

Women process multisensory emotion expressions more efficiently than men

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ABSTRACT

Despite claims in the popular press, experiments investigating whether female are more efficient than male observers at processing expression of emotions produced inconsistent findings. In the present study, participants were asked to categorize fear and disgust expressions displayed auditorily, visually, or audio-visually. Results revealed an advantage of women in all the conditions of stimulus presentation. We also observed more nonlinear probabilistic summation in the bimodal conditions in female than male observers, indicating greater neural integration of different sensory-emotional informations. These findings indicate robust differences between genders in the multisensory perception of emotion expression.

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1. Introduction

Our ability to recognize emotional expressions enables us to “read” the feelings of others and thus is a fundamental cognitive skill for the effective regulation of our social interactions. Indeed, the tone of the voice and the facial expression of our interlocutor are two crucial cues that we constantly use to predict actions in others and to decide how to orient appropriately our own behavior in a social context.

Women superiority in the recognition of non-verbal emotion expressions is often intuitively assumed but empirical investigations produced inconsistent findings, even if a gender advantage seems more often found in favor of women (Briton & Hall, 1995; McClure, 2000). These discrepancies may be due in part to the lack of ecological validity of the stimuli used in previous studies. For example, one aspect that has been neglected in previous research is the dynamic nature of facial expression and most experimental studies have been conducted using photographs (e.g. Ekman & Friesen, 1976). Facial movements have been shown to enrich emotional expression, contribute to its identification and play an important role in the perception of its intensity (Ambadar, Schooler,

& Cohn, 2005; Biele & Grabowska, 2006). Moreover, neuroimaging studies have shown that the brain regions involved in the processing of facial affect—such as the posterior superior temporal sulcus (pSTS), the amygdala, and insula—respond differently to dynamic more realistic stimuli than to static emotional expressions (Haxby, Hoffman, & Gobbini, 2000; Haxby, Hoffman, & Gobbini, 2002; LaBar, Crupain, Voyvodic, & McCarthy, 2003). Also, only a few studies explored sex differences for the processing of affective vocalizations, and in most cases included semantic confounds in the tasks (see Belin, Fillion-Bilodeau, & Gosselin, 2008 for review). Moreover, existing research has focused on the discrimination of emotional expression based upon a single sensory modality at a time whereas in natural situations, emotions are expressed both facially and vocally, raising the possibility that these sources of information are combined by human observers. In fact, recent studies have demonstrated that congruency in information expressed via facial expression and affective prosody optimizes behavioral reactions to such emotion-laden stimuli (Collignon et al., 2008; de Gelder & Vroomen, 2000; Massaro & Egan, 1996). The use of bimodal stimuli may thus provide a more comprehensive understanding of gender-differences in emotion processing.

The current study attempts to take a new look at gender-differences in the processing of emotion expression by using ecological material composed of newly validated sets of dynamic visual and non-verbal vocal clips of emotional expressions (Belin et al., 2008; Simon, Craig, Gosselin, Belin, & Rainville, 2007). Participants were required to categorize as fast as possible fear or disgust

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expressions by the presentation of auditory stimuli alone, visual stimuli alone, incongruent audio-visual stimuli (different expressions in the two modalities) and congruent audio-visual stimuli (the same expression in the two modalities). We focused on “Fear” and “Disgust” emotion expressions because both emotions have a function of prevention in situation of direct threat and thus may have a longer evolutionary history and may be more important for survival of species than other emotions such as happiness. Indeed, these two emotions may have a higher potential of presenting gender related specificity (Hampson, van Anders, & Mullin, 2006). Furthermore, despite the fact that both emotions belong to the category of ‘negative affect’, disgust and fear expressions can be clearly distinguished from one another (Belin et al., 2008; Ekman & Friesen, 1976; Simon et al., 2007; Susskind et al., 2008) and serve as a model to study the existence of separate neural substrates underlying the processing of individual emotion expressions (Calder, Lawrence, & Young, 2001).

