THESIS

ATTENTIONAL BIASES AND TIME COURSE OF

EMOTION PROCESSING IN DEPRESSION

Submitted by

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In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Summer 2014

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ABSTRACT

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Depressive mood is associated with differential patterns in emotion processing, but it is unclear which stages of processing differ in depressed individuals. The current study explored the nature of biases in early vs. late components of attention. Experiment 1 examined attention biases in orienting to and disengaging from positive and negative emotional stimuli behaviorally. Depressed participants presented greater overall biases than controls in the dot-discrimination but not in the dot-detection task. Positive and negative affect were associated with greater orienting bias and reduced disengaging bias for happy faces in the detection task and smaller bias for happy faces and greater for sad faces in the discrimination task.

Experiment 2 explored differences in the time course of emotion processing, with focus on early P3 component differences during implicit and explicit processing. Results showed greater P3 for happy than neutral trials over midline frontal electrodes and the opposite pattern over parietal electrodes in depressed but not control participants during implicit processing. P3 was slower in depressed than controls during explicit processing over lateral sites. Midline electrodes showed slower P3 for happy than neutral during implicit processing and for sad than neutral during explicit, independent of group. Results suggest the presence of attentional biases in depressed individuals independent of emotion. These biases might be better reflected during intentional than incidental emotion processing. Future study is needed to fully understand the relationship of emotion processing for different degrees of depressive symptoms, emotions, and with regard to other modalities of intention in emotion processing.

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INTRODUCTION

Major Depressive Disorder (MDD) has a lifetime prevalence of 17% in the United States (Andrade, et al., 2003) and it represents the largest source of disability-adjusted life years[1] globally within mental and behavioral disorders (Murray, et al., 2012). Prevalence of MDD in late adolescents and young adults is 8.2-8.4%, independent of their college attendance status (Substance Abuse and Mental Health Services Administration, 2012). While awareness has led to increased acceptance of depression as a real, biological (and not "mental") disorder and to improvements in diagnosis—Murray, et al. (2012) found a 38% increase in disability-adjusted life years between 1990 and 2000—, the cognitive processes associated with symptoms of depression are not yet fully understood.

Behavioral Measures of Emotion Processing

Diathesis-stress models propose that depression results from the interaction between predisposing biological and cognitive factors and exposure to stressful events (McGuffin, Katz, & Bebbington, 1988; Robins & Block, 1989; Ingram & Luxton, 2005; Blanchette & Richards, 2010). In other words, factors such as genetics, individual variations in neurotransmission and brain activity, and learned or biologically-determined cognitive styles result in a different likelihood for each individual to

[1] Disability-adjusted life years (DALYs) represents years of life lost due to premature mortality and years lived with disability (Murray, et al., 2012)

develop MDD. This predisposition does not result in depression until triggered by negative or stressful life events (Ingram & Luxton, 2005), however. Stressors which lead to the manifestation of MDD can range from the cumulative effect of minor events to the single occurrence of a major negative event in the individual's life.

The importance of this interaction is underscored by the fact that individual differences in cognition and emotion may affect the way in which stressful events are perceived and hence how they affect the individual's emotional state. In fact, a prevalent model stemming from schema theory posits that individuals with MDD possess a negative schema that affects how emotional information is processed. This is reflected as biases in perception, attention, memory, and reasoning related to negative emotional information (Beck, 1976; Beck, Brown, Steer, Eidelson, & Riskind, 1987). Results from mood induction studies have provided further evidence for a role of negative mood as a schema in emotion processing; these biases are also present when negative mood induced in the lab, independent of diagnosis of depression (Bower, 1981; Oaksford, Morris, Becki, & Williams, 1996; Pham, 2007; Blanchette & Richards, 2010).

