate repeated measures ANOVAs were done with Sex and Prime type as factors: one analysis for condition when the prime and target matched and another for when they mismatched.

In both analysis, the Sex effect was not significant ("match" condition: $F(1, 50) = 1.42$, $p = .24$ and "mismatch" condition: $F < 1$), but the Prime effect was ["match" condition: $F(0.933, 93.375) = 67.01$, $GG_\varepsilon = .93$, $p < .001$; $\eta_p^2 = .57$, and $F(1.692, 84.630) = 7.35$, $GG_\varepsilon = .93$, $p = .002$; $\eta_p^2 = .13$, for the "mismatch" condition].

When prime and target matched, the percentage of correct responses was highest on B face trials (82%), intermediate on L face trials (69%), [$F(1, 50) = 93.71$, $p < .0001$; $\eta_p^2 = .65$] and poorest on R face trials (66%), [$F(1, 100) = 4.59$, $p = .037$; $\eta_p^2 = .08$]. Even if Prime by Sex interaction was not significant [$F(1.867, 93.375) = 1.13$, $GG_\varepsilon = .93$, $p = .324$], we calculated planned comparisons in order to test sex differences between L face and R face primes. We observed in men, a significant difference between the L face (68%) and R face (63%) Prime conditions [$F(1, 50) = 6.94$, $p = .011$; $\eta_p^2 = .12$], whereas there was no difference ($F < 1$) in women.

When prime and target mismatched, the percentage of correct responses was higher for B faces (80%) than for L faces (77%), [$F(1, 50) = 9.83$, $p = .003$; $\eta_p^2 = .16$]; there was no difference between percentage of correct responses for L face and R face conditions (75%), [$F(1, 50) = 1.72$, $p = .19$]. Even if Prime by Sex interaction was not significant ($F < 1$), by reason of our strong hypothesis concerning sex differences on hemispheric lateralization, planned comparisons were conducted. They highlighted no differences between the L face and the R face Prime conditions for men ($F < 1$) nor for women [$F(1, 50) = 1.25$, $p = .27$].

3.2. Beta (β)

To determine whether a "Yes-" or "No-" saying bias was present, the bias statistic β was calculated, consisting of the number of correct recognitions divided by the number of correct rejections. Thus, $\beta > 1$ suggests that the subject is biased toward saying "Yes, this is a match," whereas $\beta < 1$ suggests a bias toward saying "No, this is not a match." An ANOVA was done with β as the dependent variable, and Sex (men or women) and Prime type (B face or L face or R face) as factors.

The ANOVA revealed a Prime effect [$F(1.835, 91.760) = 17.86$, $GG_\varepsilon = .92$, $p < .001$; $\eta_p^2 = .26$] on β without a Sex effect ($F < 1$) or a significant interaction [$F(1.835, 91.760) = 1.28$, $GG_\varepsilon = .92$, $p = .28$]. As Table 2 shows, men and women were both somewhat negatively biased when the prime was an L face [$F(1, 50) = 30.71$, $p < .001$; $\eta_p^2 = .38$] or an R face [$F(1, 50) = 22.24$, $p = .00002$; $\eta_p^2 = .31$] compared to the B face prime condition. But subjects were not more biased in one visual field compared to the other ($F < 1$).

3.3. Reaction times (ms)

All the results of the ANOVA are presented in Table 4.

The ANOVA on RTs revealed a significant main effect of Sex [$F(1, 50) = 7.58$, $p = .008$; $\eta_p^2 = .13$]: women were faster ($M = 786$ ms, $SD = 131$) than men ($M = 920$ ms, $SD = 224$) in all conditions

Table 2
β bias (number of correct recognitions divided by number of correct rejections ±SD) for men and women as a function of prime type. Men and women are both somewhat negatively biased when facial information is presented in only one visual field. There is no difference between men and women in the RVF/LH ($p = .47$).

	B face	L face	R face
Men	1.05 (±0.22)	0.91 (±0.18)	0.85 (±0.23)
Women	1.04 (±0.11)	0.91 (±0.15)	0.92 (±0.19)

Table 3
Summary of ANOVA results (F values, p-value and effect size-η_p^2) as a function of Sex, Condition, Prime and Block, for Accuracies (%).