2. Methods

2.1. Participants

Twenty-three male and twenty-three female participants, all right-handed (Oldfield, 1971), took part in the experiment. Male participants had a mean age of 25.8 years (range: 18–43 years) and female participants were on average 23.8 years old (range: 19–37 years). All participants were without any recorded history of neurological or psychiatric problems, reported normal hearing and normal or corrected-to-normal vision and did not use psychotropic medication at the time of testing. The study was approved by the local ethics committee of the Université de Montréal and all subjects gave their written informed consent prior to inclusion in the study.

2.2. Stimuli

The visual stimuli came from a standardized set of dynamic color stimuli of actors and actresses displaying prototypical facial expressions (Simon et al., 2007). Three actors and three actresses who produced unambiguous facial expressions of “fear” and “disgust” emotions were selected. The facial expressions were “prototypical” and “natural” insofar as they possessed the key features (identified using the Facial Action Coding System: FACS) identified by Ekman and Friesen (1976) as being representative of everyday facial expressions (Simon et al., 2007). The same actors and actresses portrayed the two emotions. The selected clips were edited in short segments of 500 ms with a size of 350 × 430 pixels using Adobe Premiere and Adobe Aftereffect (Adobe Systems Inc., San Jose, US). The clips always started with a neutral face which then continuously evolves into full expression.

The auditory stimuli came from the “Montreal affective voices”, a standardized set of emotional vocal expressions designed for research on auditory affective processing with the avoidance of potential confound from linguistic content (Belin et al., 2008). Among this set, we selected “Fear” and “Disgust” vocalizations portrayed by three actors and three actresses producing the stimuli with the highest level of distinctiveness. Again, each actor portrayed both emotions. The selected affective interjections were then edited in short meaningful segments of 500 ms (rise/fall time 10 ms) and normalized peak values (90%) using Adobe Audition 2.0 (Adobe Systems Inc., San Jose, US).

The bimodal stimuli were obtained by simultaneously presenting visual and auditory clips. The matching could either be “congruent”, with audio and video tracks portraying the same emotion (e.g. fearful face/fearful voice), or “incongruent”, with audio and video tracks portraying different emotions (e.g. fearful face/disgust voice). Each actor or actress in the visual clips was assigned with a specific “voice” for the two emotions throughout the experiment, either in the congruent or incongruent conditions (see Fig. 1).

2.3. Procedure

Participants sat in a silent and darkened room, their head constrained by a chinrest in front of a computer screen at a viewing distance of approximately 57 cm. Stimuli were displayed and reaction times recorded using Presentation software (Neurobehavioral Systems, Inc.). Visual stimuli (width = 10° and height = 12.5° of visual angle) were presented in the centre of the screen over a constant grey background. Auditory stimuli were presented binaturally through headphones (Philips HJ030) at a self-adjusted comfort level.

The participants were required to discriminate fear and disgust emotion expression stimuli presented only auditorily, only visually, or audio-visually. Audio-visual stimuli could be either incongruent (different expressions in the two modalities) or congruent (the same expression in the two modalities). The participants were required to respond as quickly and as accurately as possible in a forced-choice discrimination paradigm, by pressing the appropriate keyboard keys with the index

finger of each hand. The response keys were counterbalanced across subjects. The subjects were instructed to identify the portrayed emotion as either “fear” or “disgust” based on their initial reaction to the stimuli, even if they perceived a conflict between the senses. The participants were presented with a total of 576 stimuli randomly interleaved (2 [emotions: fear or disgust] × 6 [actors: 3 actors and 3 actresses] × 4 [conditions: visual, auditory, audio-visual congruent and audio-visual incongruent] × 12 repetitions [12 stimuli for each actor]). These stimuli were displayed in 6 separate blocks of 96 stimuli. Breaks were encouraged between blocks to maintain a high concentration level and prevent mental fatigue. Each stimulus presentation was followed by a 2000 ms grey background (the response period), then a central cross appeared for 500–1500 ms (random duration) prior to the next stimulus (Mean ISI 3000 ms; range 2500–3500 ms). Trials to which participants did not respond were considered as omissions and were discarded.