Depressed individuals present biases in memory and reasoning during emotion processing, providing further evidence for a relationship between depression and differential processing during the later stages of emotion processing (Deldin, Keller, Gergen, & Miller, 2000; Deldin, Keller, Gergen, & Miller, 2001. Deldin, Keller, Gergen, and Miller (2000) presented depressed and non-depressed participants with a study list of positive, negative, and neutral words. Controls showed increased recognition of previously-seen positive items compared to negative and neutral, accompanied by temporal differences as measured by event-related potentials (ERPs). Specifically, P300 component amplitude was greater during encoding and smaller during recognition compared to other stimulus types in controls but not in depressed individuals. This component consists of a positive peak occurring between 200-400ms and is associated with attention allocation and stimulus discrimination.

Naranjo, et al. (2011) found depressed may have difficulties in the identification of emotional prosody, as reflected by lower accuracy in emotion identification for positive (peaceful and happy) music; and sad, happy, and interested expressions (Rubinow & Post, 1992). These processing patterns might also affect non- emotional stimuli in the presence of emotional ones, as shown by lower recall for neutral compared to happy and sad faces in depressed individuals (Leppanen, Milders, Bell, Terriere, & Hietanen, 2004).

Processing biases are also manifested as increased sensitivity to emotional cues, such that emotionality is attributed to neutral stimuli (faces) more often by depressed than control individuals (Naranjo, et al. 2011) and already-emotional stimuli (sad, angry, and scary musical excerpts, vocal sounds, and facial expressions) are perceived as more intense by depressed individuals. A possible explanation for these effects in later stages is the presence of rumination, a maladaptive type of processing common to MDD characterized by repetitive, intrusive, negatively-focused thoughts. Rumination is associated with the interpretation of ambiguous emotional stimuli as negative (Raes, Hermans, & Williams, 2006), which can further contribute to the depressed mood. In fact, this relationship might be mediated by sustained amygdalar activity during valence identification of negative (but not positive or neutral) stimuli found in depressed individuals that persists beyond the duration of the emotion discrimination task (Siegle, Steinhauer, Thase, Stenger, & Carter, 2002).

In short, research suggests that depression is associated with the absence of positive biases and presence of negative biases with regards to memory (as measured by item recall and recognition) and post-stimulus reasoning (how it is interpreted and “thought about”. The literature is still inconclusive on whether these biases are also seen in perception and attention of emotional stimuli, the earlier, more automatic stages of processing. In fact, (Posner & Petersen, 1990)proposed that attention is divided into orienting toward stimuli (which could be considered a portion of perception) and disengaging from stimuli. This model proved valuable for research into attention biases in anxiety: Salemink, van den Hout, and Kindt (2007) evaluated compared reaction time (RT) to threat-related and neutral words in a dot-probe task and found that anxiety symptoms were associated with a greater difficulty disengaging from threat words in the presence of neutral words, but not by greater initial orienting toward threat words. The authors rejected bias scores traditionally used in this type of research for being too broad; a positive index (bias) score could result from either a faster reaction time for the emotionally-cued targets (orienting bias) or from a slowed reaction time for the neutrally-cued targets (disengaging bias).

It is yet to be established whether behavioral differences in reaction time (RT) in depression reflect differences in orienting or disengagement. The dot-probe task consists of a pair of stimuli from different categories (e.g., positive vs. neutral emotions, low vs. high-arousal, addiction-related vs. not, etc.) presented on the screen, followed by a dot in the same position replacing one of the two stimuli; participants are instructed to press a key as soon as they see the dot. This task examines attention allocation to each category by comparing reaction times to target dots cued by each different category. For example, in neutral valence-negative valence comparison pairs, faster RT when dot position is cued by negative than neutral stimuli (negative-congruent) indicates a bias toward the negative stimuli, while a RT slower for negative-incongruent suggests a bias away from the negative stimuli.

