*Research Article*

# REDUCED ELECTROCORTICAL RESPONSE TO THREATENING FACES IN MAJOR DEPRESSIVE DISORDER

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**Background:** *There is growing support for the emotion context insensitivity hypothesis, which states that major depressive disorder (MDD) is associated with a deficit in emotional reactivity. Under this hypothesis, depressed individuals exhibit reduced behavioral and physiological responses to both appetitive and aversive stimuli. We sought to examine this possibility using the late positive potential, a neural response sensitive to aversive and threatening stimuli.* **Methods:** *Forty-seven individuals participated in the study, 22 of whom met criteria for current MDD and 25 with no history of depression or other Axis I disorders. All individuals passively viewed emotional faces while event-related potentials were recorded.* **Results:** *The vertex positive potential was significantly increased in response to fearful and angry faces across the entire sample. The late positive potential was also increased in response to threatening faces, but only among never-depressed individuals. In the MDD group, this electrocortical response to emotional faces was absent.* **Conclusions:** *This study provides neural evidence in support of the view that MDD is associated with blunted emotional reactivity to negative stimuli, which until now has been examined primarily with measures of behavior, self-report, and peripheral physiology. These results are also consistent with two prior studies showing reduced amygdala activation in response to fearful faces among depressed individuals. It remains to be determined whether abnormal activity in response to emotional stimuli is associated with trait risk for MDD or results from MDD. Depression and Anxiety 27:813–820, 2010.* 

**Key words:** *depression; emotion; visual evoked potentials; facial expression; affect*

## INTRODUCTION

Major depressive disorder (MDD) ranks among the world's most common and economically burdensome illnesses[1–3] and is associated with an increased rate of mortality.[4] Depression is defined by disturbance in mood—as a persistent and pervasive feeling of sadness, a diminished interest in pleasurable activities, or both.[5] Neuroimaging techniques have been instrumental in better understanding the pathophysiology of these mood disturbances, and a number of studies have identified a resting-state pattern in which depressed individuals exhibit underactive prefrontal and overactive limbic regions.[6] Mayberg has proposed a limbic-cortical model of depression in which this pattern represents a reciprocal dysregulation that provides a basis for better understanding some of the cognitive, affective, and somatic symptoms that are

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typically associated with depression.[7,8] For example, increased amygdala and decreased prefrontal activity have been related to sustained, ruminative processing of negative, personally relevant information.[9,10]

Building upon this foundation, recent approaches to studying depression have focused on identifying abnormal patterns of emotional reactivity in individuals with MDD. The positive attenuation model of MDD asserts that depression is uniquely characterized by diminished reactivity to pleasurable stimuli.[11] By this account, reactivity to negative stimuli remains intact and may even be increased among individuals with MDD. In contrast to this perspective, Rottenberg et al. have argued for an emotion context insensitivity (ECI) model of MDD,[12] whereby depression is associated with an *overall* deficit in emotional reactivity to both positive *and* negative stimuli. The key distinction between these two models, therefore, is whether or not reactivity to negative stimuli is abnormal in MDD. In addressing this question, a recent meta-analysis found the ECI hypothesis to be well supported across a number of different paradigms using measures of self-report, behavior, and peripheral physiology.[13] For example, individuals with MDD exhibit less affective modulation of the startle reflex while viewing pleasant, neutral, and unpleasant images;[14–16] they exhibit less facial EMG activity while viewing both positive and negative facial expressions;[17] and they report blunted emotional experiences while viewing sad or amusing film clips.[12,18,19] Additionally, depressive symptoms and induced negative affect have each been associated with reduced neural differentiation between monetary gains and losses.[20,21]

Although there is substantial evidence across behavioral and physiological domains in support of the view that MDD is characterized by an overall deficit in emotional reactivity, neuroimaging studies have been mixed. A recent meta-analysis suggested evidence for both hypo- and hyperactivity in response to emotional stimuli in MDD depending on specific regions of interest, although results generally indicated increased activity in limbic regions.[22] However, most of the studies included in the meta-analysis focused on neural activation elicited by happy and sad compared to neutral faces. On the other hand, two studies found that individuals with MDD were characterized by *reduced* amygdala activity in response to *fearful* faces[23,24]—data consistent with the notion of blunted emotional reactivity in MDD.