2.4. Data analyses

Task accuracy was estimated by the calculation of the indices d' (sensitivity index) and β (Bias index) computed following Snodgrass and Corwin (1988). Only latencies of correct responses (150–2000 ms) were considered in the analysis of reaction times (RTs). In experiments equally emphasizing accuracy and processing speed, as it is the case in the present study, it is usual to combine both response speed and accuracy into a single score performance in order to obtain a general index of performance that discounts possible criterion shift or speed/accuracy trade-off effects (Townsend & Ashby, 1983). To do so, and in order to attribute the same weight to accuracy and RT performances across our participants, we normalized ($M = 0$ and $SD = 1$) the d' and the RT scores obtained across all conditions and we subtracted the normalized RTs from the normalized d' [$Z(d') - Z(\text{RTs}) = \text{“speed-accuracy composite score”}$]. The use of Z-scores in our analyses also excludes the possibility that between-gender differences were due to mean and variance differences between the male and the female groups. The speed-accuracy composite score was then submitted to repeated measures analysis of variance (ANOVA). Based on significant F-values, Bonferroni post hoc analyses were performed when appropriate. d' and RTs data are illustrated separately in a supporting figure.

In multisensory paradigms, responses are usually faster when two stimuli from separate modalities are presented at the same time than when a single target stimulus is presented in isolation (Stein & Meredith, 1993). Miller (1982) provided a method to test if the redundant target effect (faster RTs in bimodal condition) reflects a true multisensory integrative process or not. In the race model (Miller, 1982), faster RTs obtained in bimodal situations are produced because the two unimodal stimuli set up a race for the control of response and the faster process wins, that is, there is no need to postulate neural interaction between the two stimuli. However, if RTs obtained in the bimodal condition are better than the predictions of the race model, this provides evidence that information from the visual and auditory sensory modalities interacted to produce the RT facilitation. Analyses of violation of the race model inequality were carried out using the RMITest software which implements the algorithm described in Ulrich, Miller, and Schroter (2007). The algorithm estimates the cumulative probability distributions of RT in the two unimodal conditions and the bimodal condition, and tests whether redundant-targets RTs (the bimodal condition) are significantly faster than would be predicted by a race model (with t -tests).

3. Results

Differences in performance (Fig. 2) were analyzed by submitting our “Speed-Accuracy composite score” (see Section 2.4) to a 2 (gender: male and female; between-subjects factor) × 2 (actor gender: male, female) × 3 (modality: auditory, visual, bimodal congruent); within subjects factors] repeated measures ANOVA. We first observed a main effect of the factor “Gender” [$F(1,44) = 6.55$, $p \leq .01$] revealing superior general performance in women than in men. We also observed a highly significant main effect of the factor “Actor gender” [$F(1,44) = 65$, $p \leq 10E-6$] showing better performance when an actress, rather than an actor, expressed the emotion. The analysis also yielded a main effect of the factor “Modality” [$F(2,88) = 19$, $p \leq 10E-6$] demonstrating superior performance with bimodal stimuli compared to visual ($p \leq .00002$) and auditory ($p \leq 10E-6$) stimuli alone. No significant difference was observed between the visual and the auditory modalities. The ANOVA also revealed a significant interaction between the factors “Modality” and “Gender” [$F(2,88) = 3.33$, $p = .04$] indicating that the performance was significantly higher in vision than in audition in male subjects ($p = .01$) whereas it was not the case in female participants ($p = .52$). Finally we found a significant interaction effect between the factors “Actor gender” and “Modality” [$F(2,88) = 5.29$,