All trial	F	p-Value	Effect size (η_p^2)
Sex	0.921	0.341	
Condition	10.712	0.002	0.176
Prime	76.814	0.000	0.605
Block	38.798	0.000	0.437
Se x * Condition	0.582	0.448	
Sex * Prime	0.868	0.422	
Sex * Block	1.987	0.057	
Prime * Block	0.827	0.669	
Prime * Condition	16.988	0.000	0.253
Prime * Block * Sex	0.534	0.943	
Condition * Block	12.913	0.000	0.196
Condition * Sex * Prime	0.926	0.399	
Condition * Block * Sex	0.826	0.592	
Prime * Condition * Block	1.248	0.215	
Prime * Condition * Block * Sex	1.733	0.056	
"Matching" condition			
Sex	1.418	0.239	0.572
Prime	67.008	0.000	
Sex * Prime	1.129	0.327	
"Mismatching" condition			
Sex	0.223	0.638	
Prime	7.351	0.002	0.128
Sex * Prime	0.596	0.553	

($p < .01$). Main effect of the factor Block was significant [$F(3.476, 173.846) = 61.50$, $GG_\varepsilon = .39$, $p < .001$; $\eta_p^2 = .55$] but did not interacted with Sex [$F(3.476, 173.846) = 1.02$, $GG_\varepsilon = .39$, $p = .39$]: reaction times were shorter along the blocks for both men and women (see Fig. 3).

Prime factor had a main significant effect [$F(1.865, 93.280) = 27.77$, $GG_\varepsilon = .93$, $p < .001$; $\eta_p^2 = .36$]: RTs were shorter when the prime was a B face ($M = 817$ ms, $SD = 163$) than when it was an L face ($M = 864$ ms, $SD = 180$), [$F(1,50) = 50.14$, $p < .001$; $\eta_p^2 = .50$], but there was no significant difference between RTs for L and R face conditions ($M = 877$ ms, $SD = 188$) [$F(1,50) = 1.82$, $p = .18$]. There was no significant effect of Condition [$F(1,50) = 2.44$, $p = .12$], but this factor interacted with the Block [$F(5.476,273.837) = 2.24$,

Table 4
Summary of ANOVA results (F values, p-value and effect size-η_p^2) as a function of Sex, Condition, Prime and Block, for Reaction times (ms).

All trials	F	p-Value	Effect size (η_p^2)
Sex	7.589	0.008	0.131
Condition	2.448	0.124	
Prime	27.777	0.001	0.357
Block	61.498	0.000	0.551
Sex * Condition	0.717	0.401	
Sex * Prime	3.089	0.049	0.038
Sex * Block	1.021	0.392	
Prime * Block	0.669	0.844	
Prime * Condition	4.103	0.019	0.076
Prime * Block * Sex	0.765	0.743	
Condition * Block	2.244	0.044	0.043
Condition * Sex * Prime	1.523	0.223	
Condition * Block * Sex	0.826	0.592	
Prime * Condition * Block	1.194	0.258	
Prime * Condition * Block * Sex	1.173	0.277	
"Matching" condition			
Sex	8.153	0.006	0.140
Prime	34.765	0.000	0.410
Sex * Prime	0.810	0.447	
"Mismatching" condition			
Sex	6.549	0.013	0.116
Prime	9.53	0.000	0.160
Sex * Prime	3.91	0.022	0.073

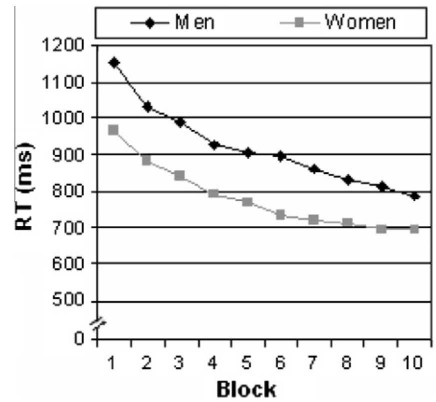

Fig. 3. Reaction times (ms) for all trials, as a function of the Blocks in men (black diamond) and in women (grey square).

$GG_\varepsilon = .61$, $p = .044$; $\eta_p^2 = .042$]. Subjects improved their reaction times between the third and the fourth block ($p < .001$) only when prime matched the target (in the "mismatch" condition: $p = .70$).

