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Sex differences on emotional processing are modulated by subclinical levels of alexithymia and depression: A preliminary ERP assessment

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ABSTRACT

Several studies have suggested that women are more sensitive than men to emotions in general. Event-related potential (ERP) studies have demonstrated N2 and P3b modulations, suggesting that women allocate more attentional resources to emotions than men do. However, the exact origin of this emotional modulation by sex is still a matter of debate. We wondered whether these sex differences might be due to some specific personality traits of women and men. Thirty participants (15 males and 15 females) were selected so that there were no sex differences on alexithymia, or depression and anxiety scales. The participants were asked to complete a "modified emotional" oddball task, in which they had to detect deviant stimuli among frequent neutral ones as quickly as possible. Behavioral performance, N2 and P3b ERP data were analyzed. When personality factors were controlled for, the sex differences on N2 and P3b components of the ERPs disappeared. Moreover, linear regression analyses showed that alexithymia was much better than sex at predicting the N2 latencies, while depression was the best factor for predicting the P3b latency. These results suggest that personality factors should be taken into account when sex differences on emotional processing are investigated.

1. Introduction

Women are seen as more skilled than men in interpersonal perception (Hall and Schmid-Mast, 2008). Indeed, many studies have shown that females are more accurate than males in terms of judging the meaning of nonverbal cues, i.e., in recalling other people's nonverbal behavior (e.g., smiling) (Hall et al., 2006), remembering their physical appearance (Schmid-Mast and Hall, 2006), or judging profiles of their personalities (e.g., Vogt and Colvin, 2003). Accordingly, there is great deal of evidence suggesting that females have an advantage over males in understanding other people's emotional expressions from faces, postures and voices (see Hall, 1978 for a meta-analysis of 75 studies), even among children and adolescents (McClure, 2000).

Emotional facial expressions (EFE) constitute a particular category of stimuli. Indeed, the more we are efficient in detecting and processing emotions, the more we are efficient in social communication and interactions with other people (Persad and Polivy, 1993). However, a lower sensitivity of males to emotionally negative stimuli has been noted in many empirical studies showing, for instance, that men (1) are less accurate in recognizing EFE, in particular, fear, disgust and sadness (Hall, 1978); (2) are less likely to be influenced by an emotionally negative context (Schirmer et al., 2004); and (3) display less activation in several neural regions (including the amygdala) in response to emotionally negative pictures (Wrase et al., 2003; Hofer et al., 2006). These results can appear as surprising, since we know that, due to adaptive values, emotionally negative signals (e.g., fear, anger) are preferentially treated throughout the information-processing stream as by males than females (e.g., Campanella et al., 2002; Delplanque et al., 2004; Pourtois et al., 2005).

With this in mind, Li et al. (2008) investigated, by means of an event-related potential (ERP) study, the neural mechanisms underlying the female advantage in identifying negative emotions. Due to their high sensitivity, ERPs have the potential to monitor brain electrical activity with a high temporal resolution (on the order of milliseconds) and is therefore of interest in determining the relationships between behavioural performance and cerebral activity (Rugg and Coles, 1995). By manipulating the intensity of emotionally negative stimuli, Li et al. (2008) showed that prominent emotional responses, indexed by larger N2 and P3b components, were evoked by highly negative stimuli in both males and females, but only females displayed similar activation in response to less intense negative stimuli. Accordingly, in an emotional oddball design in which participants had to detect deviant fearful and happy faces among standard neutral ones, Campanella et al. (2004)

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showed that deviant fearful stimuli evoked larger N2 and P3b components than deviant happy stimuli in both sexes, but the processing of deviant happy stimuli was significantly slower in men than in women.

Data from Campanella et al. (2004) and Li et al. (2008) suggest that men as well as women are sensitive to emotionally negative events of enhanced salience in their environment, while negative stimuli of lesser intensity and positive stimuli best demonstrated females' greater sensitivity (Li et al., 2008). These data are in perfect agreement with a more recent study of Lithari et al. (2010), showing that if unpleasant or high arousing stimuli are temporally prioritized during visual processing by both genders, females responded with enhanced negative components, in comparison to males, to these stimuli. Overall, this female-specific sensitivity is neurophysiologically mainly indexed by modulation of the N2 and P3b components, while earlier components such as the P100 and the N170 do not display any significant differences. The visual N2 component, peaking at posterior electrodes around 250 ms, indicates a switch of attention to biologically significant events in order to cope with them (e.g., Halgren et al., 1994; Campanella et al., 2002). The P3b component has been maximally recorded at parietal sites around 450 ms, and is functionally related to the closure of ongoing cognitive activity (e.g., Tomberg and Desmedt, 1998), i.e., to later conscious, decisional and premotor response-related stages (Bentin et al., 1999; Polich, 2004). In other words, the N2–P3b distinction allows separate the attentional (preparation-to-process) and the task-decisional (preparation-to-respond) steps of a task (e.g., Campanella and Philippot, 2006). In this particular case, it suggests that the well-known behavioral female advantage in identifying negative emotions may be attributable to a higher sensitivity to negative stimuli of lesser emotional saliency, indicated by the allocation of higher attentional resources (N2) which enable a quicker reaction (P3b) to these stimuli. Men's processing of these stimuli is slower, as shown by their delayed N2–P3b components.

Based on epidemiological studies on different representative community surveys (from the US, Canada, Europe as well as New Zealand and Australia), the consensus is that women and men differ strikingly in the prevalence, incidence and morbidity risk of specific mental disorders (Klose and Jacobi, 2004). Accordingly, in the present study, we hypothesize that sex differences in interpersonal perception may be related to inherent "female-related" and "male-related" personality factors. Alexithymia is the term applied to a clinical state and a personality trait characterized by difficulties in processing emotion (Sifneos, 1973). Several studies have found people with alexithymic characteristics to be less accurate in the recognition of EFE (e.g., Lane et al., 1996; 2000; Prkachin et al., 2009), and even if some studies found inconclusive association with sex (e.g., Lane et al., 1998), a recent meta-analysis suggests that this personality trait is more common among men (Levant et al., 2009). On the other hand, mood disorders are one of the most impairing classes of emotional and behavioral disturbances, causing problems in social, professional and interpersonal functioning (Zender and Olshansky, 2009). Depression is the most common mental illness experienced by women (Peden, 1994), and is approximately twice as frequent among women as among men. This sex ratio is cross-culturally consistent. Similarly, anxiety disorders are diagnosed twice as often in women as in men, and about half of all women with a primary diagnosis of major depression also have an anxiety disorder (Zender and Olshansky, 2009). Women are therefore more likely than men to develop co-morbid anxious and depressive disorders. Many studies investigated whether alexithymia is a predisposing or vulnerability factor that influences the onset or course of a disorder such as depression, or merely a state reaction to its presence (e.g., Haviland et al., 1988). In this view, Luminet et al. (2001) showed that, even in the context of large changes in depressive symptoms (baseline vs 14 weeks follow-up treatment), a relative stability of alexithymia was demonstrated (as TAS-20 scores at follow-up were predicted by TAS-20 scores at baseline beyond the variance explained by depression severity), indicating its status as a stable personality trait and not a state-dependent variable.