In addition to fMRI, event-related potentials (ERPs) can be used to assess neural activity in response to emotional stimuli. ERPs directly reflect electrocortical activity and have excellent temporal resolution. Prior studies examining the processing of faces have focused on the P1 and the vertex positive potential (VPP),[1] early ERP components that peak within 200 ms following stimulus presentation and differentiate emotional from neutral facial expressions.[25,26] These components are thought to reflect perceptual processing and structural encoding of facial stimuli.[27] Studies measuring the affective modulation of ERPs have also focused on the late positive potential (LPP), an ERP component that has repeatedly been shown to be enhanced in response to emotional stimuli, including faces, pictures, and words. The LPP is most prominent at centroparietal sites, becomes evident as early as 200 ms following stimulus onset, and persists throughout stimulus presentation.[28–32] Functionally, the LPP is thought to reflect increased and sustained attention to salient visual stimuli,[33] and has been related to neural activity in parietal and occipital areas using source analyses and in studies that combine ERP and fMRI methods.[34,35] Although it remains to be substantiated, it has been suggested that the LPP may index increased visual attention and processing resulting from reentrant feedback from the amygdala to the visual cortex.[35] Consistent with this possibility, manipulations that increase the salience and negative meaning of aversive stimuli have been shown to increase the LPP.[36–39] In light of their sensitivity to the emotional nature of visual stimuli, these ERP components are well-suited for further examining abnormalities in MDD across multiple stages of emotional processing.

In the current study, we sought to examine the degree to which MDD is associated with abnormal emotional reactivity to negative stimuli, as measured by the P1, VPP, and LPP in response to facial expressions. In particular, previous studies have shown that angry and fearful (i.e., threatening) faces consistently modulate these ERP components compared to neutral (i.e., non-threatening) faces,[25,26,40–43] and in one recent study depressive symptoms within a non-clinical sample were associated with a reduced VPP to fearful faces.[44] To date, however, these effects have not been systematically examined with regard to MDD. Accordingly, we predicted the following: (a) as previously shown, never-depressed individuals would exhibit enhanced ERPs in response to both angry and fearful relative to neutral faces; and (b) following the ECI hypothesis, the modulation of these ERPs by threatening stimuli would be significantly reduced among individuals with MDD compared to the never-depressed group.

## METHODS AND MATERIALS

### PARTICIPANTS

Twenty-five individuals with no history of depression and 22 currently depressed individuals participated in the study. Depressed participants were eligible if they met criteria for MDD based on the Structured Clinical Interview for DSM-IV Diagnosis (SCID).[45] Depressed individuals were excluded if they met DSM-IV criteria for another current Axis I disorder (excluding specific phobia: $n = 1$) or

[1]The VPP represents the positive end of the N170 dipole.[51] Insofar as the VPP is more pronounced when using a mastoid reference scheme, we elected to score this component rather than the N170 in the current study.

**TABLE 1. Demographic and clinical characteristics of the sample**

| | Controls ($n = 25$) | | MDD ($n = 19$) | | Comparison |
|---|---|---|---|---|---|
| | *n* | % | *n* | % | $\chi^2$ (*df*) |
| Gender | | | | | |
| Male | 7 | 28.0 | 9 | 47.4 | – |
| Female | 18 | 72.0 | 10 | 52.6 | 1.75 (1) |
| Ethnicity | | | | | |
| Caucasian | 20 | 80.0 | 13 | 68.4 | – |
| Other | 5 | 20.0 | 6 | 31.6 | 0.77 (1) |
| Treatment | | | | | |
| Current therapy[a] | 0 | 0.0 | 4 | 21.1 | – |
| Past therapy[b] | 0 | 0.0 | 17 | 89.5 | – |
| Past antidepressant medication[b] | 0 | 0.0 | 11 | 57.9 | – |
| | *M* | *SD* | *M* | *SD* | *t*(*df*) |
| Age | 40.84 | 13.16 | 38.95 | 16.56 | −0.42(42) |
| Years of education | 15.60 | 2.08 | 15.74 | 3.02 | 0.18 (42) |
| IDS-SR | 5.72 | 3.55 | 43.89 | 11.37 | 15.85(42)*** |
| Number of MDEs | – | – | 5.72 | 8.91 | – |
| Current episode (weeks) | – | – | 189.53 | 340.72 | – |