The Sex by Prime interaction was close to the significance threshold, [$F(1.865,93.280) = 3.09$, $GG_\varepsilon = .86$, $p = .058$; $\eta_p^2 = .06$] (see Fig. 4). In Men, RTs were shorter when the prime was a B face ($M = 876$ ms, $SD = 199$) than when it was an L face ($M = 929$ ms, $SD = 220$), [$F(1,50) = 31.79$, $p < .001$; $\eta_p^2 = .39$], and longest when the prime was an R face ($M = 956$ ms, $SD = 250$), [$F(1,50) = 4.08$, $p = .048$; $\eta_p^2 = .07$]. In women, RTs were shorter when the prime was a B face ($M = 759$ ms, $SD = 128$) than when it was an L face ($M = 800$ ms, $SD = 138$), [$F(1,50) = 19.14$, $p < .001$; $\eta_p^2 = .28$], but there was no RT difference for L and R faces ($M = 799$ ms, $SD = 126$; $F < 1$).

The Condition by Prime interaction was significant [$F(1.933,96.663) = 4.10$, $GG_\varepsilon = .99$, $p = .019$; $\eta_p^2 = .076$]: when the prime was a B face, RTs were shorter when the prime and target matched ($M = 801$ ms, $SD = 161$) than when they mismatched ($M = 834$ ms, $SD = 166$; $F(1,50) = 9.09$, $p = .004$; $\eta_p^2 = .15$). When the prime was an L or an R face, RTs were similar regardless of Condition ($F < 1$).

Given this significant Condition by Prime interaction, two separate analyses were done: one for condition when the prime and target matched and another for condition when the prime and target mismatched, with Sex and Prime type as factors.

Sex effect was significant for the "matching" condition [$F(1,50) = 8.15$, $p = .006$; $\eta_p^2 = .14$] and for the "mismatching" [$F(1,50) = 6.55$, $p = .013$; $\eta_p^2 = .12$]. In women, RTs were shorter than

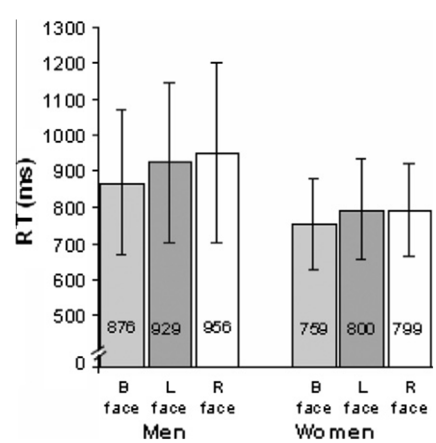

Fig. 4. Reaction times (ms) as a function of prime type and sex, regardless of similarity between prime and target (trials when prime and target matched or mismatched). The error bar represents the standard deviation.

in men in both conditions (for the "matching" condition: $M = 775$ ms, $SD = 130$ in women and $M = 917$ ms, $SD = 223$ in men; and for the "mismatching" condition: $M = 797$ ms, $SD = 131$ in women and $M = 923$ ms, $SD = 223$ in men).

Prime effect was significant when for the "matching" condition [$F(1.934,96.695) = 34.76$, $GG_\varepsilon = .96$, $p < .001$; $\eta_p^2 = .41$] and also for the "mismatching" condition [$F(1.804,90.190) = 9.53$, $GG_\varepsilon = .90$, $p < .001$; $\eta_p^2 = .16$]. When prime and target matched, RTs were shorter when the prime was a B face ($M = 801$ ms, $SD = 161$) than when it was an L face ($M = 863$ ms, $SD = 183$) [$F(1,50) = 51.99$, $p < .001$; $\eta_p^2 = .51$], but it was similar for L face and R face conditions ($M = 874$ ms, $SD = 186$) [$F(1.50) = 1.45$, $p = .23$]. When prime and target mismatched, RTs were shorter when the prime was a B face ($M = 834$ ms, $SD = 166$) than when it was an L face ($M = 866$ ms, $SD = 176$) [$F(1,50) = 12.66$, $p < .001$; $\eta_p^2 = .20$], but there was no RT difference between L face and R face conditions ($M = 880$ ms, $SD = 190$; $F(1,50) = 1.34$, $p = .25$).