The cause of alexithymia and depression sex-based differences is not yet precisely understood, although different factors such as brain structure, brain chemistry or hormonal balance are certainly involved. Developments in understanding the psychosocial aspects of depression have linked the well-known sex difference in its prevalence to styles of support-seeking/support-giving which involve some nonverbal communication (such as through EFE) and are more pronounced in women (Harris, 2001). In this view, it is suggested that, as women are more sensitive to emotions in their environment, they react more strongly and positively to social support than men do (Beehr et al., 2003). However, women are also more prone to suffer from affective disorders, such as depression or anxiety in the course of their life (Harris, 2001). Therefore, the "natural" advantage healthy women have in processing EFE may be reversed, as many psychopathological symptoms in co-morbid anxiety and depression are also associated with difficulties in the identification of emotions (e.g., Conrad et al., 2009).

Overall, we are confronted with two phenomena, both closely related to EFE processing: (1) a personality trait (alexithymia) in the healthy population which is more prevalent in men, and which induces poorer performance in emotional tasks; and (2) mood disorders (depression with co-morbid anxiety), which are more frequent in women, perhaps as a result of their higher general sensitivity to emotional cues in normal conditions (e.g., Kemp et al., 2004). The interaction of these phenomena has furthermore received some support, as modulations of EFE processing have mainly been investigated using ERPs, and it has been shown that depression, anxiety and alexithymia affect the same neural processes as sex in normal emotional processing (e.g., Campanella et al., 2004; Li et al., 2008), i.e., the N2 and P3b components, even at a subclinical level (e.g., Rossignol et al., 2008; Vermeulen et al., 2008).

The main objective of the present study is to investigate whether the classical sex modulation of EFE processing (i.e., women's greater efficiency at processing emotions in general), is linked to personality factors (such as the presence of alexithymia in men and subclinical depressive and anxious tendencies in women). To test this hypothesis, we selected two groups of participants (women and men), who were asked to complete an emotional oddball task. This task seems to us particularly well-suited to investigate the combined effects of sex and psychological traits on emotion processing. Indeed, this task has already been used to investigate how sex modulates EFE processing (e.g., Campanella et al., 2004) as well as to describe how some psychological characteristics (subclinical levels of depression, anxiety and alexithymia, see respectively, Rossignol et al., 2008; Vermeulen et al., 2008) interfere with emotional processing. In this study, for the first time, the respective contribution of sex and personality traits on emotional processing will be envisaged together. Participants had to detect deviant faces (displaying happiness or fear) as quickly as possible from a sequence of neutral faces. The important point is that the groups were constituted such that the sex did not differ in their levels of anxiety, depression or alexithymia. Our main hypothesis is that, in this particular case, when these personality variables are controlled, differences in amplitude and/or in latency in EFE processing due to sex will disappear, whereas these personality factors will influence, in amplitude and/or in latency, N2 component for alexithymia (Vermeulen et al., 2008) and P3 for depression (Maurage et al., 2008). Indeed, by means of an emotional oddball task similar to the one we used here, Vermeulen et al. (2008) showed that, as compared to matched controls, alexithymic people displayed a delayed N2 component in response to deviant emotional faces (while no difference was observed on P3), and Maurage et al. (2008) showed that, as compared to alcoholic patients with co-morbid depressive disorder, patients with depression "alone" do show a preserved N2 and a specific impairment of the P3 component.

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2. Materials and method

2.1. Participants

Three hundred students (166 females) from the Université Catholique de Louvain were recruited to fill in the 13-item Beck Inventory Depressive Scale (BDI, Beck and Steer, 1987; French version: Collet and Cottraux, 1986), the Spielberger Trait Anxiety Inventory (STAI-T, Spielberger et al., 1983; French version: Bruchon-Schweitzer and Paulhan, 1993), and the Toronto-Alexithymia Scale (TAS-20, Bagby et al., 1994; French version: Loas et al., 1996). On the basis of their scores (mean BDI males: 3.99, females: 4.73; mean STAI-T males: 40.85, females: 45.42; mean TAS males: 50.1, females: 46.2), 30 students (15 males and 15 females) were matched so that there were no significant difference between sex groups on age and on any of these scales (see Table 1). All the participants were right-handed, with normal/corrected vision and without any neurological/psychiatric diseases.

2.2. Task and procedure

The main objective of this study was to test whether there were differences between males and females when they processed EFE displaying fear and happiness. In order to avoid any differences being attributable to physical differences between neutral and emotional faces, rather than to emotion per se (Campanella et al., 2004), morphed images were used. Technical details about the morphing procedure can be found in Etcoff and Magee, 1992; Calder et al., 1996; Young et al. (1997) and Campanella et al. (2000). In the present study, two faces (one male (A) and the other female (B)) with neutral, happy and fearful expressions were taken from the Ekman and Friesen (1976) series. Two continua of faces were computed for each face ('A neutral' to 'A happy'; 'A neutral' to 'A fear'; 'B neutral' to 'B happy'; 'B neutral' to 'B fear'). Three morphed faces were created for each continuum. They were prepared by blending two faces in the proportions 35:65, 65:35, and 95:5, which we refer to as the 35, 65, and 95% morphs along the appropriate continuum. Thus BNH 35% refers to face B (female), on the continuum neutrality (N) to happiness (H), which is a mixture of 35% 'B neutral' and 65% 'B happy' (Fig. 1).