The dot-probe task has reliably identified attentional biases in anxiety for threat-related stimuli and in substance use disorders for substance-related stimuli (MacLeod, Mathews, & Tata, 1986; Stormark, Nordby, & Hugdahl, 1995; Li, Li, & Luo, 2005), but evidence for its use in depression research remains inconclusive. Bradley, Mogg, and Lee (1997) evaluated the presence of biases for depression-related, anxiety-related, and neutral words in induced and naturally-occurring dysphoria in the dot-detection task. They found individuals with depression showed vigilance for depression-related words when presented for 500 and 1000ms but not during masked presentation (14*ms*). Similarly, Gotlib, Krasnoperova, Yue, and Joorman (2004 found a bias in individuals with depression toward sad faces compared to angry and happy faces when they were presented for 1000ms.

Several versions of this task have been used, with no specific merits attributed to each version. Salemink, et al. (2007) compared the usefulness of two different versions for the assessment of biases in anxious individuals: a differentiation version in which participants indicated whether one or two dots had appeared on the screen, and a detection task in which they simply indicated the position of a single dot on the screen. Their results suggested the detection version to be superior in detecting biases in individuals with anxiety. However, the two versions have not been compared in individuals with depression.

Temporal Dynamics of Emotion Processing

As previously mentioned, neuroimaging methods have established a relationship between mood and brain functioning during emotion processing (EEG: Deldin, et al., 2001; functional Magnetic Resonance Imaging: Siegle, et al., 2002). Electroencephalography has a temporal resolution in the milliseconds and thus provides a good avenue for the investigation early stages of emotion processing; it allows for the examination of events occurring within 50ms of stimulus presentation. This approach results from scalp measurements of voltage changes elicited by the summated firing of cortical neurons. This activity is averaged and time-locked to a specific event (e.g., presentation of an image of a happy face), resulting in an event-related potential (ERP) which depicts the time course of cortical activity following that specific event as a waveform. ERPs are compared across groups, conditions, and even individuals to examine whether processing of different types of information diverges at different points in time.

Recurring patterns of ERPs associated with specific cognitive processes are referred to as ERP components, characterized by the amplitude of the waveform at a specific point in time. The P3 component, associated with task-relevant stimulus evaluation and attention allocation (Polich & Comerchero, 2003), has been associated with emotion processing. It appears to be slower and smaller over midline electrodes in depressed individuals in response to happy faces during emotion discrimination

(Cavanagh & Geisler, 2006). In another study, depressed individuals had a smaller P3 overall, along with a larger early P3 (330ms) and no increase in late P3 (460ms) for negative stimuli, an effect controls did show (Kayser, Bruder, Tenke, Stewart, & Quitkin, 2000). Bruder, et al. (1991, 1992) found no differences between individuals with depression, atypical depression (no lack of reactivity or anhedonia), and controls in P3 amplitude, but did find depressed to have a slower P3 than atypical depressed and controls, as well as longer P3 latency to auditory stimuli presented to the right hemifield, a laterality effect that controls and atypical depressed did not show. An opposite pattern was suggested by Pierson, et al. (1996), finding a faster and larger P3b in anxious-agitated patients compared to controls and blunted-affect patients.

In the examination of processing of emotional expression, it is important to distinguish among different levels of processing of the presented stimuli. Rellecke, Sommer, and Schact (2012) found that the late positive complex (LPC, occurring 400-600ms after stimulus onset) had greater amplitude for angry relative to neutral facial expressions but only during explicit emotional discrimination. Further, it had a higher amplitude in the deep processing condition (gender and emotion discriminations) than during superficial processing (word-face discrimination). While the authors did not conduct analyses on the P3, research suggests this component is also sensitive to current task demands: a task which focused participants' attention on identifying the presented emotions found greater P3 for neutral than positive and negative faces (Vanderploeg, Brown, & Marsh, 1987). In contrast, P3 amplitude is greater over the right hemisphere during discrimination between emotional and neutral faces but is more symmetrical during a comparison task (Johnston, Miller, & Burleson, 1986; Mini, Palomba, Angrilli, & Bravi, 1996; Laurian, Bader, Lanares, & Oros, 1991; Stormark, Nordby, & Hugdahl, 1995; Schapkin, Gusev, & Kuhl, 2000).