The Sex by Prime interaction was significant only when prime and target mismatched [$F(1.804,90.190) = 3.95$, $GG_\varepsilon = .90$, $p = .026$; $\eta_p^2 = .07$] (see Figs. 5a and 5b). RTs in men ($M = 886$ ms, $SD = 203$) and women ($M = 782$ ms, $SD = 128$) were both shorter when the prime was a B face than when it was an L face ($M = 924$ ms, $SD = 211$ – $F(1,50) = 8.67$, $p = .005$; $\eta_p^2 = .15$ – for men, and $M = 809$ ms, $SD = 141$ – $F(1,50) = 4.36$, $p = .042$; $\eta_p^2 = .08$ – for women). Only in men were RTs shorter when the prime was an L face than it was an R face ($M = 961$ ms, $SD = 256$); [$F(1,50) = 4.70$, $p = .035$; $\eta_p^2 = .09$]. In women, RTs were equivalent for L faces ($M = 809$ ms, $SD = 141$) and R faces ($M = 799$ ms, $SD = 124$ – $F < 1$).

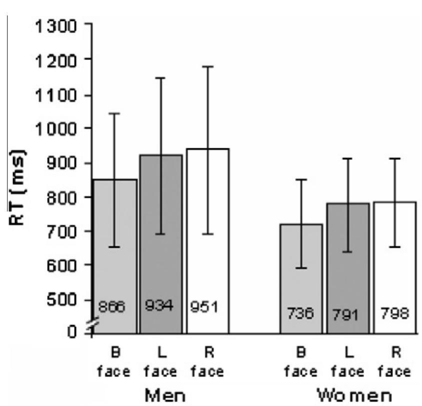

Fig. 5a. Reaction times (ms) as a function of Prime type and Sex, when prime and target matched. The error bar represents the standard deviation.

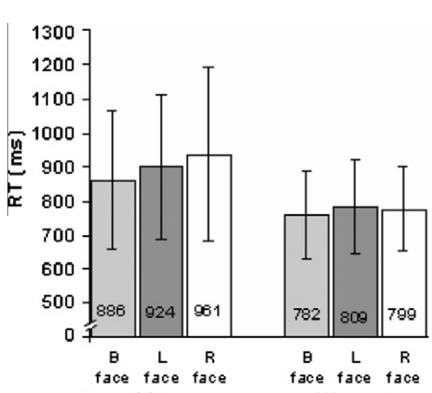

Fig. 5b. Reaction time (ms) as a function of Prime type and Sex, when prime and target mismatched. The error bar represents the standard deviation.

3.4. Effects of Sex of Faces and Sex of Subjects

The interaction between Sex of subject and Sex of face was investigated with repeated measures ANOVAs with Sex of subject, Sex of face and Condition as factors on accuracy and RT. These analyses were done only on trials in which the prime was a B face.

The effect of Sex of face on accuracy was significant [$F(1,50) = 10.24$, $p = .0024$; $\eta_p^2 = .17$]: accuracy for female faces ($M = 82\%$, $SD = 13$) was better than accuracy for male faces ($M = 78\%$, $SD = 15$) whatever the sex of the subject ($F < 1$). Moreover, the effect of the interaction between Sex of face and Condition was significant [$F(1,50) = 6.00$, $p = .018$; $\eta_p^2 = .11$]. Accuracy was better for male faces when prime and target matched than they mismatched [$F(1,50) = 4.83$, $p = .032$; $\eta_p^2 = .09$], whereas accuracy was similar for female faces regardless of the Condition.

On RTs, Sex of face factor had no significant effect ($F < 1$) but Sex of subjects was significant [$F(1,50) = 4.78$, $p = .033$; $\eta_p^2 = .09$]: as the previous analysis, women ($M = 764$ ms, $SD = 140$) were faster than men ($M = 863$ ms, $SD = 201$). Factor Condition had a main significant effect [$F(1,50) = 10.77$, $p = .002$; $\eta_p^2 = .18$]: subjects were faster when the prime and target matched ($M = 796$ ms, $SD = 169$) than when they mismatched ($M = 831$ ms, $SD = 172$).

4. General Discussion

The present study deals with sex differences in hemispheric lateralization and cooperation during face recognition. First, the Beta analysis show that, although subjects were slightly negatively biased when the prime was presented in only one visual field rather than both visual fields, there was no difference between men and women, nor between responses to stimuli presented in the LVF and the RVF. This result could be interpreted in terms of difficulty, which increases when facial information is presented in only one visual field rather than both. Subjects seem to be more careful and have a slight tendency to respond "No, it is not a match" more often. However, this carefulness is equivalent in men and women. This result indicates that our data about sex differences do not depend on a possible response bias. In addition, analyses on the Block factor indicate that subjects improved their performance along the task, as they were instructed: they were more accurate and faster as a function of the blocks.