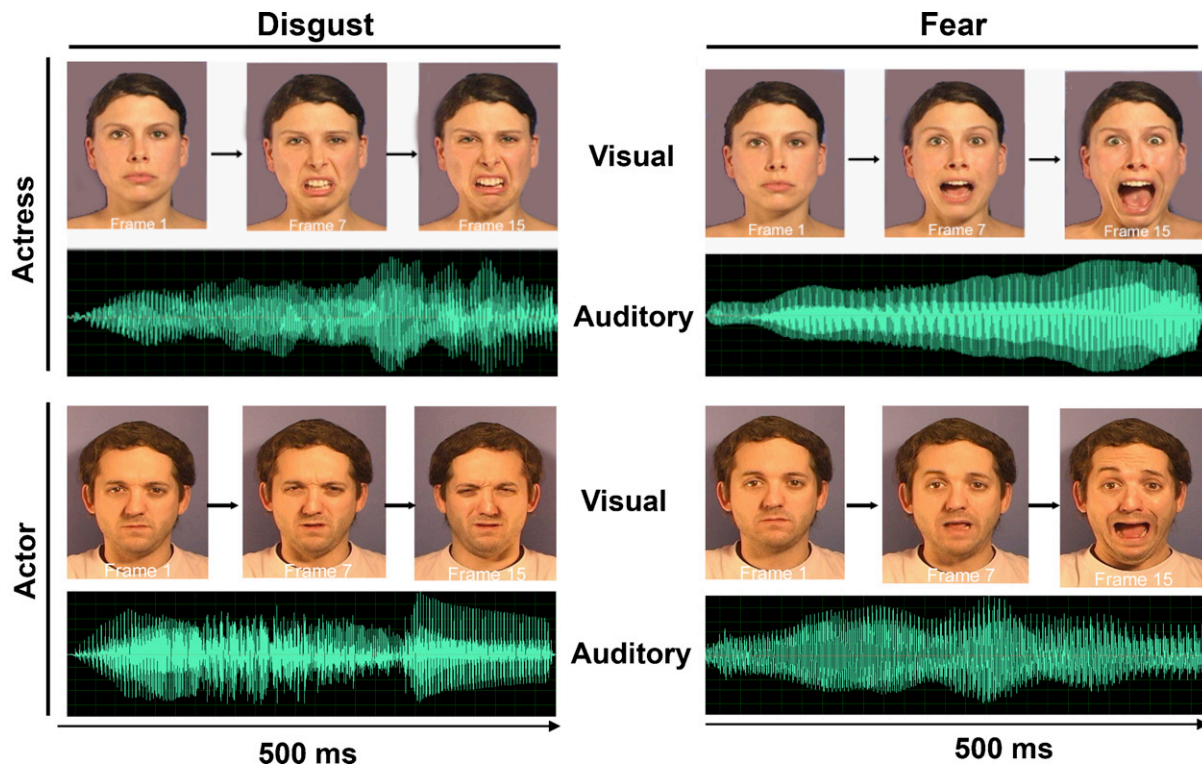


Fig. 1. Schematic representation of the stimuli. Participants were required to discriminate between affective expressions of “fear” and “disgust” displayed either by an actress or an actor. Stimuli consisted in video (Simon et al., 2007) and non-linguistic vocal clips (Belin et al., 2008). These stimuli were either displayed alone or in bimodal congruent (the same emotion in both modalities) or incongruent (different emotions in each modalities) combination.

$p = .007$] showing that the performance was significantly higher in vision than in audition when an actor expressed the emotion ($p = .003$) but not when it was an actress ($p = .96$).

To further test the presence of multisensory gain in reaction times (RTs) data, we investigated if the redundancy gain obtained for RTs in the bimodal conditions exceeded the statistical facilitation predicted by probability summation using Miller’s race model of inequality (Miller, 1982) (see Section 2.4 for details). We observed violation of the race model prediction over the fastest quantiles of the reaction time distribution, supporting interaction