*Note*: IDS-SR, inventory of depressive symptomatology (self-report); MDE, major depressive episode.
[a]Past month.
[b]Prior to past month.
***$P$-value $< .001$.

had been prescribed any antidepressant medications in the previous month; current enrollment in psychotherapy was not a selection criterion. Control participants were excluded if they met criteria for any current or past DSM-IV Axis I diagnosis. Diagnostic interviews were conducted by an advanced graduate student (DMO) with previous training and experience with the SCID. For each group, five diagnostic interviews were recorded for inter-rater reliability; all 10 diagnoses were confirmed by a clinical psychologist (GH or DNK). Three of the depressed individuals who participated in the study were excluded from analysis due to poor quality ERP recordings, leaving 19 in the final sample. Demographic and clinical characteristics of the sample are presented in Table 1. The two groups did not significantly differ on any demographic variables, including age, gender, ethnicity, and education level. Informed consent was obtained from participants prior to the experiment, and all participants received $80.00 for their participation. This research was formally approved by the Stony Brook University Institutional Review Board.

## MEASURE OF DEPRESSIVE SYMPTOMS

The self-report version of the Inventory of Depressive Symptomatology (IDS-SR)[46,47] was used to assess the severity of depressive symptoms over the previous week. The IDS-SR is a 30-item measure that spans the nine symptoms used to define a major depressive episode,[5] as well as melancholic and atypical symptoms. The IDS-SR has been shown to have excellent psychometric properties among depressed adults,[48,49] and the severity of depressive symptoms may be interpreted based on the following cutoff scores: normal levels of symptoms are reflected by scores from 0 to 13, mild from 14 to 25, moderate from 26 to 38, severe from 39 to 48, and very severe from 49 to 84.

## STIMULUS MATERIALS AND TASK

A total of 130 color images were chosen from the NimStim Face Stimulus Set,[2] with 26 chosen for each of the following emotions: fearful, angry, neutral, happy, and sad.[3] The same 26 actors (13 male, 13 female) were used for each emotion; each of the 26 actors was presented once for each of the five emotions. The task was administered on a Pentium D class computer, using Presentation software (Neurobehavioral Systems, Albany, CA) to control the presentation and timing of all stimuli. Prior to viewing each face, a white fixation cross ("+") was presented in the center of a black screen for a randomly determined interval ranging from 1,000–1,500 ms. A randomly selected face was then displayed in color for 1,000 ms. At the beginning of the task, an instruction telling the participants that "Simply view these faces" was displayed for 4,000 ms.

## PROCEDURE

After a brief description of the experiment, all the participants were interviewed using the SCID and completed the IDS-SR. Electroencephalograph (EEG) sensors were then attached and the participant was given detailed task instructions. The participants were told that they would be viewing faces depicting a range of emotions. All the participants performed 10 practice trials, where they viewed faces from two actors not included in the main task. After the practice

[2]Development of the MacBrain Face Stimulus Set was overseen by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development. Please contact Nim Tottenham at tott0006@tc.umn.edu for more information concerning the stimulus set.

[3]For the current study, only ERP responses to angry, fearful, and neutral faces were considered. In the present sample, the LPP did not significantly differ between happy and neutral faces, nor between sad and neutral faces in either the control or MDD group ($P$s $> .15$). That is, across all subjects, happy and sad faces were not associated with an increased LPP. This pattern is consistent with several previous studies showing enhanced ERPs to high-arousal facial expressions (e.g., fearful and angry) but not low-arousal expressions such as happy and sad.[40,54]

trials, all the participants performed 130 trials, with a break at the mid-point of the experiment. Each face was presented once, and the order was randomly determined for each participant.

### PSYCHOPHYSIOLOGICAL RECORDING, DATA REDUCTION, AND ANALYSIS

The continuous EEG was recorded using the ActiveTwo BioSemi system (BioSemi, Amsterdam, Netherlands). Recordings were taken from 34 scalp electrodes based on the 10–20 system (including FCz and Iz), as well as two electrodes places on the left and right mastoids. The electrooculogram generated from blinks and eye movements was recorded from four facial electrodes: two approximately 1 cm above and below the participant's left eye, one 1 cm to the left of the left eye, and one 1 cm to the right of the right eye. The ground electrode was formed by the Common Mode Sense active electrode and the Driven Right Leg passive electrode.