The main results of this study are as follows: (a) hemispheric lateralization is stronger in men than in women; (b) women respond faster than men in all prime conditions, whereas both men and women have similar accuracy levels; (c) both men and women recognize female faces better than male faces.

In this experiment, in which faces were visible without their external features (i;e, hair, face shape), both men and women responded more accurately to female than male faces. This result differs from others data of the literature showing a women advantage in female faces recognition (Lewin & Herlitz, 2002; Rehnman & Herlitz, 2006, 2007). But, the task used in the present study differs from those used in those previous studies (Lewin & Herlitz, 2002; Rehnman & Herlitz, 2006, 2007), which were tasks implying episodic memory, whereas, our task requires, at most, working-memory capacities. Our result could be explained by greater experience with female faces than male faces in childhood, leading to a more fluent processing of female faces in adulthood (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002; Ramsey-Rennels & Langlois, 2006). However, given only three female faces and three male faces were used in our study, carefulness should be required to interpret this result. In order to reach a definitive conclusion, a much larger number of female and male faces should be used.

Concerning the right hemispheric lateralization that we observed in men only, our data are quite different from those observed in the Yovel et al. (2003) study but enhance our knowledge of this issue. Yovel et al. (2003) observed right hemispheric (RH) dominance in accuracy and reaction time only when the prime and target matched (correct recognition). In our task, this pattern of results was replicated in men only. On trials when the prime and target matched, men performed more accurately when facial information was projected to the RH rather than the left hemisphere (LH). No equivalent difference was observed in women, who had similar accuracy regardless of whether facial information was projected to the RH or the LH. Our reaction time data show RH dominance only in men when prime and target mismatched. A similar pattern of results was observed, although not statistically significant, when prime and target matched. In women, similar reaction times were observed in the two hemi-face conditions. Recall that the number of subjects was low ($n = 12$) in the Yovel et al. study whereas 52 subjects participated in the present study. We think that the larger number of subjects in our study provides more reliable indications that hemispheric lateralization for this task exists solely in men. Men respond better and faster when facial information is projected to the RH compared to the LH. Since this is the case, we can propose that in men the RH is more efficient at processing faces than the LH, which is consistent with previous results showing stronger hemispheric lateralization in men than in women (Bourne, 2005; Fiori et al., 2001; Jones, 1979; Proverbio et al., 2006; Rizzolatti & Buchtel, 1977).

Many researchers have shown the efficiency and the velocity of configural processing – versus analytical processing – for face recognition (de Schonen & Deruelle, 1993; George et al., 1996; Yin, 1969). Moreover, several studies have shown that the RH is more efficient at configural processing whereas the LH is more efficient at analytic processing (Bourne et al., 2009; de Schonen & Deruelle, 1993; Patterson & Bradshaw, 1975; Ross & Turkewitz, 1981). In particular, when faces are processed configurally, the right middle fusiform gyrus is more activated than they are processed featurally (Rossion et al., 2000). However, Yovel et al. (2003) showed that, in this particular task, "*the two hemispheres exchange information symmetrically at early stages (...) and together generate a shared facial representation.*" Thus, configural processing by the RH is probably not sufficient to perform this task. When the information is primed in one hemisphere only, it has to be transferred to the opposite hemisphere.

In men, when the prime is delivered to the RH, configural processing can be carried out at once, and quickly, because it is the most efficient kind of processing; it is then followed by the analytical processing by the LH after transfer of the information from the RH to the LH. When the prime is delivered to the LH, the analytical processing is executed first, but it takes longer than in the previous condition because it is less efficient than configural processing; it is then followed by configural processing by the RH after transfer of the information from the LH to the RH. Furthermore, additional analytical processing would be necessary after the configural processing. The different flow of these operations could explain the longer RTs in men when the prime is delivered to the LH than to the RH.