The important point here is that, as shown in Table 2, ANH 95%, ANF 95%, BNH 95% and BNF 95% were recognized as showing a neutral expression, as were ANH 65%, ANF 65%, BNH 65% and BNF 65%, while ANH 35% and BNH 35% were predominantly recognized as happy, and ANF 35% and BNF 35% were predominantly recognized as fearful. With this in mind, we created four different triads of stimuli that we used in an oddball paradigm. The first triad ANH 35%–ANH 65%–ANH 95% defined a frequent stimulus perceived as neutral (frequent; ANH 65%), and two deviant stimuli, one showing the same neutral state as the frequent stimulus (happy–neutral; ANH 95%), and the other depicting a different emotion (happiness; ANH 35%). The other three triads were: (1) BNH 35% (happy)–BNH 65% (frequent–neutral)–BNH 95% (happy–neutral); (2) ANF 35% (fear)–ANF 65% (frequent neutral)–ANF 95% (fear–neutral); and (3) BNF 35% (fear)–BNF 65% (frequent neutral)–BNF 95% (fear–neutral).

Like Campanella et al. (2002), Rossignol et al. (2007) and Vermeulen et al. (2008), we used this variant of the classical oddball design mainly for methodological reasons: by using morphed images, we could compare deviant stimuli that were separated from the frequent stimulus by an equal distance (30%) on the morphing continuum. Therefore, as the physical amount of difference between the two deviant stimuli and the frequent one is similar, any specific differences evidenced only for the detection of the emotional deviant stimuli among the frequent ones (and not for the detection of deviant neutral ones) cannot be attributed to the physical properties of the stimuli, but only to the emotional change present in the "emotional" deviant stimuli but not in the "neutral" deviant ones. In others words, we presented our participants with two types of deviant morphed faces, both separated by a distance of 30% from the frequent stimulus (perceived as 'neutral'), but one depicting neutrality (like the frequent stimulus), and the other depicting an emotion (happiness or fear). Therefore, to be as clear as possible, deviant "emotional" faces will be called "happy" or "fearful" faces in the following paragraphs, while deviant "neutral" faces will be termed "Fear–Neutral" and "Happy–Neutral" faces, along their appropriate continuum.

Overall, each triad defined one block, and comprised a total of 120 stimuli (for instance, the triad ANH 35%–ANH 65%–ANH 95% defined a block composed with 90 frequent stimuli, 15 Happy faces and 15 Neutral-happy faces). The participants were presented with these four blocks of stimuli (each representing one triad as described above, i.e., neutral-happy face A, neutral-happy face B, neutral-fear face A, and neutral-fear face B) that were each repeated four times in order to obtain a good signal-to-noise ratio Indeed, by this way, we obtain a total of 480 trials representing deviant faces, with 120 Happy and 120 Happy–Neutral faces stemming from ANH and BNH triads (15 trials ANH + 15 trials BNH, repeated four times each), and 120 Fear and 120 Fear–Neutral faces stemming from ANF and BNF ones. Each block lasted around 3 min and the order of these 16 blocks was counterbalanced across subjects. The task was to detect as quickly as possible (by clicking on a button with the right forefinger) the occurrence of any stimulus that differed from the frequent one.

During the ERP recordings, the participants sat in a darkened room on a chair placed 1 meter from the screen, with their heads restrained by a chin rest. The visual stimuli subtended a visual angle of $3 \times 4°$. Before starting the task, subjects had to fix a small white cross in the center of the screen. Each morphed image was presented for 700 ms. A black screen was displayed between stimuli, for a random duration of between 800 and 1100 ms. From the onset of the stimulus, the participants had at least 1500 ms to answer. Response times and error rates were recorded. The participants were told that speed was important, but not at the cost of accuracy. Only correct answers (i.e., deviant stimuli for which the subject pressed the answer key) were considered in the analysis of reaction times and ERPs.

All the procedures used in this experiment complied with the guidelines set out by the local Ethics Research Committee.

Table 1
Mean and standard deviations (in parentheses) for age, BDI, STAI-T and TAS-20 values. These scores did not differ between males and females.

	Age	BDI	STAI-T	TAS-20
Males	21.2	3.6	46.3	48.4
($n = 15$)	(1.7)	(3.6)	(8.7)	(13.3)
Females	20.9	4.1	46.2	55.2
($n = 15$)	(2.4)	(4.5)	(11.4)	(11.7)
$t(14) =$	0.036	0.278	0.033	1.684
$p =$	0.724	0.785	0.974	0.114

2.3. EEG recording and analysis

The EEG was recorded by 32 electrodes mounted in an electrode Quick-Cap. The electrodes were positioned in the international 10–20 system locations and intermediate positions. Recordings were made with a linked mastoid physical reference but re-referenced using a common average (Bertrand et al., 1985). This method was chosen because it has been shown that the average reference is more sensitive to modifications of visual ERP components related to face processing than other possible references (such as the earlobes, the nose or non-cephalic points), particularly in terms of categorical differences (Joyce and Rossion, 2005). Nevertheless, it must be noted that this rereferencing method can alter the spatial characteristics of recorded data, as the fewer the electrode signals used to create the average, the larger the influence each of them will have on the resulting average signal. However, this potential issue can be minimized with a large enough sample of electrodes (at least 20; see Katznelson, 1981).

The EEG was amplified by battery-operated A.N.T.® amplifiers with a gain of 30,000 and a band-pass of 0.01–100 Hz. Ground (AFz) was placed on the midline just between FPz and Fz electrodes. The impedance of all the electrodes was kept below 10 kΩ. The EEG was continuously recorded (sampling rate 500 Hz, A.N.T. Eeprobe software) and trials contaminated by EOG artifacts were eliminated off-line, using the procedure developed by Semlitsch et al. (1986), which consists in computing for each individual participant an average artefact response based on a percentage of the maximum eye movement potential (generally recorded on Fp1, Fpz and Fp2 prefrontal electrodes). The EOG response was therefore subtracted from the EEG channels on a sweep-by-sweep, point-by-point basis in order to obtain ocular artefact-free data (but see new online rejecting method, Klados et al., 2011). Trials contaminated by movements (inducing amplitudes ≥ 30 μV) are also automatically excluded. Importantly, it should be noted that, after EOG rejections, the mean number of remaining accepted trials does not differ between groups and conditions (Fear: Males: 55.8 (S.D.: 7.1), Females: 55.6 (S.D.: 6.7); Fear–Neutral: Males: 56.4 (S.D.: 6.7), Females: 56 (S.D.: 5.9); Happy: Males: 57.4 (S.D.: 6.6), Females: 56.6 (S.D.: 4.3); Happy–Neutral: Males: 57 (S.D.: 7.1), Females: 55.3 (S.D.: 5.1). Periods beginning 200 ms prior to the stimulus onset and continuing for 800 ms were created. Three parameters were coded for each stimulus: (1) the type of the stimulus (deviant emotional, deviant neutral, or frequent neutral); (2) the emotion displayed by the stimulus (happy, fear, happy–neutral, fear–neutral); and (3) the response type (keypress for deviant stimuli, no keypress for frequent ones). The data were filtered with a 30 Hz low-pass filter.