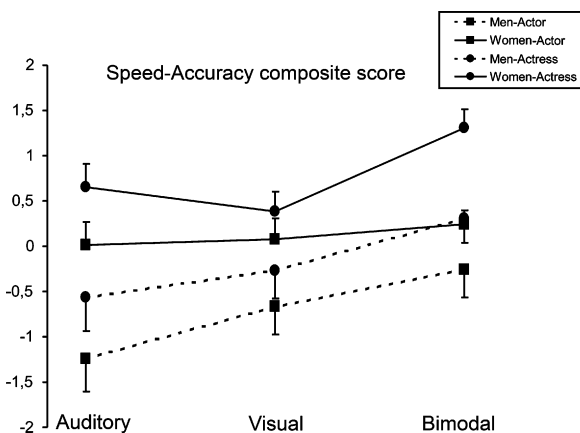


Fig. 2. The figure displays the performance obtained in the visual, auditory and bimodal congruent conditions of stimulus presentation. The speed-accuracy composite score is obtained by subtracting normalized reaction times from the normalized d' recorded in our task, thus eliminating any potential speed/accuracy tradeoff effects in the data; the higher the score, the more efficient the performance (see Section 2.4 for details). Error bars denote standard error. We observed a superior performance in women over men and also an enhanced performance when an actress rather than an actor expressed the emotion.

accounts in bimodal conditions of presentation, and this was even more present in women than in men (Fig. 3). In women, if an actress or an actor expressed the emotion the race model was significantly violated over the 10th, 20th and 30th percentiles of the RT distribution whereas in men the race model was significantly violated only over the 10th and 20th percentiles of the RT distribution.

A 2 (gender: male and female; between-subjects factor) \times [2 (actor gender: male, female) \times 3 (modality: auditory, visual, bimodal congruent); within subjects factors] repeated measures ANOVA was performed on the Bias indices (β 's) (see Fig. 4). We observed a main effect of the factor “Actor gender” [$F(1,44) = 24.64$, $p \leq .00001$] revealing that the bias was significantly oriented toward a “fear” response when an actress expressed the emotion and, inversely, the bias was more oriented toward a “disgust” response when it was an actor who expressed the emotion.

Because there are no “correct” responses with incongruent bimodal stimuli, a tendency to respond either “fear” or “disgust” was estimated by subtracting the proportion of “fear” responses from the proportion of “disgust” responses ($p_{\text{Disgust}} - p_{\text{Fear}}$; see Fig. 5). The index, which varies between -1 (subject always responded “fear”) and 1 (subject always responded “disgust”), was analyzed by means of a 2 (gender: male and female; between-subjects factor) \times [2 (actor gender: male, female) \times 2 (conditions: fearful face/disgust voice and disgust face/fearful voice); within subjects factors] repeated measures ANOVA. We observed a highly significant main effect of the “Actor gender” factor [$F(1,44) = 30.3$, $p \leq .000002$] showing that the index was more positive when an actor expressed the incongruent emotions as being “disgust” responses, whereas the index was more negative when an actress expressed the incongruent emotions as more “fear” responses. This result is thus in close connection to the one previously observed with our bias measurement, with a tendency to attribute more “fear” to the actress and more “disgust” to an actor. We also observed a significant interaction between the factors “Actor gen-