The current study aims to assess behavioral and electrophysiological differences in emotion processing between individuals with and without subclinical depression symptoms (Depressed and Control groups). Using a dot-probe task, Experiment 1 sought to explore whether individuals with subclinical depression symptoms presented differential patterns from controls in orienting to and disengaging from positive and negative emotional stimuli. The experimenter hypothesized that individuals in the Depressed group would present a smaller orienting index toward happy faces in happy-neutral trials, indicative of a lack of faster responses to dots appearing after happy faces, and a larger disengaging index toward sad faces in sad-neutral trials, reflected as slower responses to neutral faces in the presence of sad faces. No between group differences are expected regarding orienting index toward sad faces and disengaging index from happy faces.

Further, the effects of intentionality on P3 amplitude and latency during emotion processing have yet to be established in individuals with depression compared to controls. Using ERPs, experiment 2 examined the time course in early stages of processing with a focus on the relationship between intentionality and differences in P3 component amplitude and latency between depressed individuals and controls. The experimenter hypothesized that Depressed individuals would present a slower (longer latency) and lower (smaller amplitude) P3 component in response to happy faces and a lower P3 for negative stimuli. It was also hypothesized that these between-group differences, if present, would be more apparent in the explicit than in the implicit condition.

CHAPTER

Experiment 1

Method

Participants

One hundred and nine undergraduate students received course credit for their participation in this study; twenty-five were excluded due to errors in data collection. The 84 remaining participants (61 female) ranged between 18 and 28 years of age (M=19.91, SD=2.03) and included 77 right-handed individuals. All participants provided written consent and had normal or corrected-to-normal vision and no history of neurological impairments.

Materials

Stimuli

Cues for the dot-probe task consisted of twenty faces selected from the Radboud Faces Database (Langner, et al., 2010) to include equal amounts of male and female faces with happy, neutral, and sad emotional expressions (Figure 1a). Images were selected for the ten subjects within each sex with highest rated clarity of emotional expressions and consensus for all three emotions (validation information from Langner, et al., 2012). Mean percent agreement, intensity, clarity, genuineness, and valence ratings for selected image subset is presented in Table 1. Images were modified (GNU Image Manipulation Program) to a black background, grayscale, and dimensions of 220x300 pixels (visual angle: 3.70° x 5.05°). Happy-neutral, sad-neutral, happy-sad, and neutral-neutral expressions from each subject were then combined to create 70 side-by-side face pairs.

Center for Epidemiological Studies Depression Scales

The CES-D (Radloff, 1977) consists of 20 items (Appendix A) assessing the extent to which an individual experienced depressive symptoms in the previous week. Items are scored from 0 (rarely or none of the time) to 3 (most or all of the time) for a total range of 0-60 points on the scale, where a score of 16 or more suggests significant depressive symptoms were experienced (Radloff, 1977). Based on this cutoff score, participants were assigned to a Control (<16) or Depressed (≥16).

Positive and Negative Affect Schedules

The PANAS assess positive and negative mood experienced during a specific timeframe (Watson, Clark, & Tellegen, 1988). Individuals indicated from 1 (very slightly or not at all) to 5 (extremely) how much they felt each of 20 items at the moment (Appendix), resulting in separate positive and negative affect scores ranging from 10-50 in which higher scores represent higher levels of affect.

Procedure

Participants provided informed consent and completed a demographics questionnaire, the CES-D, and the PANAS. The dot-probe task was completed in a sound-attenuated room on a Windows computer at a viewing distance of 90cm. Task trials (Figure 1b) consisted of a fixation cross (1500milliseconds) centered on the screen, followed by an interstimulus interval (500ms), a face pair (each face centered in its corresponding half of the screen) with a centered fixation cross (1000ms), and a red dot (100ms with response-to-stimulus interval of 1500ms). Four trial types were created for each face pair based on congruency and hemifield of presentation: e.g., a happy-neutral pair resulted in HAPPY-neutral—where caps indicate the emotion cueing the dot target—, happy-NEUTRAL, neutral-HAPPY, and NEUTRAL-happy trials. One hundred and forty trials were presented in two fully-randomized blocks; each started with experiment instructions, four practice trials without faces, six practice trials with faces, and 140 experiment trials with an intertrial interval of 1500ms.

