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The Temporal Electro cortical Profile of Emotive Facial Processing in Depressed Males and Females and Healthy Controls

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Abstract

Background—Previous work indicates that emotive processing, such as of facial expressions, may be altered in major depressive disorder (MDD). Individuals with MDD tend to exhibit a mood-congruent processing bias, though MDD may also be characterized by blunted emotive processing in general. Females tend to exhibit enhanced facial emotive processing than males. Few groups have examined temporal electrophysiological event-related potential (ERP)-indexed profiles, spanning preconscious to sustained, conscious processing of facial expressions in MDD; systematic comparisons of ERPs to emotive stimuli between depressed males and females are also lacking.

Methods—This study examined the temporal ERP profile to a simple expression recognition task in adult depressed males and females (N=52; 29 females) and controls (N=43; 23 females).

Results—The MDD group rated facial expressions as sadder overall than controls. Females exhibited enhanced and speeded pre- and conscious face processing than males. Subtle group differences emerged to specific expressions at mid-latency ERPs (N2, P2) indicating both blunted late pre-conscious perceptual processing of expressions and prolonged processing of intensely sad faces.

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Contributors: N Jaworska collected assisted with conceptualizing the study, collected the data, analyzed it and wrote the manuscript. W Fusee assisted with collecting all of the clinical data, in patient assessment and recruitment.

P Blier is the PI on the clinical trial from which the patients were recruited. He also carries out patient assessments. He also edited the final draft of the manuscript.

V Knott is the PI on the current study. He oversaw the work of N Jaworska and assisted in the data analysis and in editing drafts of the manuscript.

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Limitations—A more involved emotive processing task, employing threatening faces, may have revealed more robust group ERP differences. Menstrual cycle should be controlled for in future work.

Conclusions—This is the first study to systematically assess the temporal ERP profile, including of ERPs preceding the face-sensitive N170/VPP, to expressions in MDD. Overall, early perceptual and late conscious expression processing did not differ fundamentally between groups. Altered emotive processing may be a candidate index for monitoring and predicting antidepressant treatment outcome.

Keywords

Depression; event-related potentials (ERP); emotion; faces; sex

Introduction

The identification and effective processing of facial expressions is critical for successful emotional communication and in regulating social interactions. Therefore, preferential recruitment of attentional resources and enhanced pre-conscious processing of faces and associated expressions versus non-face stimuli is likely. Negative expressions are most effective in interfering with on-going tasks and in recruiting attention (Mathews et al., 2004), likely because they convey critical information for effective interpersonal interactions and, more broadly, for survival.

In accordance with cognitive theories proposing that major depressive disorder (MDD) is associated with a mood-congruent processing bias (Kovacs & Beck, 1978), depressed individuals have shown enhanced memory and attention for sad expressions, and interpret neutral faces more negatively than controls (Leppänen et al., 2004; Gollan et al., 2008). This bias may extend to all negative expressions, such as fear and anger (Bouhuys et al., 1999; Leyman et al., 2007). However, some research also indicates that there may be blunted processing of all emotive information in MDD (Gur et al., 1992; Leppänen et al., 2004). Thus, MDD may be associated with reduced perceptual sensitivity to positive expressions and more complex/sustained processing of negative ones (Gollan et al., 2008), though few studies demonstrate this clear double-dissociation. Mood-congruent biased emotive processing has also been noted in treated and remitted depressives (Bhagwagar et al., 2004; Savaskan et al., 2008) and has been correlated with symptom severity and less favorable recovery (Hale, 1998; Bouhuys et al., 1999).

The face-sensitive N170 is thought to reflect early visual processes implicated in identifying a stimulus as a face (Eimer & Holmes, 2007). Though some have found the N170 to be unaltered by expressions (Ashley et al., 2004; Santesso et al., 2008), others have. For instance, increased emotive intensities (Sprengelmeyer & Jentzsch, 2006) and expressions of anger and fear enhanced the N170 (Batty & Taylor, 2003; Stekelenburg & de Gelder, 2004; Krombholz et al., 2007), though previous work from our group found it to be increased to joyful versus neutral and sad faces (Jaworska et al., 2010). Similarly, the anterior face-sensitive vertex positive potential (VPP) has been shown to be more pronounced to negative versus neutral expressions (Sewell et al., 2008; Foti et al., 2010; Luo et al., 2010), though we found it to be enhanced to emotive (happy and sad) faces (Jaworska et al., 2011). Both N170 and VPP latencies were decreased to positive expressions (Batty & Taylor, 2003; Jaworska et al., 2011). Thus, face-sensitive ERPs are enhanced to emotive expressions, while their latencies may be shortest to positive ones.

Evidence of rapid brain responses to and modulation by expressions (<170 ms) indicates that affect detection precedes face recognition (Eimer & Holmes, 2007). The posterior P1,

thought to index preconscious attention allocation, appears to be modulated by emotive intensity (Turetsky et al., 2008; Utama et al., 2009). The P1 was found to be decreased to sad expressions (Turetsky et al., 2008), and its latency shortened to fearful ones (Lee et al., 2010). However, others found it to be unaltered by either emotive expressions or intensity (Degabriele et al., 2011). Although less frequently studied, the mid-anterior N1 was greater to fearful expressions (Luo et al., 2010), though another group reported no emotion-related N1 modulations (Rossignol et al., 2005).