All bioelectric signals were digitized on a laboratory computer using ActiView software (BioSemi). The EEG was sampled at 1,024 Hz. Off-line analysis was performed using Brain Vision Analyzer software (Brain Products). All data were re-referenced to the average of the two mastoids and band-pass filtered with cutoffs of 0.1 and 30 Hz. The EEG was segmented for each trial, beginning 200 ms before each face onset and continuing for 1,200 ms. The EEG for each trial was corrected for blinks and eye movements using the method developed by Gratton et al.[50] Specific trials for individual channels were rejected using a semi-automated procedure, with physiological artifacts identified by the following criteria: a voltage step of more than 50 μV between sample points, a voltage difference of 300 μV within a trial, and a maximum voltage difference of less than 0.5 μV within 100-ms intervals; the data were also inspected visually for additional artifacts.

ERPs were constructed by separately averaging fearful, angry, and neutral faces. For each ERP average, the mean level of activity in the 200-ms window prior to face onset served as the baseline. The P1 and the VPP were each scored as the mean level of activity in a 20-ms window surrounding the peak deflection for each participant. The P1 was identified as the local positive peak between 100 and 150 ms at a pooling of Oz, O1, O2, and Iz, where it has previously been shown to be maximal.[25] Similarly, the VPP was identified as the local positive peak from 150 to 200 ms at a pooling of Cz, FC1, FC2, FCz, and Fz.[51] The LPP was scored as the mean level of activity from 400 to 1,000 ms at a cluster of centroparietal sites (i.e., Cz, Pz, CP1, and CP2), where it has been shown to be maximal in a number of previous studies.[28–32,34,36,37,39] All ERPs were evaluated with a 3 (Face type: fearful, angry, and neutral) × 2 (Group: depressed and non-depressed) mixed-model ANOVA. All statistical tests were performed using SPSS (Version 17.0) General Linear Model software, with Greenhouse-Geisser correction applied to *P* values associated with multiple *df*, repeated measures comparisons. Unless specified otherwise, all tests were two-tailed and used a significance threshold of $P<.05$.

# RESULTS

## DEPRESSIVE SYMPTOMS

As expected, the participants in the MDD group reported moderate to severe levels of depressive symptoms on the IDS-SR (range = 27–69), whereas the control participants reported normal levels of depressive symptoms (range = 0–13); this difference was statistically significant (Table 1).

## ERPs

Stimulus-locked ERPs in response to each type of face (fearful, angry, and neutral) are presented in Figure 1 for control and depressed participants. The P1 was maximal at occipital recording sites approximately 120 ms following stimulus onset. This component was enhanced for angry and fearful compared to neutral faces, although the effect of face type was only marginally significant ($F(2,84) = 2.64$, $P = .08$); the interaction between face type and Group was not statistically significant ($F(2,84) = 0.53$, $P > .50$). Following the P1, the VPP was maximal at frontocentral sites approximately 175 ms following stimulus onset. The VPP significantly differed across face type ($F(2,84) = 4.71$, $P < .05$), and follow-up comparisons confirmed that the VPP was significantly more positive in response to fearful ($t(43) = 3.32$, $P < .01$) and angry ($t(43) = 2.35$, $P < .05$) compared to neutral faces. This effect of face type was not significantly moderated by Group ($F(2,84) = 0.57$, $P > .50$).

The LPP was evident as a sustained relative positivity to threatening faces beginning at approximately 300 ms.