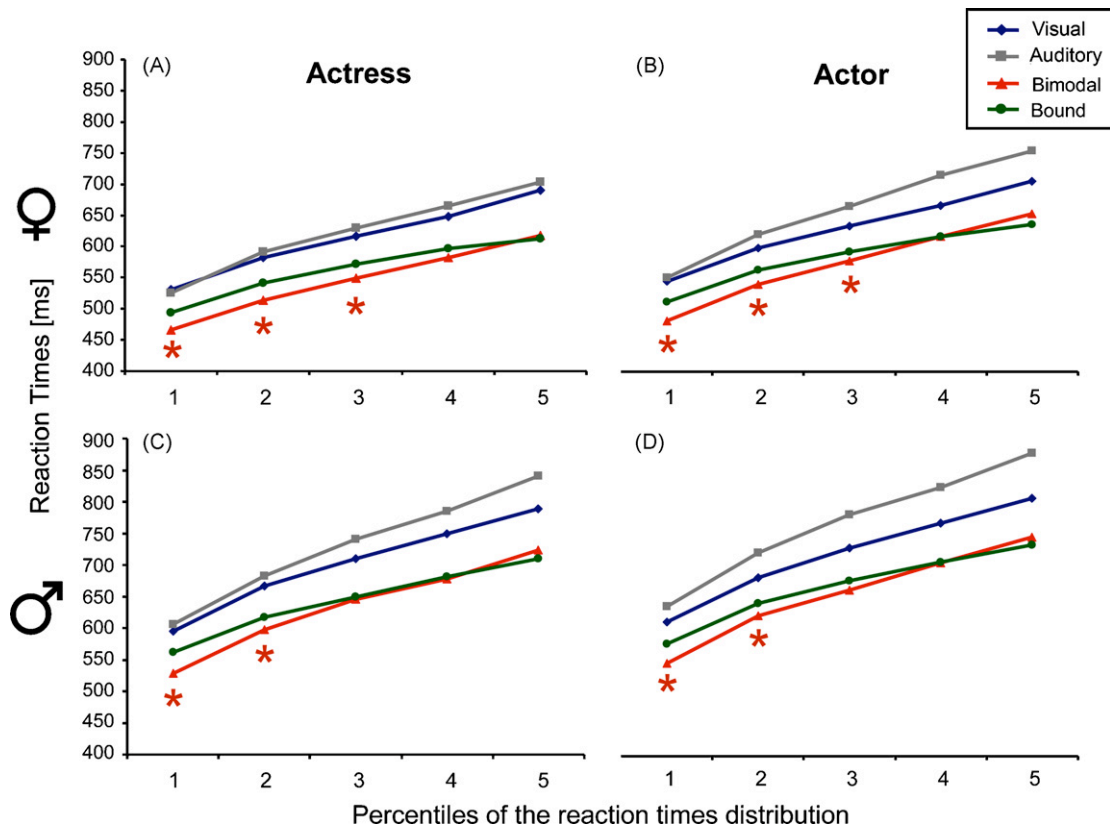


Fig. 3. Redundancy gain analysis and test for violation of the race model inequality (Miller, 1982; Ulrich et al., 2007). The figure illustrates the cumulative probability distributions of the reaction times (only the first half of the quantiles are displayed) with congruent bimodal stimuli (red triangles) and their unisensory counterparts (grey squares for auditory, blue diamonds for visual), as well as with the race model bound (green dots) computed from the unisensory distributions. Reaction times were obtained either when an actress (A and C) or an actor (B and D) displayed the emotion. Bimodal values inferior to the bound indicate violation of the race model and the asterisks refer to statistical significance. In all conditions the race model inequality is significantly violated over the fastest quantiles of the reaction time distribution, supporting interaction accounts, and this was even more present in women (3 percentiles violated) than in men (2 percentiles violated). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article).

der” and “Condition” [$F(1,44) = 4.31, p = .04$] showing that the bias toward “fear” for the actresses was particularly present in the condition “disgust face/fearful voice”, meaning that the auditory channel dominated the response selection in this particular case.

4. Discussion

The present study investigated the multisensory processing of emotional expressions using dynamic visual and non-linguistic vocal clips of affect expressions. The results showed striking differences between women and men in their ability to process and

express emotional expressions, suggesting that “gender” is a fundamental variable when studying mechanisms of emotion expression processing.

We found that women outperformed men in the processing of auditory, visual and bimodal congruent stimuli (Fig. 2). The fact that such enhanced performance was present for all these conditions of stimulus presentation suggests an advantage of the way

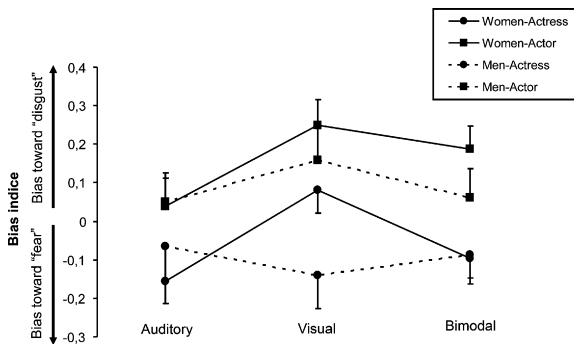


Fig. 4. The figure displays the Bias indices β obtained in the visual, auditory and bimodal congruent condition of stimulus presentation. Error bars denote standard error. When an actor expresses the emotion, the bias is directed toward a “disgust” response whereas it is the opposite when an actress expresses the emotion.