In order to have a good signal-to-noise ratio, averages and response times were performed across the four repetitions and across faces A and B. For each subject and for each emotion and type, the components of interest (namely the N2 and the P3b) were investigated by gathering individual values of maximum peak amplitudes and peak latencies on the classical difference waveforms "Deviant minus Frequent" magnitude (see, Campanella et al., 2002; Polich, 2004). More precisely, for each individual participant, we consider for each stimulation of interest (averages of deviant happy, deviant fear, deviant happy–neutral, deviant fear–neutral stimuli) the difference waveforms obtained by subtracting the Frequent stimulations from the Deviant ones (for instance, for deviant happy stimulations, we computed the difference waveforms Deviant happy minus Frequent neutral). Then, for defining the N2 component values, we look for the maximum peak amplitude and its latency on bilateral posterior electrodes (P7, P8) during a [250–350] ms time interval, whereas electrode Pz and a [350–650] ms time range were used for the P3b component values. The data were tested using repeated measures of analysis of variance (ANOVA), simple effects were explored throughout, sources of significant interactions were systematically examined through simple effects, Bonferroni post-hoc tests were used when appropriate and linear regression analyses were performed using S.P.S.S. 17.02®. The alpha level of significance was set at 0.05 throughout.

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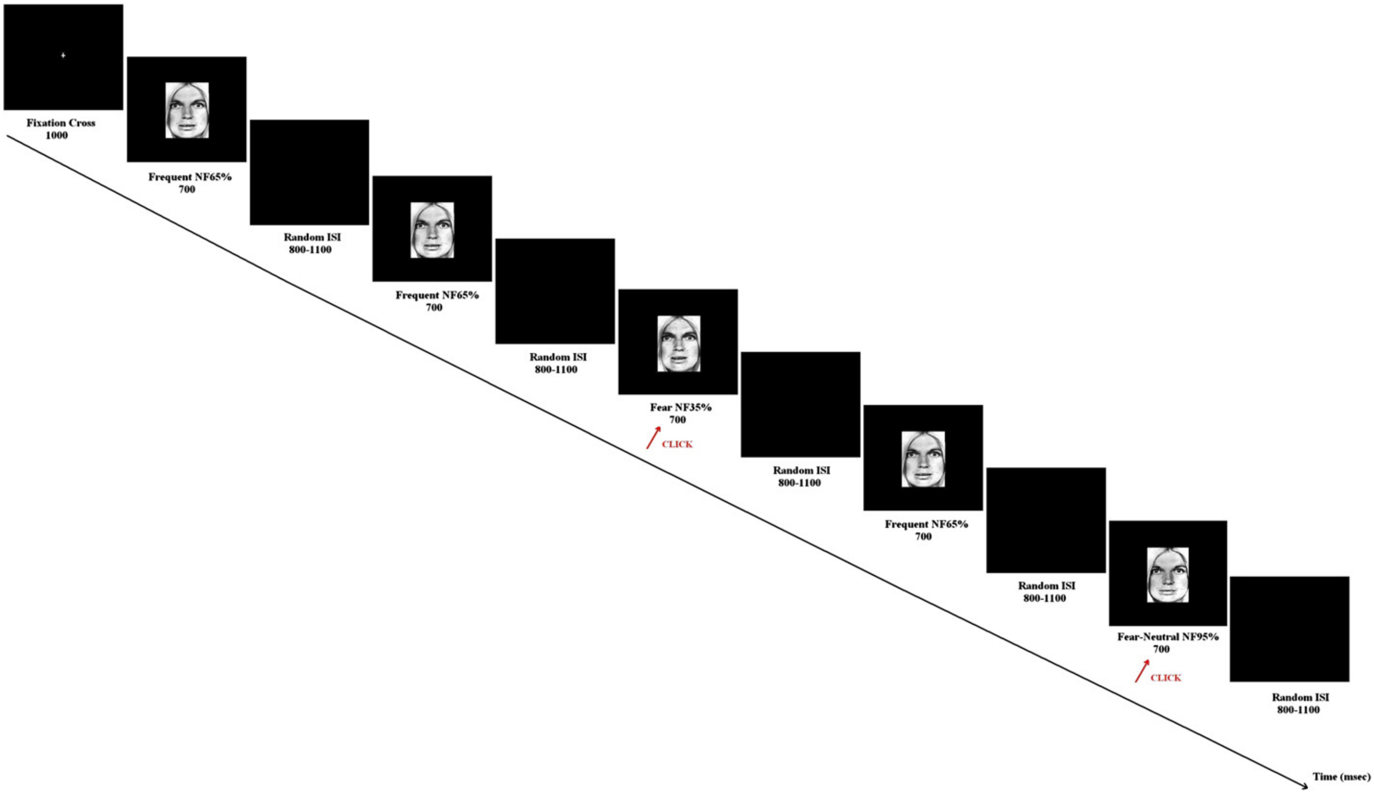

Fig. 1. Illustration of the task by means of the BNF (Female Face, Neutrality to Fear) triad used in one block of the oddball design. Fear NF 35% refers to the picture displaying 35% neutrality and 65% Fear, and was perceived as "fearful". It defines the "emotional" deviant stimulus, while Frequent NF 65% (frequent stimulus) and Fear–Neutral NF 95% ("fear–neutral" deviant stimulus) were both seen as neutral.

3. Results

3.1. Behavioral data

As 98% of responses were correct, only the response times (RTs) for correct responses were analyzed statistically. The data are summarized in Table 3. In order to check for any effect of psychological variables, we used a median split among the 30 participants on the BDI, STAI-T and TAS-20 scores to create between-group variables (low and high scores) based on the depression and anxiety, and alexithymia scores (median: BDI = 3; STAI-T = 45; TAS-20 = 52),[1] independent of sex. All the low- vs. high- groups comparisons were statistically significant at $p<0.001$ along their appropriate group variables (BECK, TAS-20 or STAI-T) (Table 4).

We then computed a 2 × 2 × 2 × 2 × 2 × 2 ANOVA on response times (RTs) for correct responses, with, respectively, Sex (male, female), TAS-20 (low, high), STAI-T (low, high) and BDI (low, high) as between factors, and deviance (emotional, neutral) and emotion (happiness, fear) as within variables. The significant ($p<0.05$) results are:

(1) A main effect of emotion ($F(1,16)=88.320$; $p<0.001$). RTs were shorter for deviant morphed faces on the Neutrality to Fear continua than for those on the Neutrality to Happiness ones (534 ms vs. 611 ms; $p<0.001$).
(2) A main effect of deviance ($F(1,16)=33.487$; $p<0.001$). RTs were shorter for emotional faces than for neutral faces (555 ms vs. 590 ms; $p<0.001$).