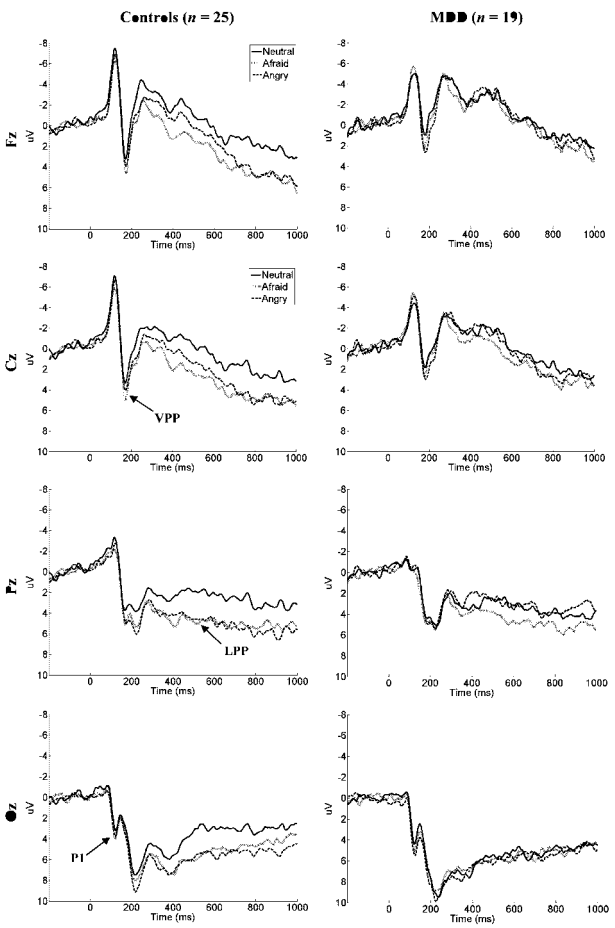


**Figure 1. ERPs recorded at midline channels in response to neutral, afraid, and angry faces for never depressed (left) and currently depressed individudals (right).**

The scalp topographies of the difference between threatening and neutral faces are presented in Figure 2. As seen in the Figure 2, fearful faces elicited a somewhat more broadly distributed positivity compared to angry faces among control participants, although the LPP was prominent at centroparietal sites for both angry and fearful faces. The magnitude of the LPP in the overall sample varied by face type ($F(2,84) = 5.61$, $P<.01$), and this effect was qualified by an interaction between face type and Group ($F(2,84) = 3.63$, $P<.05$). This Face Type by Group interaction remained significant even after including Gender as a covariate ($F(2,82) = 3.31$, $P<.05$). Confirming the impression from Figures 1 and 2, a follow-up ANOVA among the control participants yielded a significant effect for Face Type ($F(2,48) = 12.35$, $P<.001$), and pairwise comparisons revealed that the LPP was significantly enhanced for threatening compared to neutral faces (fearful: $t(24) = 4.43$, $P<.001$; angry: $t(24) = 4.49$, $P<.001$). For depressed participants, the LPP was not significantly modulated by Face Type ($F(2,36) = .73$, $P>.40$). This pattern of results indicate that the expected modulation of the LPP by threatening faces was intact for healthy participants, but for depressed participants, the LPP did not significantly differ between fearful, angry, and neutral faces.

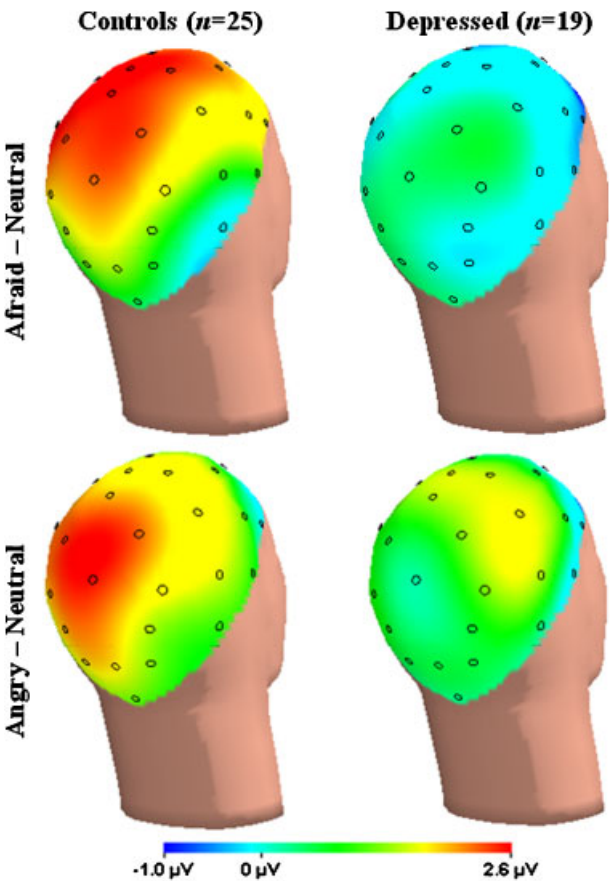


**Figure 2. Scalp topographies depicting the LPP from 400–1000 ms following stimulus onset for never depressed (left) and currently depressed (right) individuals. The voltages represent the difference between threatening and neutral faces.**