The two blocks consisted of Detection and Discrimination variations of the dot-probe task. During Detection participants were instructed to press a key with their left or right index finger (counterbalanced across participants) as quickly and accurately as possible every time a red dot appeared on the screen, while during Discrimination participants had to press a key with left or right index fingers to indicate on which side of the screen the dot appeared, left or right.

Data Analysis

Differences in age and PANAS scores between the two groups were examined using independent t-tests. Overall reaction times (RT) were analyzed in a repeated-measures ANOVA with 2 Group (Control, Depressed) as between-subjects factor and 2 Emotion (Happy, Sad) and 2 Congruency (Congruent, -Incongruent) as within-subjects factors. Bias scores were calculated following Salemink et al. (2007) by calculating an orienting index,

Orienting index = dN,N – dX, N;

where dN, N refers to RT to dots replacing neutral expressions in the presence of other neutral expressions and dX, N refers to RT to dots replacing comparison expressions (X = happy or sad) in the presence of other neutral expressions; and a disengaging index,

Disengaging index = dN,X – dN, N;

where dN,X refers to dots replacing neutral expressions in the presence of comparison expressions (X = happy or sad). More negative orienting scores indicate faster RT for dots cued by the corresponding emotion (orienting bias) and more positive disengaging scores indicate slower RT for dots miscued (presented in the opposite location) by the corresponding emotion (disengaging bias).

Mixed-model, repeated measures analyses tested Group and Emotion as predictors of Bias Scores with likelihood ratio tests to identify the best-fit model for each type of task. Type of Index was entered as a covariate to examine the possible dissociation between Orienting and disengaging stages of attention (Posner & Petersen, 1990) suggested by Salemink, et al.'s (2007) anxiety research. Between-group differences in positive and negative affect associated with depressive mood were tested and entered as a second covariate. Significant effects were determined at $\alpha=0.05$.

Results

Independent t-tests showed no significant differences in age or reaction time between the Control and Depressed groups, $t(86)=-1.126$, $p>.05$. The Depressed group scored higher in negative affect, $t(86)=-4.868$, $p<.05$, and lower in positive affect, $t(56)=2.308$, $p<.05$. Group means and standard deviations are presented on Table 2. Further analyses of reaction time by group, emotion, and congruency (Figure 2) showed no significant main effects or interactions on reaction time (Table 3).

Detection Task

The best-fit model, $\chi2(14)= 13.739$ (Table 4), did not identify any significant predictors. There was a trend of Index Type*Emotion*Positive PANAS interaction, $F(1,220)=3.489$, $p=.063$, which predicted higher positive affect to be associated with a greater orienting bias toward Happy faces and reduced disengaging bias from Happy faces (Figure 3).

Discrimination Task

The best-fit model, $\chi2(12)= 44.128$, included all predictors and covariates as well as a significant quadratic effects of Positive and Negative Affect scores (Table 5). A Group*Index Type interaction suggested greater differences in Orienting and Disengaging bias scores in Depressed than Controls, $F(1,352)=30.332$, $p<.05$ (Figure 4a). Holding Group constant, this model predicted direct relationships between Negative Affect and disengaging biases, $F(1,352)=3.911$, $p<.05$ (Figure 4b), and between Positive Affect and Orienting biases, $F(1,352)=12.097$, $p<.05$ (Figure 5c). Finally, a significant Group*Emotion*PANAS Positive interaction, $F(1,352)=20.948$, $p<.05$ (Figure 5c), suggested PANAS Positive Affect to be associated with greater biases for Sad faces and smaller for Happy faces in Depressed than Controls.