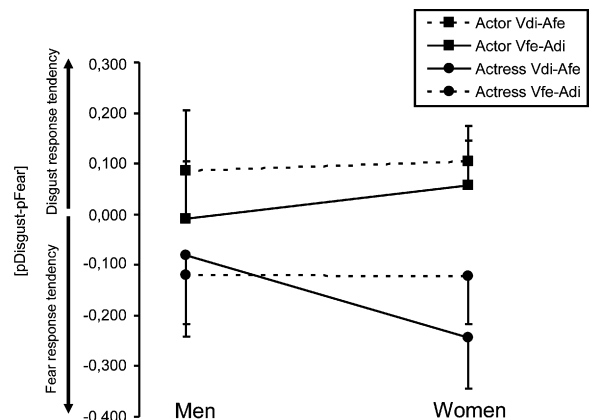


Fig. 5. Bias to respond either “fear” or “disgust” in incongruent bimodal conditions was estimated by subtracting the proportion of “fear” responses from the proportion of “disgust” responses ($pDisgust - pFear$). Women and men participants tend to report more a “disgust” response when an actor expresses the emotion whereas they categorize more readily the stimuli as expressing “fear” when the stimuli are produced by an actress.

women process emotion expressions in comparison to men that is not specific to one sensory modality in particular. When participants processed emotional information with congruent bimodal stimuli, they showed improved performances compared to either unimodal condition. As already demonstrated in a previous study (Collignon et al., 2008), we observed that RTs in congruent bimodal conditions exceeded the race model estimation (Miller, 1982) over the fastest quantiles of the reaction time distribution, providing evidence that information from the visual and auditory sensory modalities truly interacted to produce the RT facilitation. Although this integrative effect was present in both groups, it was found to be stronger in women than in men. This result suggests that women not only process more efficiently unisensory emotional information but may also be better at integrating vocal and facial expressions (Fig. 3). It is worth noting that this result is not trivial or a direct consequence of the unimodal superiority since the “inverse effectiveness” principle in multisensory integration, which states that the result of multisensory integration is inversely proportional to the effectiveness of the unisensory stimuli (Stein & Meredith, 1993), would have predicted less integration in women on the basis of their higher performance in unisensory conditions.

Such behavioral differences are likely to be related to neuro-anatomical changes in brain regions responsible for the processing of emotional content. In a recent review, Cahill (2006) underlined that regions known to be involved in emotional processing show major sexual dimorphisms in terms of function and architecture. Most of the neuroimaging studies looking for sex differences used unimodal emotional stimuli however. Experiments investigating visual emotion judgments showed major gender-differences, particularly enhanced activations in emotional regions in women when compared to men (Hofer et al., 2006; Schulte-Rüther, Markowitsch, Shah, Fink, & Piefke, 2008). To our knowledge, there is only one neuroimaging study that has investigated sex differences in the processing of bimodal visual/auditory stimuli, with auditory material (common proper names) containing little semantic information (Hall, Witelson, Szechtman, & Nahmias, 2004). Hall's study found significant differences in activity between men and women, with women showing increased limbic activity in crossmodal situations.