It is important to observe that neither the main effect of sex, nor the emotion × sex, deviance × sex, and emotion × deviance × sex interactions were statistically significant ($p>0.250$). Moreover, among the personality "between" variables, only the BDI × TAS-20 interaction approached significance ($F(1,16)=3.409$; $p=0.083$). This suggests a tendency for only respondents with high scores on BDI and TAS-20 to react slowly to both deviant faces.

3.2. ERP data

Although no sex differences and only a slight personality tendency were observed with the RTs, it may still be interesting to compute statistical analyses on the amplitude and latency values of the N2 and P3b components, as ERPs are able to detect even minor neurocognitive restrictions that are undetectable at the behavioral level (e.g., Maurage et al., 2009) Fig. 2 illustrates raw waveforms obtained (by females and by males) in response to frequent and deviant stimuli, as N2 and P3 components are observable by computing the

Table 2
The mean percentages of 100 students (not involved in the present study) who perceived each of the morphed faces (A and B) as expressing neutrality, fear or happiness. Students had to respond to the faces by clicking on buttons labeled "neutral", "fear", "happy", "sad" and "disgust", with the last two categories collapsed here as "other". Complete results can be found in Rossignol et al. (2009).

Continuum	% neutral responses	% fear responses	% happy responses	% other
NF 35	15	83	–	2
NF 65	94	5	–	1
NF 95	96	2	1	1
NH 35	19	1	78	2
NH 65	86	3	5	6
NH 95	91	2	4	3

[1] A cut-off score of 10 was used on the BDI to exclude people displaying a clinical level of depression (Furlanetto et al., 2005). The STAI-T scores group the participants as follows: less than 36: very low; 36–45: low; 46–55: normal; 56–65: high; more than 65: very high. Based on Taylor et al. (1997), people are considered as non-alexithymic if they have a TAS score of 51 or below, while scores between 52 and 60 reflect moderate levels, and scores of 61 and above are beyond the clinical threshold.

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Table 3
Mean reaction times (RTs) and standard deviations (in parentheses) recorded for responses to deviant faces. Means and standard deviations (in parentheses) of the peak latency values for the N2 and P3b components recorded in response to deviant faces.

RTs (ms)	Fear	Fear–neutral	Happy	Happy–neutral
Males	517 (49)	543 (59)	580 (59)	616 (88)
Females	529 (37)	556 (52)	604 (49)	646 (63)
Total (mean)	518	549	592	631
Peak latency (N2; ms)	Fear	Fear–neutral	Happy	Happy–neutral
Males-P7	297 (37)	306 (25)	301 (28)	310 (24)
Males-P8	295 (29)	310 (29)	307 (32)	311 (24)
Females-P7	288 (14)	302 (21)	301 (22)	314 (24)
Females-P8	294 (26)	304 (24)	303 (26)	303 (30)
Peak amplitude (N2; μV)	Fear	Fear–neutral	Happy	Happy–neutral
Males-P7	−2.92 (1.92)	−2.76 (2.43)	−2.44 (1.39)	−1.73 (1.29)
Males-P8	−3.85 (2.28)	−3.15 (2.34)	−1.90 (2.55)	−2.88 (3.37)
Females-P7	−3.23 (2.84)	−2.32 (2.45)	−2.67 (1.83)	−2.76 (2.15)
Females-P8	−3.22 (2.70)	−2.96 (2.84)	−1.91 (2.46)	−2.85 (1.76)
Peak latency (P3; ms)	Fear	Fear–neutral	Happy	Happy–neutral
Males-Pz	510 (55)	523 (54)	518 (50)	522 (55)
Females-Pz	490 (33)	498 (39)	510 (42)	518 (37)
Peak amplitude (P3; μV)	Fear	Fear–neutral	Happy	Happy–neutral
Males-Pz	3.99 (1.34)	3.18 (0.99)	2.77 (1.05)	2.63 (1.35)
Females-Pz	3.08 (1.23)	3.04 (1.58)	2.45 (1.35)	2.51 (1.44)

subtraction “Deviant minus Frequent” on occipito-temporal sites (P7, P8) for the N2, and on parietal Pz for the P3.

3.2.1. N2 latencies

N2 latencies were analyzed through a similar 2×2×2×2×2×2×2 ANOVA, with sex (male, female), BDI (low, high), STAI-T (low, high), TAS-20 (low, high) as between factors, and deviance (emotional, neutral), emotion (fear, happiness) and electrode (P7, P8) as within variables. The results are:

(1) A main effect of deviance ($F(1,16)=19.462$; $p<0.001$), showing that the N2 latencies for neutral faces were longer than for emotional ones (296 vs. 309 ms) ($p<0.001$).
(2) The absence of a main sex effect ($F(1,16)=0.463$; $p=0.506$) (mean of 304 ms for males and 300 ms for females) and non-significant sex×deviance ($F(1,16)=0.678$; $p=0.423$) and sex×emotion ($F(1,16)=1.536$; $p=0.233$) interactions.
(3) The absence of main BDI, STAI-T and TAS-20 effects ($F(1,16)=1.191$; $p=0.291$ for BDI; $F(1,16)=2.271$; $p=0.151$ for STAI-T; $F(1, 16)=0.026$; $p=0.875$ for TAS-20).
(4) Significant interactions among emotion, sex and STAI-T ($F(1,16)=8.758$; $p=0.009$), emotion, sex, STAI-T and BDI ($F(1,16)=20.082$; $p<0.001$), and emotion, sex, BDI and TAS-20 ($F(1,16)=12.059$; $p=0.003$), suggesting that sex differences in the perception of fearful and happy deviant morphed faces are linked to differences in personality factors. The results show that the latency of the N2 peak was earlier (285 ms) for emotional-fearful stimuli in males with high scores on TAS-20 and STAI-T and low scores on BDI, and (291 ms) for emotional-happy stimuli in women with high scores on BDI, TAS-20 and STAI-T. Furthermore, the N2 peak was delayed (mean of 318 ms for males and 321 ms for females) in students with high scores on BDI and low scores on TAS-20 and STAI-T.

Table 4
The characteristics of the low and high groups based on a median split for BDI, STAI-T and TAS-20 scores. Each group differed at $p<0.001$.