Mid-latency ERPs (post-N170) appear to be influenced by facial expressions. The posterior P2, thought to reflect orientation to salient stimuli (Carretié et al., 2001), was attenuated by fearful and angry expressions (Schutter et al., 2004; Stekelenburg & de Gelder, 2004), though we previously found it to be increased to sad ones (Jaworska et al., 2010). The anterior N2, indexing attentional orienting, was enhanced by expressions (Balconi & Pozzi, 2008), and has been shown to emerge earlier and be maximal for threatening faces (Liddell et al., 2004; Kiss & Eimer, 2008). The effects of facial expressions on the P3, reflecting conscious attention allocation, are mixed. While some have found its enhancement to fearful or happy faces (Liddell et al., 2004; Luo et al., 2010), others reported no P3 changes to expressions (Balconi & Lucchiari, 2005).

Finally, a handful of studies have investigated the effects of emotive facial processing on later ERPs (post-P3), such as the late positive potential (LPP), though to index conscious, elaborate and evaluative processing (Schupp et al., 2004). The LPP is preferentially elicited by negative expressions, such as fear and sadness (Orozco & Ehlers, 1998; Schupp et al., 2004; Van Strien et al., 2010) and intense versus mild and neutral faces (Jaworska et al., 2011) have been shown to preferentially evoke it.

Relatively few studies have investigated the temporal ERP profiles associated with facial expression processing in MDD. To date, there appears to be no published work on the influence of facial expressions on the N170 or ERPs that precede it in the disorder. One study examined the VPP to specific expressions in MDD versus control groups, but noted no differences (Foti et al., 2010). The few studies that have assessed mid-latency ERPs to facial processing in the context of depression have yielded inconsistent results (Deldin et al., 2000; Kayser et al., 2000; Cavanagh & Geisler, 2006). Studies examining slow wave ERPs (1–5 s) suggest that depressives exhibit more sustained processing of negative, and diminished processing of positive, expressions (Deveney & Deldin, 2004; Shestiyuk et al., 2005). However, one group examining the LPP noted that it was increased to threatening faces in the control but not MDD group, suggesting blunted processing (or avoidance) of negative information.

As a final point, there is scant research probing sex effects on ERPs to facial expressions in MDD. This is despite evidence of a close relationship between emotional sensitivity and mood disturbance liability/disorders (Hofer et al., 2006), which are more prevalent in females (Parker & Brotchie, 2010). Furthermore, the dynamics of and neural activity to facial processing appears to differ between the sexes (Fusar-Poli et al., 2009), with females exhibiting enhanced/speeded facial encoding mechanisms than males (Lewin & Herlitz, 2002; Felmingham et al., 2010). The few studies that have assessed sex differences to expression-elicited ERPs have document increased ERPs in females (P1: Proverbio et al., 2006; Lee et al., 2010; P3: Yamamoto et al., 2000), suggesting greater cortical resource allocation to face processing (at various stages) in females. One study indicated that females exhibited greater N2 and P3 amplitudes to moderately negative images (not specifically faces) that were absent in males (Yuan et al., 2009).

Early- (anterior N1, posterior P1), mid- (anterior N2, posterior P2, P3) and late-latency (LPP) ERPs, as well as face-specific ERPs (N170, VPP) were examined to neutral and emotive expressions (non-target) as well as to target surprised faces in MDD males and females and healthy controls. ERPs were expected to be smaller to neutral versus emotive faces; greater intensities (100% expression) were predicted to be associated with larger ERPs. Early-mid latency ERPs were expected to be enhanced in females. In line with the mood-congruent processing bias, group differences to specific ERPs were expected to manifest as larger amplitudes (and perhaps shorter latencies) to sad expressions. However, it was also possible that smaller ERPs to emotive expressions (i.e., blunted processing) would emerge in MDD.

Methods

Patients

Fifty-three (N=53) adults with a primary diagnosis of Major Depressive Disorder (MDD) were tested (Table 1). Patients were recruited from the Mood Disorders Research Unit at the University of Ottawa Institute of Mental Health Research Center. Patients were diagnosed by trained psychiatrists with the Structured Clinical Interview for DSM (Diagnostic and Statistical Manual of Mental Disorders) IV-TR Diagnoses, Axis I, Patient Version (SCID-IV-I/P; First et al., 1997). The Hamilton Rating Scale for Depression, 17 and 29 item versions (HAM-D-17/29; Hamilton, 1960) and the Montgomery-Åsberg Depression Rating Scale (MADRS; Montgomery & Åsberg, 1979) were also administered to index symptom severity. All patients had MADRS scores ≥ 22 at the time of study enrollment. Notable exclusion criteria were: Bipolar Disorder (BP-I/II or NOS) diagnosis, life-time history of psychosis, current (<6 months) drug/alcohol abuse/dependence (except nicotine/smoking), seizures history or increased seizure risk (e.g. brain trauma/lesion, pro-convulsant medication use), unstable medical condition (i.e., unstabilized for ≥ 3 months) and history of anorexia/bulimia. Patients at a significant risk for suicide were also excluded. No patients were taking antidepressants at the time of testing as they were enrolled in a clinical trial and were tested prior to starting study medication. Washout consisted of five times the $t_{1/2}$ of medication(s) previously taken.