However, since brain functions and circuitry in emotion processing are both dependent of phylogenesis and ontogenesis, these studies do not tell us if women are “wired” from birth to be especially sensitive to emotional cues or if these changes are the end-process of experience. The fact that some differences are already present extremely early in life suggests that biology may play a role since there has hardly been any opportunity for socialization and experience to shape these sex differences (Baron-Cohen, 2003; Hines & Alexander, 2008; McClure, 2000). Evolutionary psychologists have proposed that females, because of their role as primary caretakers, might be wired to display fast and accurate decoding of affects in order to detect distress in preverbal infants or threatening signals from other adults, thus enhancing the survival chances of their offsprings (Babchuk, Hames, & Thompson, 1985). However, these studies should not rule out the fact that culture and socialization do play a powerful role in determining gender-differences in the processing of emotional expressions. It is highly probable that ontogenetic and phylogenetic factors operate in an integrated fashion to determine the differences in the way women and men process emotional expressions (Baron-Cohen, 2003).

Beyond the effect of woman superiority in emotional expression processing, we also observed that, irrespective of the gender of the observer, performance is better when women express the emotion (Fig. 2). This result could be related to what we observed in our control study showing that emotions expressed by an actress were judged as being more intense than emotions expressed by an actor (see supporting Fig. 2). It is thus possible that women express emo-

tion more intensely, leading to a better discrimination. In western cultures, women are believed to be more emotionally expressive in general than are men, probably because they are more encouraged than men to express emotion (Brody & Hall, 1993; Kring & Gordon, 1998; Polce-Lynch, Meyers, Kilmartin, Forssmann-Falck, & Kliewer, 1998). Also, the expression of emotion seems to be hardwired into our genes since a recent study demonstrated that sighted and blind individuals use the same facial expressions in response to specific emotional stimuli, suggesting that the ability to regulate emotional expressions is not only learned through observation (Matsumoto & Willingham, 2009). From an evolutionary perspective, the ability to communicate efficiently an emotional state may be of particular importance in women who often assume a primary role as caretakers (Babchuk et al., 1985).

Interestingly, we also observed a response bias toward “fear” expression in actresses and “disgust” expression in actors (Fig. 4). This result is in agreement with our observation that, in incongruent bimodal condition, participants had a tendency to orient their response toward a “disgust” response when an actor expressed the emotion and to orient their response toward “fear” when an actress expressed the emotion (Fig. 5). These results may be related to the “baby X” experiment. In this experiment, Seavey, Katz, and Zalk (1975) demonstrated that if one is shown a videotape in which a 3-month-old child appears upset, and is told the child is a male, one is more likely to label the child's emotion as anger. If one is told that the child is a girl, the child's emotion is labeled as fear. We thus may be biased to decode differently an ambiguous emotion expression depending of the gender of the sender, based on gender-stereotyped beliefs in the expression of emotions.

The absence of control of the hormonal status of the women involved in the experiment represents a limitation of the study. Several studies investigating facial emotion processing have indicated that women's ability on this task differs significantly over the course of the hormonal cycle, with better performance found in the late follicular, or preovulatory phase, relative to the luteal phase (Derntl et al., 2008; Guapo et al., 2009; Pearson & Lewis, 2005). We however do not believe that this invalidates the findings of the present study. Since most of the participants were university students, it seems likely that a significant portion of the studied women were using hormonal birth control. Assuming this is true, because most hormonal contraception creates an endocrine state that is similar to the luteal phase, task performance for these women may be lower, on average, than it would be in a freely cycling group, so it is likely in fact that the present data understate the natural sex difference.

Beyond the Mars-Venus stereotypes, research into gender-differences is necessary to better understand psychopathological conditions where major gender-differences exist in their incidence and/or nature (Cahill, 2006). An example of the clinical relevance of our understanding of gender-differences may be found in autism spectrum conditions which appear to affect males far more often than females and which are characterized by important deficits in the recognition of emotion expressions (Schultz, 2005). Recently, Baron-Cohen introduced a provocative but insightful theory assuming that autism could be an exacerbation of the male's brain (Baron-Cohen, 2002). The Baron-Cohen group proposed that autism and Asperger's syndrome represent the pathological extreme of male cognitive-interpersonal behavior characterized by impaired empathizing and enhanced systematizing. Our findings that male subjects discriminate and express less efficiently emotional affects may support, at least in part, such theories.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.neuropsychologia.2009.09.007.

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