	BDI		STAI-T		TAS-20	
	Low	High	Low	High	Low	High
Gender (M/F)	9/8	6/7	8/7	7/8	7/9	8/6
Mean (S.D.)	1.41 (1.22)	7.30 (3.94)	38.06 (4.28)	54.40 (6.68)	42 (7.64)	63.71 (5.12)
t (28) value	−5.199 $p<0.001$		−7.999 $p<0.001$		−9.001 $p<0.001$	

3.2.2. P3b latencies

P3b latencies (recorded at Pz) were analyzed through a 2×2×2×2×2×2 ANOVA, with sex (male, female), BDI (low, high), STAI-T (low, high), TAS-20 (low, high) as between factors, and deviance (emotional and neutral) and emotion (fear and happiness) as within variables. The results are congruent with those found on RTs and on N2 latencies: there was a main effect of deviance ($F(1,16)=5.178$; $p<0.037$), suggesting that both males (509 ms) and females (507 ms) took more time to detect neutral faces than emotional ones (difference: 7.39 ms; $p=0.016$). No other analyses with the sex variable were significant ($p>0.150$).

3.2.3. N2 and P3b amplitudes

Similar ANOVAs were computed on the amplitude values for N2 and P3b components. The main results indicated:

(1) A significant deviance×emotion interaction ($F(1,16)=14.550$; $p=0.002$) on N2, suggesting that emotional-fearful faces evoked higher N2 amplitudes than emotional-happy ones (−3.392 μV) or neutral faces (−2.586 μV). Again, the sex variable did not have any significant effect ($p>.100$), but the personality factors interacted with the deviance factor (deviance×BDI×TAS-20: $F(1,16)=4.476$; $p=0.05$; deviance×emotion×BDI×TAS-20: $F(1,16)=12.024$; $p=0.003$), suggesting that fearful faces evoked larger N2 amplitudes in participants who had high scores on TAS-20 and BDI (mean difference −4.638 μV).
(2) A main effect of emotion ($F(1,16)=11.307$; $p=0.004$) was evident on P3b. This indicates greater amplitudes in response to fearful stimulations than to happy ones (difference: 0.709 μV; $p=0.003$). There was also an interaction among deviance and BDI ($F(1,16)=5.086$; $p=0.038$), suggesting that higher scores on the BDI scale were associated with lower P3b amplitudes (means of 2.5 μV and 2.8 μV for the high and low groups respectively). Again, none of the effects related to sex were significant ($p>.100$).

3.2.4. Complementary analyses

Overall, our results suggest that, independent of sex, but in interaction with personality variables, the participants detected “emotional” differences quicker than neutral ones (different intensities of neutrality). This behavioral effect on RTs is neurophysiologically indexed by earlier peak latency values on both N2 and P3b (see Table 3),

In order to double-check on the idea that the earlier N2 and P3b peaks recorded for emotional faces were more interrelated with personality factors than with sex, we performed multivariate linear regression analysis using the backward method. This procedure involves starting with a model including all independent variables, testing them for statistical significance, and deleting one by one the least significant. In backward elimination, all independent variables are added together and removed one at a time based on the removal criteria. In the present study, the *in p-value* was set at 0.05 and the *out p-value* (p criteria for removing a variable) was set at 0.1. Backward stepwise regression is the preferred method of exploratory analyses, where the analysis begins with a full or saturated model and variables

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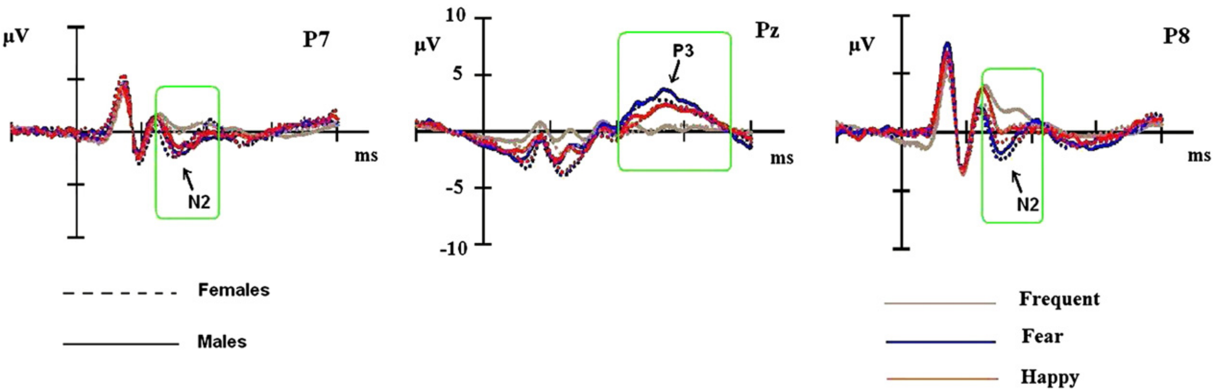

Fig. 2. Illustration of raw waveforms obtained for Frequent, Fear and Happy stimuli on midline parietal (Pz) and occipito-temporal electrodes (P7, P8) for males (thick lines) and females (dashed lines). N2 (on P7, P8 electrodes) and P3 (on Pz) components were obtained by subtracting frequent from deviant stimulations.

are eliminated from the model in an iterative process (Kleinbaum et al., 2008). The results are illustrated in Fig. 3 and summarized in Table 5. They suggest that the TAS-20 score (explained variance 16.2%; $p=0.028$) was the best single predictor of N2 latency, while the BDI score was the best predictor of P3b latency (explained variance of 30%; $p=0.002$).

4. Discussion

Recent ERP studies have shown that, in addition to the increased sensitivity of both sexes to highly negative stimuli, women are more sensitive than men to positive stimuli and to emotionally negative stimuli of lesser saliency. This may be an important mechanism underlying the female advantage in identifying emotions (Campanella et al., 2004; Li et al., 2008). Nevertheless, the origin of this female advantage is still a matter of debate. In the present study, we explored whether this sex modulation of EFE processing might be linked to some personality factors specifically associated with men and with women, i.e., alexithymia in men (Lane et al., 1998; Levant et al., 2009) and depression with co-morbid anxiety (Zender and Olshansky, 2009).

To achieve this, 30 participants (15 male and 15 female) completed a variant of the oddball paradigm, in which morphed images were used (Campanella et al., 2002). Our main hypothesis was that, when the personality variables were controlled for, sex differences in the perceptions of happy and fearful faces would disappear.