Control Participants

Forty-three (N=43) non-depressed, healthy controls were recruited and matched to patients on gender, age and education (Table 1). Controls were interviewed to ensure the absence of a personal psychiatric history and alcohol/drug abuse or dependence (assessed with a modified non-patient version of the SCID [SCID-IV-I/NP]), history of seizures, brain trauma or known brain lesion(s). Controls also completed the Beck Depression Inventory-II (BDI-II; Beck et al., 1996) to assess for the existence and severity of depression symptoms and were included in the study only if they scored ≤ 13 . Finally, only controls with no psychiatric history in first-degree relatives were included in this study (assessed with the Family Interview for Genetic Studies [FIGS]; Maxwell, 1992).

Testing Session Procedures

Prior to testing, participants abstained for >3 hr from caffeine and/or smoking/nicotine, as well as from alcohol/drugs (other than contraceptives and medication required for a stabilized physical condition) beginning at midnight. Upon arrival to the laboratory, subjective mood evaluations were carried out. Concurrently, electrodes were applied, after which the experiment commenced. This study was approved by the Royal Ottawa Health Care Group and the University of Ottawa Social Sciences and Humanities Research Ethics Boards and informed consent was obtained from all participants. Participants were

compensated \$30.00 CDN/session (patients participated in multiple sessions as part of a larger study).

Subjective Mood Questionnaires

Mood was assessed with the Profile of Mood States (POMS; McNair et al., 1992) on which participants rated their subjective state using a Likert scale on 65 mood adjectives, from which values were aggregated to form seven mood dimensions (tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue-inertia, confusion-bewilderment and total mood disturbance).

Emotional Faces Recognition Task

The faces recognition task was adapted from Krolak-Salmon et al. (2001). Thirty-six photographic faces displaying one of four expressions (sadness [sad], joy, surprise [sur], neutral) were presented individually on a screen in front of the seated participant (~1 m) in a dim, electrically-shielded and sound-attenuated room. Each emotion was expressed at three intensities (20%, 50%, 100%) by one actor. Two males and two females displayed one emotion at all intensities (i.e., 16 actors). Expressions at 20% intensity were considered “neutral” as they are not reliably distinguished (Orgeta & Phillips, 2008) and 0% expressions are more likely to be confused with negative than with other facial expressions (Palermo & Coltheart, 2004). Photographs were digitized and converted to grey-scale images, matched for luminance and contrast, with the neck and hair cropped out (Figure 1).

Each expression (neutral, sad50, sad100, joy50, joy100, sur50, sur100) was pseudo-randomly presented 80 times (no identical faces presented back-to-back) for 400 ms (ISI: 1500 ms; Presentation Software, Neurobehavioral Systems, Albany, CA, USA). Participants pressed a button to surprised faces (sur50, sur100) to ensure that they paid attention to expressions. Hits (% correct responses to sur50 & sur100), false alarms (FA; % responses to non-surprised faces) and reaction times (RT) were recorded.

Facial Expression Rating Questionnaire

After the task, participants rated 10 faces (one male and one female expressing each of joy50, joy100, sad50, sad100 and neutral) presented during the task. Faces were rated using a Likert scale from 0 (not at all) to 10 (very much) on two valence questions: how 1) “sad” and 2) “happy” does the face look. Participants rated the faces based on their gut reaction, taking 2–3 min to rate all faces. Two questionnaire versions, containing different faces but bearing the same expressions, were administered. No differences existed between the versions, thus, ratings were averaged across the questionnaires.

Electrophysiological Recordings & Data Reduction

EEG activity was recorded (500 Hz) using a cap embedded with 32 Ag/AgCl electrodes (EasyCap, Herrsching-Breitbrunn, Germany) positioned according to the 10-10 system (Chatrian et al., 1985). Additional electrodes on the supra-orbital ridges and external canthi of the eyes monitored electrooculographic (EOG) activity. An AFz electrode served as the ground. Impedance was maintained at $\leq 5 \text{ K}\Omega$ and EEG activity was recorded with an amplifier bandpass filter set at 0.1–80 Hz (BrainVision Recorder, Richardson, TX, USA). Acquired signals were stored for subsequent analyses (BrainVision Analyzer, Richardson, TX, USA).