In women, in whom RTs are similar whichever hemisphere the prime is presented to, the information is assumed to be transferred at once to the other hemisphere and both kinds of processing – configural and analytical – are carried out in parallel. This hypothesis is in agreement with our earlier result showing that, in women, the LH seems to be as competent as the RH at processing facial information, as reflected by the equivalent N170 wave in both hemispheres, whereas this information is clearly lateralized in the RH in men (Fiori et al., 2001; Proverbio et al., 2006). Those electrophysiological data support the hypothesis that neural structures devoted to face processing (and particularly the face fusiform area) might be differently lateralized between men and women. Finally, in this task, the different stages of facial information processing may be developed mostly in parallel in women than in men. The stronger hemispheric lateralization in men compared to women would therefore be disadvantageous when they perform tasks like the one in this experiment.

In all the conditions, including bilateral prime presentation, women responded faster than men, which was observed for the first time in this study. When facial information was projected to both hemispheres, both men and women presented a "bilateral gain": they reacted faster and better compared to the hemi-face prime conditions. But women were still faster than men in this condition. An interpretation in terms of interhemispheric transmission times (IHTTs) can be proposed to explain this result. Nowicka and Fersten (2001), in a letter detection task using event-related potentials (ERPs), estimated IHTTs as latency differences between early components of the N170 in the LH and the RH, and they showed that IHTTs tend to be faster and more symmetrical in women than in men. In an fMRI study, Kansaku and Kitazawa (2001) also showed greater bilateral activation in women during language processing and suggested that it could result from a difference in IHTTs. Yovel et al. (2003), who did not study sex differences, found no evidence of asymmetry in interhemispheric transmission at the early stages of visual processing (at 100–150 ms) but such asymmetry was manifested in the N170 component. N170 latency was shorter and amplitude larger when facial information had been primed in the LVF compared to the RVF. These authors concluded that the two hemispheres symmetrically exchange facial information at an early stage (at 100–150 ms) and generate a shared facial representation that is better quality when the information was presented in the RH than in the LH (Yovel et al., 2003). Moreover, Proverbio et al. (2006), in a study of sex differences in an emotional judgment task, found that the P1 and N1 peak latencies arrived earlier in women than in men and the N1 peaked earlier in the RH than in the LH in men only. Women's earlier P1 and N1 could reflect an advantage in processing visual information regardless of which visual field the prime appears in. The earlier N1 latency in the RH in men than in women suggests that this hemispheric asymmetry appears very early, as soon as 100 ms post-stimulus, in processing facial information, in men only. The functionally equivalent and competent cerebral networks distributed over both hemispheres in women could facilitate the transfer of facial information. This advantage in women could also be the expression of cerebral anatomical differences.

Women seem to have a more bulbous splenium than men (Aboitiz, Scheibel, Fisher, & Zaidel, 1992; Allen, Richey, Chai, & Gorski, 1991; de Courten-Myers, 1999). Recall that the splenium is the most posterior part of the corpus callosum, by which visual information is transferred. This sex-related difference may indicate differences in axon number, size, or myelinization, all of which could alter interhemispheric communication. We suppose that, since women have more fibers in the splenium, their interhemispheric transmission speed could be higher than men's. These two hypotheses are naturally not mutually exclusive.

Lastly, we can speculate about the reasons for the lesser hemispheric specialization in women compared to men. It has often been hypothesized that hormone levels influence brain asymmetry. Fetal hormones seem to have an influence on left-right asymmetries. Testosterone in utero may lead to a more rapid growth of the RH or, alternatively, retard the growth of the LH in males (de Lacoste, Horvath, & Woodward, 1991). Recent observations indicate that the circulating level of steroid hormones may also influence cerebral lateralization in females. Cerebral asymmetries are influenced by menstrual cycle (Rode, Wagner, & Güntürkün, 1995). Hausmann and Güntürkün (2000) showed that a high level of progesterone induces a more bilateral, or at least a less asymmetric, cerebral organization. More recently, Bayer, Kessler, Güntürkün, and Hausmann (2008) showed that interhemispheric integration fluctuates across the menstrual cycle and is reduced during menses.

In conclusion, the present experiment makes new contributions to the knowledge of sex differences in hemispheric lateralization of face recognition, in favor to a stronger hemispheric lateralization in men compared to women, and a faster interhemispheric cooperation in women. Those sex differences in cerebral asymmetries are related to functional cerebral networks that are differentially involved in face processing and to interhemispheric transmission times. We can suggest that the more bilateral functioning in women gives them an advantage in processing speed in this task, without difference in accuracy between men and women. Finally, sex is a variable that affects cerebral asymmetries, and findings confirm that it must be taken into account when studying hemispheric differences.

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