As expected, the behavioral results showed that, independent of sex, the participants found it easier to detect emotional deviant faces than neutral ones. This can be attributed to the well-known

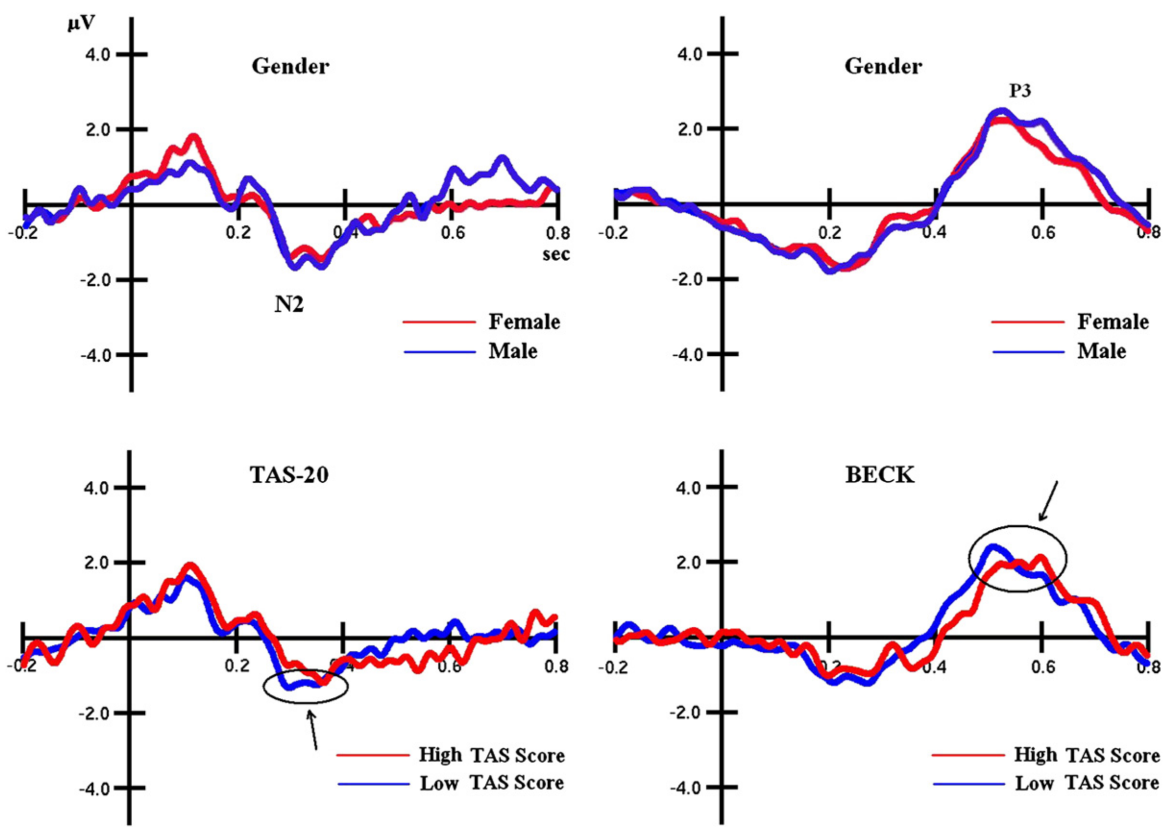

Fig. 3. Illustration of the difference waveforms (Deviant minus Frequent) for the N2 (P8) and P3 (Pz) components in response to deviant emotional and neutral faces for males and females participants. No significant difference due to gender is observable on N2 and P3 components. However, independently of gender, averages based on low- vs. high-TAS values displayed a significant modulation of N2 latency, while similar averages performed on the basis of BECK scores showed P3 latency modulation.

Table 5
Synthesis of F and p values obtained from the linear regression analyses computed on N2 and P3b latencies using a backward procedure. TAS was the best predictor of N2 latency, while BECK was the best one for P3. *Backward criterion Probability F-to-remove ≥ 0.100.

Model-N2	Variables entered	Variables excluded[a]	R square	F	Significance
1	TAS, gender, BECK, STAI-T	/	24.7	2.048	0.118
2	TAS, STAI-T, BECK	Gender $t=0.406$; $p=0.688$	24.2	2.764	0.062
3	TAS, STAI-T	Gender $t=0.375$; $p=0.710$ BECK $t=1.158$; $p=0.258$	20.3	3.433	0.047
4	TAS	Gender $t=0.510$; $p=0.614$ BECK $t=-0.024$; $p=0.981$ STAI-T $t=-1.180$; $p=0.248$	16.2	5.400	0.028
Model-P3	**Variables entered**	**Variables excluded[a]**	**R square**	**F**	**Significance**
1	TAS, Gender, BECK, STAI-T	/	31,2	2.839	0.045
2	TAS, STAI-T, BECK	Gender $t=-0.44$; $p=0.965$	31,2	3.935	0.019
3	TAS, BECK	Gender $t=-0.15$; $p=0.988$ STAI-T $t=-0.431$; $p=0.670$	30,7	5.991	0.007
4	BECK	Gender $t=-0.178$; $p=0.860$ STAI-T $t=-0.376$; $p=0.710$ TAS $t=-0.550$; $p=-0.587$	30	11.976	0.002

categorical perception effect of facial emotional expressions, as two different morphed faces representing the same emotional state (here, "neutrality" for NF 65 and NF 95%) are harder to discriminate than two different morphed faces displaying two different emotional states (e.g., "neutrality" for NF 65% and "fear" for NF 35%), even when the difference in morphing between the frequent and the two deviant stimuli is the same (Etcoff and Magee, 1992; Calder et al., 1996; Young et al., 1997). In the present study, we showed that, for fearful and happy stimulations, men and women matched on personality variables exhibited the same "facilitation effect" when detecting emotional changes. In other words, even if the physical amount of distance between the frequent stimulus and the two deviant ones is similar, participants perceived a larger amount of change in the emotional condition than in the neutral one.