EEG data was re-referenced to the average of the left and right mastoids (TP_{9/10}). Signals were filtered (0.1–30 Hz) and ocular corrected (Gratton et al., 1983). Data was segmented into epochs (1200 ms) for each stimulus (–100–1100 ms post-stimulus). Segmentation was followed by artifact rejection, which excluded epochs exceeding $\pm 75 \mu\text{V}$ and containing

faulty channels. Epochs were baseline corrected (mean activity -100 ms pre-stimulus). Codes synchronized with stimuli delivery were used to average epochs for specific stimuli (sad50, sad100, joy50, joy100, sur50, sur100; neutral: average of sad20, joy20, sur20) per participant. At least 40 epochs were included in any further ERP analysis; one patient was excluded from analyses ($N=51$ MDD; $N=43$ control).

ERP Analyses

ERPs were identified based on grand-averaged waveforms and precedent literature. The following components were identified for non-target emotive faces: P1 (at $O_{1/2}$; max +ve voltage at 70–140 ms), N1 (at Fz; max –ve voltage at 70–110 ms), N170 (at $P_{7/8}$; max –ve voltage at 140–180 ms), VPP (at Cz; max +ve voltage at 120–180 ms), P2 (at $O_{1/2}$; max +ve voltage at 200–250 ms), N2 (at Fz; max –ve voltage at 180–260 ms) and P3 (at Pz; max +ve voltage at 280–500 ms). Peak latencies of each component were evaluated from stimulus onset time. The mean positive amplitude was assessed for the LPP (at Pz; 500–650 ms post-stimulus). The amplitude and latency of the P3 (at Pz; 350–600 ms post-target) were assessed for target sur50 and sur100 faces. Trials with false alarm and missed responses were excluded from ERP analyses.

Statistical Analyses

Separate, repeated-measures analyses of variances (ANOVAs; SPSS Inc., Chicago, IL, USA) were carried out on each POMS dimension with group (MDD; controls) and sex (males; females) as between-subject factors. Similarly, behavioural performance indices (hits, FA, RTs) to targets (sur50, sur100) were assessed with separate ANOVAs, with group and sex as between-subject factors. Face ratings on the “sad” and “happy” questions were carried out using repeated-measures ANOVAs with non-target faces (joy50, joy100, sad50, sad100, neutral) as the within- and sex and group as between-subject factors. Amplitudes and latencies (except for the LPP) were assessed for each ERP with repeated-measures ANOVAs with non-target faces and hemisphere for select ERPs (N170, P1, P2) as the within- and sex and group as between-subject factors. Univariate ANOVAs were also applied to P3 amplitudes and latencies to sur50 and sur100 faces separately, with group and sex as between-subject factors. All main effects and interactions ($p<0.05$) were Greenhouse-Geisser corrected. Bonferroni corrections (built into SPSS) were applied to adjust for multiple comparisons. Exploratory correlations were carried out between the N170 (averaged at $P_{7/8}$), P3 and LPP amplitudes, to sad100 and joy100 expressions and MADRS, HAMD-17 and HAMD-29 scores. Separate correlations were run for each sex; significance level was $p<0.01$ to correct for multiple comparisons.

Results

Profile of Mood States (POMS)

As no sex effects existed, scores in Table 2 are collapsed across sexes. POMS scores were unavailable for one MDD patient ($N=52$; controls: $N=43$). A main group effect was noted for all POMS dimensions: Tension-Anxiety [$F(1,91)=110.59$, $p<.001$], Depression-Dejection [$F(1,91)=243.47$, $p<.001$], Anger-Hostility [$F(1,91)=71.36$, $p<.001$], Fatigue [$F(1,91)=216.76$, $p<.001$], Confusion-Bewilderment [$F(1,91)=155.18$, $p<.001$], Vigour-Activity [$F(1, 91)=169.29$, $p<.001$] and Total Mood Disturbance [$F(1,91)=300.20$, $p<.001$]. Scores were greater for the MDD versus control group for all dimensions except for lower vigour-activity scores in the MDD group.

Emotional Faces Recognition Task

There were no group or sex effects on hits, RT, or FA (Table 3; sexes collapsed).

Facial Expression Rating Questionnaire

As no sex specific effects were noted, ratings in Table 4 are collapsed across sexes. For the “happy” rating, a main effect of face was noted [$F(4,364)=653.66, p<.001$], with a difference in ratings between all faces (min $p<.001$). In validation of the presented stimuli, joy100 faces were rated as most happy, while sad100 were least happy.

For the “sad” rating, a main effect of face existed [$F(4,364)=406.41, p<.001$], with a difference in sad ratings between all faces (min $p<.001$). As expected, sad100 faces were rated as most sad while joy100 were rated as least sad. A main effect of group was noted [$F(1,91)=3.90, p=0.05$] with the MDD group rating the faces as more sad overall ($3.74 \pm .11$) than controls ($3.42 \pm .12$; Table 4).

ERP Amplitudes and Latencies to Non-Target Emotional Faces

P1 Amplitude & Latency—A main effect of face was noted for P1 amplitude [$F(4,360)=11.72, p<.001$], with follow-up comparisons indicating a smaller P1 for joy100 versus all other faces (min $p<.005$). The P1 for joy50 was also smaller than for all other faces (min $p<.05$; Figure 2).