Discussion

Experiment 1 explored the nature of attention biases in individuals who experienced a depressive mood in the previous week. Two different versions of the dot-probe task were used to examine biases in orienting to and disengaging from positive and negative stimuli as compared to neutral stimuli (happy, sad, and neutral faces, respectively). The results of the first task, in which participants were asked to detect a target cued by face pairs, did not support the hypothesis on group differences in orienting or disengaging biases for either emotion. It appears that attention to emotional stimuli cueing a target does not differ by emotion when simple detection of the target is required. In contrast, bias scores during discrimination reflected greater biases in depressed than control participants more strongly reflected in disengaging than orienting attention. These biases favored processing of both positive and negative stimuli, opposite from the direction hypothesized. Results are in agreement with previous research suggesting that biases in depressed individuals are only present for longer presentation times, a feature absent in the detection task and more closely associated with the later disengagement of attention stage than quick, initial orienting (Bradley, Mogg, & Lee, 1997; Gotlib, Krasnoperova, Yue, & Joorman, 2004).

While the detection task is superior to the discrimination task in establishing the presence of attention biases in anxiety disorders (Salemink, van den Hout, & Kindt, 2007), the current study proposes that the opposite is true of depression, with greater sensitivity to biases found in the discrimination task. Moreover, while Salemink et al. (2007) only encountered differences in disengaging in anxious individuals, biases in depressed individuals involve both orienting and disengaging stages of attention to emotional stimuli. The presence of biases demonstrated by this experiment is in disagreement with Bradley, Mogg, and Lee (1997), who found no presence of biases for negative words in depressed individuals. However, their study did not use specific bias score calculations but rather mean reaction time comparisons. Further, the authors reported that a group of depressed individuals in a mood induction procedure within the same study did present overall biases for depression-related words during a discrimination task, providing further support for the results suggesting that state affect may interact with depressive status in showing attention biases. Finally, despite the inclusion of positive words in the experiment, the authors did not examine or report the presence of biases regarding this type of stimuli in their participants.

Contrary to the presented results, another study reported biases for sad but not for happy faces in depressed individuals compared to controls on a dot discrimination task (Gotlib, Krasnoperova, Yue, & Joorman, 2004). The group of depressed participants in Gotlib et al. (2004) was composed of individuals with a clinical diagnosis of major depressive disorder, which might underlie the differences in results between the two studies. It is possible that the patterns demonstrated by individuals with a diagnosis of depression, which is often a persistent depressive mood lasting well over 2 weeks, are different from those presented by individuals who find themselves in a transient depressive state, as was the case in this study where participants were only asked about their symptoms in the preceding week. Further, the attention bias calculated in their study consisted of a traditional bias score in which emotion-congruent trials are subtracted from emotion-incongruent trials, whereas in the present study bias scores reflect separate comparisons of emotion-congruent and –incongruent trials to neutral trials to examine different components of attention (orienting and disengaging). It is possible that bias scores compared to a neutral emotion are more sensitive to differences in reaction than those resulting from comparisons within the same emotions.

Results also suggested that positive affect appeared to have a greater effect than depressive mood as well as an interaction with it affecting the presence of attention biases. During detection higher positive affect at the time of the experiment triggered biases in processing happy faces in both groups and accentuated bias differences for happy and sad faces between groups. Further, higher positive and negative affect were associated with greater bias indexes, independent of index type and emotion. This is consistent with results from mood induction studies, with induced affect resulting in differential processing of mood-congruent and mood-incongruent information (Smith, et al., 2006; Bower, 1981; Blanchette & Richards, 2010; Oaksford, Morris, Becki, & Williams, 1996; Pham, 2007; Schmid & Mast, 2010). Research into the positivity bias—a tendency to process positive emotional information preferentially compared to negative or neutral information— suggests a mechanism for this in which just as negative moods can lead to negative biases which trigger more negative moods in a loop, positive moods can trigger an “upward spiral” in which positive emotions increase processing of positive information, increasing emotional well-being (Fredrickson & Joiner, 2002). In short, it appears that not only are depressive symptoms associated with a predisposition to process emotional information differently, but symptoms and predispositions may further interact with state affect, leading to greater individual differences that may be affected by environmental variables in the nature of depression.