To investigate whether LPP magnitude was associated with depressive symptom severity, we performed several additional tests. Across the entire sample, the LPP difference between threatening (i.e., angry and fearful) and neutral faces was inversely related to IDS-SR score ($r = -.46$, $P<.01$). Thus, increasing depressive symptoms related to reduced differentiation between threatening and neutral facial expressions. Due to the bimodal distribution of IDS-SR scores, we also performed this correlation separately in each group. Within the control group, the LPP difference between threatening and neutral faces was again inversely related to IDS-SR score ($r = -.38$, $P<.05$, one-tailed). This indicates that, although the control group was within the normal range of symptoms on the IDS-SR, the presence of mild depressive symptoms in this group was associated with less differentiation in the LPP between threatening and neutral faces. Within the depressed group, however, this association between the LPP and IDS-SR score did not reach significance ($r = -.18$, $P = .24$, one-tailed), possibly due to a floor effect on LPP magnitude. Likewise, the LPP was not significantly associated with the length of the current episode or the number of previous episodes within the depressed group (both $Ps > .25$, one-tailed).

## DISCUSSION

Consistent with previous research,[25,26] the VPP was significantly enhanced for fearful and angry compared to neutral faces. VPP magnitude was not significantly moderated by the presence of current MDD, indicating that the modulation of this early neural response to threatening faces is intact among depressed individuals. This pattern can be contrasted with the LPP: As previously shown,[40–42] individuals with no history of depression exhibited a sustained relative positivity at centroparietal recording sites that was enhanced for fearful and angry compared to neutral faces. Individuals meeting criteria for current MDD, however, failed to exhibit this affective modulation of the LPP—threatening faces were not associated with an increased late electrocortical response among the MDD group. Together, these results suggest that threatening faces elicit increased early neural activity among depressed individuals, who fail to engage the neural networks typically associated with later facilitated processing of emotional stimuli. Due to the low spatial resolution of ERPs, these data cannot speak directly to which specific brain regions account for the observed deficits in the MDD group. However, a number of groups have suggested that affective modulation of the LPP indexes increased activity in visual cortex, possibly from reentrant feedback from the amygdala.[34,35] Along these lines, the current data are consistent with two

prior studies showing reduced amygdala activation to threatening faces among depressed individuals.[23,24] Although support for the ECI hypothesis has thus far has come primarily from measures of self-report, behavior, and peripheral physiology,[13] there is now an emerging body of neural data indicating that MDD is associated with reduced emotional reactivity to *threatening* stimuli.

Although there is growing empirical support for the association between MDD and a deficit in emotional reactivity, the direction of causality is not well understood. Rottenberg et al. have argued that MDD may cause this deficit to arise, with depressed mood causing an individual to disengage from his or her environment, become biased against taking action, and become less emotionally reactive to both pleasant and aversive stimuli.[12] Conversely, it is also feasible that a deficit in emotional reactivity may be a risk factor for developing depression. Along these lines, there is evidence for reduced amygdala activation in response to threatening faces among children high in behavioral inhibition[52]—a shy, fearful, and passive temperament that has been linked to an increased risk for depression.[53] While the current data cannot definitively address this question, it is notable that within the control group the presence of mild depressive symptoms over the previous week was also associated with blunted LPP modulation by threatening faces, a finding which is consistent with the perspective that emotional reactivity is influenced by current mood state. It will be informative for future studies to examine potential causal associations more directly, and to this extent ERPs may be a particularly useful approach. Specifically, ERP paradigms are easily adapted for children,[41] thereby making it feasible to conduct longitudinal studies within high-risk samples to examine whether neural correlates of abnormal emotional reactivity are predictive of future MDD. In addition, ERPs are a relatively cost-effective measure of brain activity as compared to fMRI, and they are well-suited to repeated measures designs that may be helpful in addressing whether blunted neural reactivity to emotional stimuli normalizes upon recovery from MDD.