A main effect of face was noted for P1 latency [$F(4,360)=13.05, p<.001$], with a shorter latency for joy100 versus all other faces (min $p<.05$). Additionally, a shorter latency was noted for joy50 than for neutral and sad50 (min $p<.05$; Figure 2).

N1 Amplitude & Latency—No main effects or interactions were noted for N1 amplitude.

A main effect of sex was found for N1 latency [$F(1,90)=25.86, p<.001$], with longer latencies for males ($99.09 \pm .95$ ms) versus females ($92.48 \pm .89$ ms). A face $\times$ sex interaction also existed [$F(4,360)=3.46, p=.012$], with longer latencies for neutral versus both joy100 ($p=.006$) and sad100 ($p=.021$) faces for females. For males, N1 latency for joy100 was longer than for joy50 ($p=.038$). For all faces, N1 latency was shorter for females than males (min $p<.05$; Figure 3).

N170 Amplitude & Latency—A main effect of face was found for N170 amplitude [$F(4,360)=4.85, p=.001$], with a smaller amplitude for sad100 versus both joy50 ($p=.011$) and joy100 ($p<.001$). The N170 for neutral was smaller than for both joy50 ($p=.024$) and joy100 ($p=.003$); the amplitude for sad50 was smaller than for joy100 ($p=.022$; Figure 4).

No main or interaction effects were found for N170 latency.

VPP Amplitude & Latency—A main effect of face was noted for VPP amplitude [$F(4,360)=17.34, p<.001$], with follow-up comparisons indicating a smaller VPP for neutral versus all other faces (min $p<.001$). Additionally, the VPP for sad50 was smaller than for joy100 and sad100 (min $p<.05$). A main effect of sex was found [$F(1,90)=14.14, p<.001$], with females (10.39 ± 0.66 μ V) having larger VPP amplitudes than males (6.74 ± 0.71 μ V; Figure 3).

A main effect of sex existed for VPP latency [$F(1,90)=10.81, p=.001$], with shorter latencies in females (141.1 ± 1.53 ms) than males (148.47 ± 1.64 ms; Figure 3).

N2 Amplitude & Latency—A main effect of face was found for N2 amplitude [$F(4,360)=3.530, p=.01$], with a more negative amplitude for joy50 versus both neutral ($p=.038$) and sad100 ($p=.001$). The N2 amplitude to sad50 was also more negative than to sad100 ($p=.006$; Figure 3).

Assessment of N2 latency indicated a face $\times$ sex $\times$ group interaction [$F(4,360)=2.87, p=.027$] but no direct group differences were noted. For the MDD group, sex differences were found in N2 latency for joy50 ($p=.017$) and joy100 ($p=.015$), with shorter latencies for females versus males. For control males, N2 latency for sad100 was longer than for neutral ($p=.038$). For MDD females, N2 latency for sad100 was longer than for neutral, joy100, and sad50 (min $p<.05$). For MDD males, N2 latency was longer for joy50 versus neutral, sad50 and sad100 (min $p<.05$).

P2 Amplitude & Latency—A main effect of face was found for P2 amplitude [$F(4,360)=3.7, p=.006$], with a greater amplitude for sad50 versus neutral, joy50 and joy100 (min $p<.05$). P2 amplitude was also larger for joy100 than sad100 ($p=.027$; Figure 2). A face $\times$ group interaction existed [$F(4,360)=3.35, p=.013$], though follow-up comparisons revealed no direct group differences. For controls, P2 amplitude was greater for sad50 versus all other faces (min $p<.005$) but sad100; it was also greater for sad100 versus neutral ($p=.012$) and joy100 ($p=.006$), with a similar trend compared with joy50 ($p=.058$). For the MDD group, the P2 to neutral was greater than joy50 ($p=.016$; Figure 2).

A face $\times$ hemisphere $\times$ group interaction trend was noted for P2 latency [$F(4,360)=2.22, p=.07$]. Pairwise comparisons indicated that P2 latency for the MDD group (224.38 ± 1.78 ms) was longer than for controls (218.52 ± 1.94 ms) for sad100 in the left hemisphere.

P3 Amplitude & Latency—A main effect of face was noted for P3 amplitude [$F(4,360)=6.34, p<.001$], with a greater P3 for sad50 versus neutral, joy50 and joy100 (min $p<.05$). Similarly, a greater P3 existed for sad100 versus neutral, joy50 and joy100 (min $p<.001$). A main effect of sex was found [$F(1,90)=7.26, p=.008$], with larger P3 amplitudes in females (8.99 ± 0.48 μ V) than males (7.09 ± 0.52 μ V; Figure 5).

A main effect of face existed for P3 latency [$F(4,360)=2.53, p=.049$], with a longer latency for sad100 than for neutral, joy50 and sad50 (min. $p<.05$).