Experiment 2

Method

Participants

Thirty-six undergraduate students (20 female) who completed Experiment 1 also participated in Experiment 2. This subset of participants ranged between 18 and 28 years of age (M=20.12, SD=2.637).

Materials

Stimuli

Images of 20 subjects (10 female) depicting Happy, Sad, and Neutral expressions were obtained from the NimStim face database (Tottenham, et al., 2009). The 60 images were edited to grayscale with a black oval mask (to obscure the hair), and dimensions of 210x270 pixels (visual angle: 3.536° x 4.546°).

The CES-D and PANAS, discussed in Experiment 1 Method section, were also used in this experiment to assess depression symptoms and state affect.

Procedure

Participants were fitted with a 64-electrode QuikCap with Ag/AgCl electrodes (NeuroScan) before completing the emotion processing tasks in a sound-attenuated room at a viewing distance of 90cm. Participants' attention was manipulated by instructing them to make a Gender judgment (Implicit emotion processing) or an Emotion judgment (Explicit emotion processing) on each trial, which they indicated by way of a key press. Task instructions were counterbalanced for each emotion, such that half of the images were assigned to explicit processing on the first block and to implicit processing on the second, and vice versa. At the beginning of each trial—shown on Figure 5—, the prompt (Implicit or Explicit; 2000ms) was followed by an inter-stimulus interval (1500ms) and a fixation cross (1000ms). Then an image (Happy, Sad, or Neutral) was shown for 2000ms and after an inter-stimulus interval of 1000ms the subject was prompted and allowed 2000ms to make the corresponding judgment (Gender or Emotion).

EEG Acquisition

EEG was recorded from 19 electrodes (Fp1, Fp2, F3, F7, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, and O2) placed according to the 10-20 system (Figure 6) on a 64-electrode QuikCap with Ag/AgCl electrodes (NeuroScan). . Signals were recorded at a sampling rate of 500Hz and amplified with a band pass of .10-50Hz with the vertex was as initial online reference. Horizontal electrooculogram was monitored with electrodes placed on the outer canthi of the left and right eyes. Impedances were kept below 11Ωin epochs from -200 to 800ms.

Data Analysis

Mean age and PANAS scores were compared in independent t-tests with $\alpha = .05$. Mean reaction times on this task were examined in mixed-model, repeated measures analyses with Group (Control, Depressed), Task (Implicit, Explicit), and Emotion (Happy, Sad, Neutral) as predictors. Likelihood ratio tests with $\alpha=0.05$ were used to identify the best-fit model.

EEG data was digitally filtered (.1-30 Hz), segmented into epochs ranging from 200ms before stimulus onset to 800ms after stimulus onset, baseline corrected, and re-referenced to the common average. Epochs with amplitudes exceeding -100 or

+100 μV were rejected. Group (Depressed, Control), Caudality (Frontal, Central, Parietal), and Emotion (Neutral, Happy, Sad) were tested as predictors of P3 baseline-to-peak amplitude (200-400ms) and latency (peak onset) in mixed-model, repeated measures analyses with likelihood ratio test to find the best-fit model. Separate analyses were conducted for Implicit and Explicit tasks and for Global (electrode pairs F3/F4, C3/C4, P3/P4) and Midline (Fz, Cz, Pz) effects electrode groups. Global analyses also included Hemisphere (Left, Right) as a predictor variable.

Results

Group means and standard deviations are shown on Table 6. There were no between-group differences in age, $t(28)=-1.294$, $p>.05$, or current negative affect, $t(26)=-0.982$, $p>.05$. The Depressed group scored higher in current positive affect, $t(26)= 2.734$, $p<.05$.