Despite the absence of difference between males' and females' RTs, we also conducted ERP analyses. ERPs are sensitive enough to detect even minor neurocognitive restrictions that are undetectable at the behavioral level (e.g., Rugg and Coles, 1995). We analyzed two main components of the ERPs, N2 and P3b, as these have been shown to be modulated in emotional tasks by sex (Campanella et al., 2004), by alexithymia (Vermeulen et al., 2008), and by subclinical levels of depression with co-morbid anxiety (Rossignol et al., 2008). The results show that the categorical perception effect, behaviorally reflected in faster RTs to emotional faces, and indexing that emotional faces are easily detectable compared to neutral ones, is neurophysiologically reflected in earlier N2 and P3b peak latency, while both components have been shown to be linked to "visual awareness" (Liddell et al., 2004). Indeed, Liddell et al. (2004) showed that, compared to neutrality, subliminal versus supraliminal displayed emotions evoked respectively enhanced N2 and P3 components. This suggests that the present "emotional" behavioral effect may originate in the allocation of attentional resources (N2), so that the neural mechanisms for appraising signals of emotions may be initiated without the need for conscious detection of these signals. In this view, personality influence may be achieved through top-down processes that modulate the way emotions are initially and automatically perceived. Obviously, this latter point deserves further investigations. Also, as neutral deviants were not perceived as 'deviant' (from the frequent standard) to the same extent as emotional deviants, it can be suggested that differences in N2/P3b could be due to adaptive factors such as habituation (e.g., see Polich, 2007 for a review of such effects on P3a and P3b components), as neutrality is more often perceived by participants than happiness or fear.

This result concurs with those found by Campanella et al. (2002), who investigated the neurophysiologic correlates of emotional categorical perception. But more interestingly, it shows that (1) the detection of the emotional (fear or happiness) differences is not due to sex differences in the N2 and P3b modulations when personality factors (depression, anxiety, alexithymia) are controlled for; and (2) personality factors, independent of sex, clearly influence N2 and P3b latencies in the detection of emotional changes. Our linear regression analysis show that TAS-20 and BDI scores predict N2 and P3b latencies, but STAI-T and sex do not. Again, these results match previous ones. It has been shown by means of similar emotional oddball design that alexithymic people display delayed responses in the N2 component, which is related to the attentional processing of deviant emotional faces (Vermeulen et al., 2008), while people presenting even a subclinical level of depression show delayed P3b responses, indicating altered decisional and cognitive closure mechanisms (e.g., Maurage et al., 2008).

Overall, these results lead us to a main consideration: sex modulates EFE processing, *but only in combination with typical male and female personality factors*. Obviously, these results are preliminary and need to be replicated. Moreover, they do not allow us to explain why males and females generally display such personality differences. Furthermore, our psychological investigation was limited to alexithymia, depression and anxiety, because these factors have already been extensively explored in ERP emotional tasks and their effects on the N2 and P3b components of ERPs are well documented. We are aware that other personality traits, such as for instance empathy, also deserve to be included in similar study. Empathy is a multidimensional construct comprising the ability to perceive, understand and feel the emotional states of others. It, too, displays sex differences (e.g., Schulte-Rüther et al., 2008; Derntl et al., 2009). Therefore, further studies like this one should take empathy into account. Moreover, in order to obtain a good signal-to-noise ratio, we averaged female and male faces (e.g., face A Fear and face B Fear) to obtain a common set of trials for each deviant stimuli. By increasing number of trials and sample size, further studies may investigate whether female and male participants differently process female and male EFE. Finally, in the present study, trait-anxiety was only observed as co-morbid with depression; however, participants may show anxious tendencies without depressive ones, and trait-anxiety is well-known to affect ERPs recorded to facial emotions (see for instance Rossignol et al., 2005). Therefore, further studies should also include participants displaying anxious tendencies without depressive ones to investigate whether (and how) this factor may

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influence emotional gender differences. In this view, it would be also really interesting to differentiate people showing trait- vs. social anxiety (e.g., Rossignol et al., 2007). Finally, even if this question may seem purely methodological, it is important to outline that the location of reference channel during ERP recordings can have important theoretical consequences. Indeed, studies investigating the same processes using different reference leads (and also a different number of channels) may furnish different results, since each reference will introduce its own unique fluctuations into a recording (Joyce and Rossion, 2005). As Katznelson (1981) suggested that the proximity of linked mastoid reference to occipito-temporal generators make it suspect for studies of high-level visual processing, another possibility is the common average reference, recommended by certain guidelines for scalp electrophysiological research (Picton et al., 2000). Of course this reference is not without its own problems: fewer the electrode signals used to create the average, the larger influence each of them will have on the resulting average signal (Dien, 1998). However, this latter problem can be minimized with a large enough sample of (at least) 20 electrodes (Katznelson, 1981). Therefore, we choose in the present study as well as in Campanella et al. (2004) to use a common average reference. However, other studies investigating ERP correlates of emotional gender differences used different reference site and number of channels, such as for instance Li et al. (2008) who used a linked mastoid reference and 64 channels. Consequently, it is critical in further ERP studies to determine how reference may affect the gender effect on emotional processes so that results can be reliably compared across studies.

Nevertheless, we think that our data are noteworthy for at least three main reasons. The first is *methodological*, as the present results clearly attest that all further studies of EFE modulation by sex should consider at least alexithymia and depression (even at a subclinical level) in their experimental procedures and statistical analyses. The second reason concerns *clinical applications*. As our data lend support to the idea that the psychological background of men (with a higher prevalence of alexithymia) and women (with a higher prevalence of mixed anxious-depressed states) furnishes a potential mechanism for why females are generally more sensitive to emotional cues in their environment. However, this female advantage to process emotions may form part of a vicious circle, as this higher sensitivity to emotional signals may also explain why women are more prone than men to develop affective disorders in their lifetime (Harris, 2001; Kemp et al., 2004; Li et al., 2008). Therefore, the interaction between sex, emotional processing and the development of affective disorders such as depression and anxiety should be investigated in clinical settings. A suitable therapeutic approach might be to teach these patients to allocate fewer attentional resources to environmental emotional stimulations. In this context, procedures inspired from researches on social phobia may be envisaged: indeed, recent studies suggest that repeatedly learning to disengage attention from threat cues during a training program may help phobic people to be able to turn their attention away from similar negative cues and thereby process less threatening aspects of the situation (e.g., see the Attention Modification Program in Amir et al., 2008). The third reason that our results are important is situated at the *fundamental level.* We hope that we have illustrated the importance, and indeed the necessity, of considering personality factors (such as alexithymia) and cognitive performance (in emotional tasks) together, so as to improve our understanding of psychopathology through a direct dialogue between clinicians and researchers.

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Salvatore Campanella and Luciana Falbo contributed equally to this paper. Salvatore Campanella is a Research Associate, Mandy Rossignol and Pierre Maurage are Postdoctoral Researchers, and Delphine Grynberg is a Research Fellow at the Belgian *Fonds National de la Recherche Scientifique* (F.N.R.S.).

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