LPP Mean Amplitude—A main effect of face was found for mean LPP amplitude [$F(4,360)=6.34, p<.001$], with larger LPPs for sad100 than neutral ($p=.003$), joy50 ($p<.001$) and sad50 ($p=.001$). The LPP to joy50 was smaller than for neutral ($p=.021$) and joy100 ($p=.004$). A main effect of sex existed [$F(1,90)=3.95, p=.05$], with a greater LPP for females ($4.14 \pm .40$ μ V) versus males ($2.96 \pm .42$ μ V; Figure 5).

Correlations—For females, only a trend for a negative correlation between MADRS scores and P3 amplitude to sad100 faces was found ($r=-0.39, p=.043, N=27$).

P3 Amplitude & Latency to Target Faces—A main effect of sex was noted for P3 amplitude to sur50 [$F(1,75)=7.40, p=.008$] and sur100 faces [$F(1,91)=16.82, p<.001$] faces, with females exhibiting a greater P3 (sur50: $14.59 \pm .69$ μ V; sur100: $18.28 \pm .74$ μ V) than males (sur50: $11.76 \pm .78$ μ V; sur100: $13.84 \pm .79$ μ V). No main effects or interactions existed for sur50/100 latency.

Discussion

This study examined performance and ERPs on a simple facial expression recognition task in depressed males and females and controls. Consistent with expectations and diagnosis, the MDD group was characterized by mood disturbances. In line with the mood-congruent processing bias, depressed individuals rated faces as sadder overall than controls, suggesting that emotive and socially meaningful information is evaluated more negatively in the disorder. Expressions influenced all ERPs, though valence and intensity selectively

modulated specific ERPs. Females typically had larger ERPs with shorter latencies than males, indicating enhanced pre- and conscious as well as speeded facial processing, respectively, in females. Depressed individuals did not exhibit robust ERP differences to specific expressions than controls. Subtle group differences were noted in mid-latency ERPs, with controls exhibiting increased P2 amplitudes to sad expressions that was absent in the MDD group, though P2 latency to intensely sad faces was longer in MDD; a similar finding existed for N2 latency in MDD females. No correlations between select ERPs to intense expressions and depression ratings existed. Further interpretation and implications of these results are discussed below.

We noted an attenuated P1 to joyful expressions and decreased latency to intensely joyful ones, confirming previous results indicating that early perceptual ERPs are emotion-sensitive (Pourtois & Vuilleumier, 2006; Santesso et al., 2008). However, research assessing the influence of less arousing positive (happy) and negative (sad) expressions on the P1 has yielded inconclusive findings (Lee et al., 2010). Somewhat inline with our results, others noted an attenuated P1 to liked (versus disliked) and attractive (versus unattractive) faces (Halit et al., 2000; Pizzagalli et al., 2002). We previously found a blunted P1 to joyful versus intensely sad faces in the right occipital region, though an increased P1 to intensely joyful versus mildly emotive and neutral expressions was found in the left parietal region (Jaworska et al., 2010). Our current results suggest “automaticity” in very early perceptual processing of positive expressions.

With respect to the N1, shorter latencies were noted for intensely sad and joyful expressions compared with neutral ones in females, suggesting longer perceptual processing of ambiguous faces. In males, N1 latency was enhanced to intensely versus mildly joyful faces, indicating somewhat different early, perceptual processing of emotive information between the sexes. This was further supported by decreased overall N1 latencies in females versus males, indicating speeded perceptual processing of faces in females (Lewin & Herliz, 2002; Felmingham et al., 2010). We found no evidence for altered early, pre-conscious processing of emotive information in MDD.

Though exceptions exist, the N170 has been found to be expression-sensitive, with most studies documenting its enhancement to highly arousing negative expressions (Batty & Taylor, 2003; Stekelenburg & de Gelder, 2004; Krombholz et al., 2007). We found it to be most pronounced to joyful faces, consistent with our previous findings (Jaworska et al., 2010). Given that an opposite pattern was observed for the P1, it is feasible that early sensory processing is most automatic for positive expressions while face identification may be maximal for them. Consistent with the idea that highly arousing stimuli elicit a maximal N170, pilot work in our laboratory indicated that intensely joyful faces were rated as most aroused while mildly sad ones were least aroused (data not shown). Thus, it is feasible that increased arousal versus positive valence *per se* elicits a prominent N170.

The VPP has also been shown to be enhanced to fearful and angry expressions (Sewell et al., 2008; Foti et al., 2010; Luo et al., 2010). However, we previously found it to be enhanced to emotive (happy and sad) faces (Jaworska et al., 2011), consistent with the current study. Previous work has also found the VPP to be shortest to positive expressions (Batty & Taylor, 2003; Jaworska et al., 2011). Thus, highly arousing and positive faces appear to elicit maximal VPPs with shortest latencies. Though it has been argued that the VPP and N170 are equivalent (Joyce & Rossion, 2005), we noted distinct features between the two. The VPP was smallest to neutral faces indexing preferential processing of emotional (versus just arousing) faces. A main effect of sex emerged for the VPP but not N170, suggesting increased cortical resource allocation and faster processing of faces in females. We found no evidence that face-sensitive ERPs were uniquely altered by specific expressions in MDD.

