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

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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)
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 psycho-pathological 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 Depressivity Scale (BDI, Beck and Steer, 1987; French version: Collet and Cottraux, 1986), the Spielbergier Trait Anxiety Inventory (STAI-T; Spielbergier, 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: 3.39, 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 differences 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 Etoff 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 BHN 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%, BNF 95% and BNF 95% were recognized as showing a neutral expression, as were ANH 65%, ANF 65%, BNF 65% and BNF 65%, while ANH 35% and BNF 95% 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 35%–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) BHN 35%–happiness–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).

Table 1

<table>
<thead>
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<th>Age</th>
<th>BDI</th>
<th>STAI-T</th>
<th>TAS-20</th>
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<tr>
<td>Males</td>
<td>21.2 ± 3.6</td>
<td>46.3 ± 4.8</td>
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<tr>
<td>(n = 15)</td>
<td>(1.7)</td>
<td>(3.6)</td>
<td></td>
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<tr>
<td>Females</td>
<td>20.9 ± 4.1</td>
<td>46.2 ± 5.2</td>
<td></td>
</tr>
<tr>
<td>(n = 15)</td>
<td>(4.5)</td>
<td>(11.4)</td>
<td></td>
</tr>
<tr>
<td>r(14) =</td>
<td>0.036</td>
<td>0.033</td>
<td></td>
</tr>
<tr>
<td>p =</td>
<td>0.724</td>
<td>0.114</td>
<td></td>
</tr>
</tbody>
</table>

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°×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.

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 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 cephalic points), particularly in terms of categorical differences (Joyce and Rossion, 2005); Nevertheless, it must be noted that this referencing method can alter the spatial characteristics of recorded data, as the fewer the electrodes 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.R® amplifiers within a gain of 3000 and a band-pass of 0.10–100 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. Eprose software) and trials contaminated by EO artifacts were eliminated offline, 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 (the ‘deviant’ stimuli) are also removed. Importantly, it should be noted that, after EOG rejections, the mean number of remaining accepted trials does not differ between groups and conditions (Fears: Males: 55.8 (S.D.: 7.1), Females: 55.6 (S.D.: 6.7); Fear–Neutral: Males: 56.4 (S.D.: 6.7), Females: 56.3 (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 stimulus; 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 of component of interest (namely the N2 and the P3b) were investigated by generating individual values of maximum peak amplitudes and peak latencies on the classical difference waveforms “Deviant minus Neutral” 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, and deviant fear–neutral) 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 Neutral frequent). Then, for defining the N2 component values, we look for the maximum peak amplitude and its latency on bilateral posterior electrodes (Pz) during a [250–300] ms time interval, whereas electrode Pz and a [350–650] ms time range was examined for the P3b components (for the P3b) were used data for the P3b components (including the N2 component) ± 300 ms time interval, whereas electrode Pz and a [350–650] ms time range was examined for the P3b components (including the N2 component) ± 300 ms time interval, whereas electrode Pz and a [350–650] ms time range was examined for the P3b components (including the N2 component) ± 300 ms time interval. To explore the 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 of component of interest (namely the N2 and the P3b) were investigated by generating individual values of maximum peak amplitudes and peak latencies on the classical difference waveforms “Deviant minus Neutral” 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, and deviant fear–neutral) 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 Neutral frequent). Then, for defining the N2 component values, we look for the maximum peak amplitude and its latency on bilateral posterior electrodes (Pz) during a [250–350] ms time interval, whereas electrode Pz and a [350–650] ms time range was examined for the P3b components (including the N2 component) ± 300 ms time interval, whereas electrode Pz and a [350–650] ms time range was examined for the P3b components (including the N2 component) ± 300 ms time interval.
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), 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 (535 ms vs. 590 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...
variables. The results are:  

3.2.1. N2 latencies  

P8) for the N2, and on parietal Pz for the P3.  

The characteristics of the low and high groups based on a median split for BDI, STAI-T and TAS-20:  

Peak latency values for the N2 and P3b components recorded in response 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.  

Table 4  

Table 3  

mean reaction times (RTs) and standard deviations (in parentheses) recorded for the peak  

3.2.2. P3b latencies  

P3b latencies (recorded at Pz) were analyzed through a 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 > 0.100), 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 > 0.100).  

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 neuropsychologically 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 were added and removed based on the statistical significance of each individual variable. This procedure was applied to the full model of personality factors, including BDI, STAI-T, and TAS-20 as predictors of the N2 and P3b peak latencies. The results showed that, in addition to the main effects of deviance and emotion, there were significant interaction effects between deviance and personality variables. Specifically, 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.  

P-values were used to assess the significance of the regression coefficients. A p-value of <0.05 was considered statistically significant. The results showed 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.  

Table 3  

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

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.
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
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>0.10.

<table>
<thead>
<tr>
<th>Model-N2</th>
<th>Variables entered</th>
<th>Variables excluded*</th>
<th>R square</th>
<th>F</th>
<th>Significance</th>
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<tr>
<td>2</td>
<td>TAS, STAI-T, BECK</td>
<td>Gender ( r = 0.406; p = 0.688 )</td>
<td>24.2</td>
<td>2.764</td>
<td>0.062</td>
</tr>
<tr>
<td>3</td>
<td>TAS, STAI-T</td>
<td>Gender ( r = 0.375; p = 0.710 ), BECK ( r = 1.158; p = 0.258 )</td>
<td>20.3</td>
<td>3.433</td>
<td>0.047</td>
</tr>
<tr>
<td>4</td>
<td>TAS</td>
<td>Gender ( r = 0.510; p = 0.614 ), BECK ( r = -0.024; p = 0.981 ), STAI-T ( r = -1.180; p = 0.248 )</td>
<td>16.2</td>
<td>5.400</td>
<td>0.028</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model-P3</th>
<th>Variables entered</th>
<th>Variables excluded*</th>
<th>R square</th>
<th>F</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TAS, Gender, BECK, STAI-T</td>
<td>/</td>
<td>31.2</td>
<td>2.839</td>
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<tr>
<td>2</td>
<td>TAS, STAI-T, BECK</td>
<td>Gender ( r = -0.44; p = 0.965 )</td>
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<td>3.935</td>
<td>0.019</td>
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<tr>
<td>3</td>
<td>TAS, BECK</td>
<td>Gender ( r = -0.15; p = 0.988 ), STAI-T ( r = -0.431; p = 0.670 )</td>
<td>30.7</td>
<td>5.991</td>
<td>0.007</td>
</tr>
<tr>
<td>4</td>
<td>BECK</td>
<td>Gender ( r = -0.178; p = 0.860 ), STAI-T ( r = -0.376; p = 0.710 ), TAS ( r = -0.550; p = 0.587 )</td>
<td>30</td>
<td>11.976</td>
<td>0.002</td>
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</table>

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 influence N2/P3b latencies.

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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 resulti 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 researchs 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.

Acknowledgments

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