Several neuroimaging studies have found depression to be associated with *increased* activity in limbic regions, results that appear at first to contradict the ECI hypothesis and findings of blunted emotional reactivity in MDD. However, it is also possible that the link between depression and emotional reactivity is moderated by stimulus-related differences, such as personal relevance. For example, in two studies where participants were asked to generate words representative of their own sad moods,[9,10] amygdala responses to these words were sustained in depressed individuals compared to controls and related to self-report levels of rumination. Additionally, although Rottenberg et al.[12] found depressed individuals' emotional responses to negative stimuli to be blunted overall, their responses to idiographic stimuli were more dysphoric than their responses to normative stimuli. It is possible, therefore, that personally relevant stimuli may specifically engage negative, depressogenic schemas and result in strong emotional reactions and increased neural activity in limbic regions. On the other hand, normative emotional stimuli that are adaptively meaningful but lack personal relevance (i.e., threatening faces) may fail to capture the attention of depressed individuals and result in decreased limbic activity, smaller ERP and physiological responses, and blunted emotional reactions.

In addition, neural data in support of an association between MDD and blunted emotional reactivity may depend on the use of highly arousing stimuli, such as threatening faces. When low-arousal emotional stimuli (e.g., happy and sad faces) have been used in previous studies examining neural activation, comparisons between depressed and non-depressed groups have been inconsistent.[22] With regard to the LPP, several ERP studies of emotional face processing have failed to observe differences between happy, sad, and neutral faces, whereas angry and fearful faces reliably yield an increased LPP.[40–42,54] Although there may be a unique relationship between depression and the processing of threatening stimuli, it is also possible that low-arousal stimuli represent relatively weak manipulations for observing abnormalities in the neural correlates of affective processing. Stimuli such as the International Affective Picture System[55] are ideally suited to more directly address this possibility, as they include a wider range of highly arousing pleasant and unpleasant stimuli. Another important consideration is that anxiety and depression may differentially influence patterns of emotional reactivity, particularly for negative stimuli. For example, in a recent study self-reported state anxiety predicted an increased LPP to unpleasant images during a stimulus categorization task.[56] Similarly, non-depressed individuals with a diagnosis of generalized anxiety disorder exhibited an increased LPP and greater behavioral interference when viewing unpleasant images in the same paradigm.[57] In light of the high comorbidity between MDD and anxiety disorders,[58] it will be important for future work to examine both unique influences as well as interactions between depressive and anxious symptoms on emotional reactivity.

# CONCLUSIONS

In summary, the current study represents the first observation of decreased brain activity in response to threatening faces among non-medicated adults with current MDD, thereby offering neural evidence in support of the ECI hypothesis that MDD is associated with blunted emotional reactivity. Moreover, this impairment appears to be specific to later, elaborative processing—early, face-specific processing was unaffected by the presence of current MDD. When viewing angry or fearful faces, never-depressed individuals exhibited an enhanced LPP at centroparietal recording sites compared to neutral

faces, whereas this ERP component in the MDD group did not significantly distinguish between neutral and threatening facial expressions. One strength of the current study is the use of a non-medicated MDD group without comorbid Axis I psychopathology, which enhances the internal validity of these results. It will be important, however, to replicate the current findings in less selected samples of individuals with MDD. The majority of individuals in the depressed group had chronic, recurrent MDD, and it would be of interest to examine whether similar abnormalities are present within a more representative clinical sample, including individuals with first episode MDD. Additionally, one limitation of the current study is the somewhat divergent distribution of gender between the MDD and the control groups, particularly in light of evidence that men and women differ in their patterns of reactivity to negative stimuli.[59] The interaction of LPP magnitude with current MDD status in the current sample did persist after controlling for gender, but it will be important for future studies to examine the extent to which MDD is associated with abnormal reactivity independent of other group or demographic differences. Overall, the LPP appears to be an effective measure for detecting abnormal neural processing of emotional stimuli in depression, and this approach appears useful for further refining our understanding of emotion-related abnormalities that characterize MDD.

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