The P2 has been shown to be modulated by emotive information, with reported P2 reductions to fearful and angry faces (Schutter et al., 2004; Stekelenburg & de Gelder, 2004). Previous work in our laboratory found it to be maximal to sad versus neutral and mildly positive expressions in the right occipital region (Jaworska et al., 2010). Similarly, in the current study a greater P2 was noted to mildly sad versus neutral and joyful expressions, though it was also greater for intensely joyful versus intensely sad ones. These results suggest a maximal P2 to less arousing negative expressions. The P2 may reflect perceptual grouping processes as it tends to be small for stimuli that facilitate grouping and maximal for those that hinder it (Rousselet et al., 2008). Highly arousing and positive expressions may facilitate grouping and be accompanied by a decreased P2. In a similar vein, following initially enhanced pre-conscious processing of positive and arousing stimuli, reflecting rapid stimulus identification/categorization, increased perceptual processing may subsequently be devoted to ambiguous expressions. A similar interpretation could apply for the N2 as it was maximal to mildly joyful versus neutral and intensely sad faces.

Subtle group differences emerged for the P2 and N2. For controls, the P2 was greater for sad versus all other expressions. This was not observed for the MDD group; instead, only a larger P2 to neutral versus mildly positive expressions existed. This may reflect increased automaticity in late pre-conscious processing of negative faces in MDD. Alternatively, it suggests attenuated perceptual processing of emotive information, consistent with previous work (Leppänen et al., 2004). P2 latency for the MDD versus control group was longer to intensely sad expressions in the left hemisphere, indicating longer late pre-conscious processing of these faces. Though no direct group differences were noted for the N2, subtle sex-dependent N2 latency differences emerged. Specifically, though no N2 latency differences existed between faces in control females, for MDD females latencies were enhanced to intensely sad expressions, consistent with the P2 latency results. For control males, N2 latency to intensely sad faces was longer than to neutral ones, indexing longer processing of intense negative stimuli. In MDD males, N2 latency was longer for mildly joyful versus neutral and sad expressions suggesting increased processing of mild, mood-incongruent faces.

We noted maximal P3s to sad expressions and longer latencies to intensely sad versus all but intensely joyful faces, consistent with the idea that the most informative social cues preferentially capture conscious attention resources. Additionally, we found that P3-indexed conscious processing of faces was greater in females. Given that performance was comparable between the sexes, this did not confer a performance advantage, though task ease may have prevented the emergence of sex differences. Previous work has found no P3 differences to faces between sexes (Campanella et al., 2004; Lee et al., 2010), another group noted opposite results to ours (Oliver-Rodriguez et al., 1999), while yet another indicated that P3 sex differences to facial expressions may be hemisphere-dependent (Gasbarri et al., 2006). The current study indicates enhanced pre- and conscious facial processing in females. We found no evidence of altered conscious attention capture by specific facial expressions in MDD. The handful of studies that has assessed the P3 in emotive tasks in MDD suggest blunted conscious attention allocation to emotive information (Kayser et al., 2000; Cavanagh & Geisler, 2006; Bruder et al., in press). Our findings did not support this, though study design variability may partially account for this.

In line with our previous work (Jaworska et al., 2011), we noted greater LPPs to intensely sad versus with all but intensely joyful expressions. The LPP to mildly joyful faces was also smaller than to neutral and intensely joyful faces, indicating that neutral, perhaps due to their ambiguity yet potential relevance, and intense expressions elicit greater sustained motivated processing than mildly emotive ones. LPP-indexed enhanced sustained processing of faces was evident in females versus males. Previous work indicates that MDD individuals

exhibited blunted LPPs to threatening faces (Foti et al., 2010), while others noted no effect of positive or negative pictures (not faces) on an LPP-like component in MDD (Kayser et al., 2000).

Conclusions and Limitations

We assessed ERP profiles associated with facial expression processing in MDD. Consistent with the purported mood-congruent processing bias in MDD, MDD individuals rated expressions as sadder overall than controls. However, we found little evidence for substantially altered ERPs to specific expressions in MDD. Subtle modulations in mid-latency ERPs suggested attenuated late pre-conscious perceptual processing of emotive stimuli in MDD, though this was accompanied by longer processing of intensely sad faces, especially in females. Females exhibited increased and speeded pre- and conscious facial processing.

Precedent work indicates that the robust ERPs tend to emerge to threatening faces, especially at early-mid latencies, perhaps reflecting a pre-attentive scan of threat. Our rationale for excluding these was because we wanted to examine the influence valence on ERPs in MDD while minimizing the influence of arousal. However, inclusion of threatening faces may have revealed more pronounced group ERP differences. Task design is another important consideration when comparing study outcomes. In the current study, participants responded to surprised faces; a more involved task (e.g. memory task) may have, more robustly, differentiated the groups. Although given that we wanted to assess temporal profiles of expression processing, our task was well-suited for this aim. Another methodological consideration that may complicate direct comparisons between studies (in addition to reference choice) is the site at which an ERP is assessed.

Despite our subtle between-group differences, the potential utility of ERPs during emotive processing in MDD should not be discounted. Previous work indicates that cognitive changes may emerge with short-term treatment (Harmer et al., 2003). Assessing attention allocation to emotive stimuli and associated ERPs before and during initial treatment periods may be useful in predicting clinical response. If clinical outcome can be predicted based on short-term changes in ERPs to emotive stimuli, earlier switching to more effective antidepressants may be feasible, and should be probed in future studies.

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Figure 1.
Examples of facial stimuli.

Figure 2. P1 and P2 (at O₂) to sadness at 50% and 100% intensity (sad50, sad100), joy at 50% and 100% intensity (joy50, joy100) and neutral in the MDD and control groups.

Figure 3. N1, N2 and VPP (at Fz) to sadness at 50% and 100% intensity (sad50, sad100), joy at 50% and 100% intensity (joy50, joy100) and neutral in males and females.

Figure 4. N170 amplitude (at O₈) to sadness at 50% and 100% intensity (sad50, sad100), joy at 50% and 100% intensity (joy50, joy100) and neutral in MDD and control groups.

Figure 5. P3 and mean LPP (50–650 ms; at Pz) to sadness at 50% and 100% intensity (sad50, sad100), joy at 50% and 100% intensity (joy50, joy100) and neutral in males and females.

Table 1

Major Depressive Disorder (MDD) and Control Group Characteristics & Demographics (Sexes Collapsed)

	MDD (N=53)	Control (N=43)
Sex (Female/Male)	29/24	23/20
Age Range	19–63	21–60
Age (M ± S.D.)	40.7 ± 11.8	36.5 ± 9.8
Education Years (M ± S.D.)	16.0 ± 2.4	16.4 ± 1.9
HAMD-17 (M ± S.D.)	20.9 ± 5.2	-
HAMD-29 (M ± S.D.)	31.1 ± 6.2	-
MADRS (M ± S.D.)	30.8 ± 5.4	-
BDI-II (M ± S.D.)	-	3.7 ± 4.8
Ethnicity	48 Caucasian; 3 Asian; 1	39 Caucasian; 1 Asian; 2
	South Asian; 1 African	South Asian; 1 African

HAMD-17/29: Hamilton Rating Scale for Depression, 29 & 17 item versions;

MADRS: Montgomery- Åsberg Depression Rating Scale; BDI-II: Beck Depression Inventory-II

Table 2

Profile of Mood States (POMS) in Major Depressive Disorder (MDD) and Control Groups (Mean $\pm$ Standard Error)

POMS Dimensions	MDD *** (N=52)	Control (N=43)
Depression-Dejection	35.4 $\pm$ 1.4	3.4 $\pm$ 1.5
Vigor-Activity	5.0 $\pm$.7	19.4 $\pm$.8
Confusion-Bewilderment	16.5 $\pm$.7	4.1 $\pm$.7
Fatigue-Inertia	20.2 $\pm$.7	4.4 $\pm$.8
Anger-Hostility	16.9 $\pm$ 1.0	3.9 $\pm$ 1.1
Tension-Anxiety	18.2 $\pm$.8	5.2 $\pm$.9
Total Mood Disturbance	102.5 $\pm$ 3.9	1.6 $\pm$ 4.3

 $p < .001$: All POMS dimensions differed between the MDD versus control groups

Table 3

Behavioral Performance Measures on the Emotive Faces Recognition Task in Major Depressive Disorder (MDD) and Control Groups (Mean $\pm$ Standard Error)

Performance Measures	MDD (N=52)	Control (N=43)
Hits (%)	81. $\pm$ 14	79 $\pm$ 14
Reaction Time (ms)	522 $\pm$ 108	525 $\pm$ 78
False Alarms (%)	.8 $\pm$.9	.9 $\pm$.9

Table 4

Facial Stimuli Ratings on the “Happy” and “Sad” Dimensions in Major Depressive Disorder (MDD) and Control Groups (Mean $\pm$ Standard Error)

		MDD (N=52)	Control (N=43)
“Happy” Rating	Joy50	7.2 $\pm$ 1.6	7.5 $\pm$ 1.5
	Joy100	8.9 $\pm$ 1.0	9.3 $\pm$.8
	Neutral	3.3 $\pm$ 1.6	3.4 $\pm$ 1.4
	Sad50	2.0 $\pm$ 1.9	2.0 $\pm$ 1.5
	Sad100	1.0 $\pm$ 1.5	.6 $\pm$ 1.0
“Sad” Rating *	Joy50	.9 $\pm$ 1.2	.7 $\pm$.9
	Joy100	.4 $\pm$.7	.4 $\pm$ 1.0
	Neutral	3.6 $\pm$ 1.8	2.7 $\pm$ 1.9
	Sad50	5.8 $\pm$ 1.9	5.7 $\pm$ 1.9
	Sad100	7.9 $\pm$ 1.7	7.7 $\pm$ 2.1

For both happy and sad ratings, all faces were rated differently (min. $p < 0.001$);

* $p = 0.05$: Overall, the MDD vs. control group rated the faces as more sad.