Reaction Time

Descriptives for reaction time are presented on Table 7. The best-fit model, $\chi2(7)=73.331$ (Table 8), predicted a reaction time 95.255ms (41.883ms) faster for Sad than Happy faces. A main effect of Group approached significance, $F(1,30)=3.789$, $p=.061$, predicting reaction time 256.703ms (131.884ms) shorter for depressed than non-depressed individuals. A main effect of Neutral emotion also approached significance, $F(1,111)=3.627$, $p=.059$, predicting a reaction time 81.192ms (42.792ms) shorter for Neutral than Happy trials (Figure 7).

P3 Amplitude

ERP waveforms for global and midline effects over central and parietal electrodes are shown on Figures 8-10.

Global Effects

The best-fit model, $\chi 2(25)=57.81$ (Table 9), predicted an effect of Electrode of smaller P3 amplitudes 4.539 μV (0.793) over frontal than parietal, $F(1,514)=32.801$, $p<.05$, and possibly 1.493 μV (0.793) smaller than central electrodes, $F(1,514)=3.549$, $p=.06$ (ns) during Implicit processing. The model for explicit processing, $\chi 2(25)=54.963$ (Table 9), was similarly associated with P3 amplitude 3.564μV smaller over frontal than parietal electrodes, $F(1,514)=3.605$ $p<.05$ (Figure 11).

Midline Effects

The best-fit model for implicit processing, $\chi 2(12)=40.767$ (Table 10), predicted P3 amplitude 0.539 μV (0.793) greater over parietal than frontal electrodes, $F(1,240)=14.928$, $p<.05$, and a significant Group*Emotion interaction, $F(1,240)=7.856$, $p<.05$, associated with greater P3 amplitude by 4.279μV (1.527) Happy than Neutral faces, holding Group constant. Significant interactions predicted P3 amplitude 4.925μV (2.159) smaller for Cz than Fz, $F(1,240)=5.201$, $p<.05$, and 5.874μV (2.159) smaller for Pz than Fz, $F(1,240)=7.398$, $p<.05$, holding Group and Emotion constant (Figure 12). The best-fit model for explicit processing, $\chi 2(12)=43.205$ (Table 10), yielded no significant main effects or interactions.

P3 Latency

Global Effects

The best-fit model, $\chi 2(25)=235.894$ (Table 11), identified an effect of Caudality was associated with P3 latency 43.104ms (18.686) greater over Central than Frontal electrodes, $t(514)=2.307$ $p<.05$ and 39.909ms (18.686) greater over Parietal than Frontal. Holding Group constant, suggested shorter P3 latency by 60.909*ms* (28.836) was predicted for parietal than frontal electrodes, $F(1,514)=-2.112$, $p<.05$. Emotion, $F(1,514)=2.136$ $p<.05$, was associated with slower P3 for Happy than Neutral trials by 40.282ms (18.686), $F(1,514)=2.156$ $p<.05$. Holding Group constant, P3 was slower 71.703ms (28.836) for Happy than Neutral, $F(1,514)=-2.487$, $p<.05$; and holding Emotion constant Frontal electrodes predicted longer P3 latency than Central electrodes by 74.341ms (25.647) $F(1,514)=-2.899$, $p<.05$, and possibly than Parietal electrodes by 47.506ms (25.647), $F(1,514)=-1.852$, $p=.065$ (ns). Finally, a significant Group*Emotion*Electrode interaction, $F(1,514)=2.313$, $p<.05$, predicted P3 81.691ms (38.317) slower over Central than Frontal electrodes, holding Group and Emotion constant (Figure 13).

The explicit processing best-fit model, $\chi 2(25)= 227.083$ (Table 11), predicted P3 latency 46.261ms (22.769) slower for Depressed than Control, $F(1,467)=2.032$ $p<.05$. A Laterality*Emotion*Electrode interaction approached significance, $F(1,514)=-1.895$, $p=.059$ (ns), such that holding Laterality and Emotion constant, Central electrodes were associated with P3 latency 61.438ms (32.420) greater than Frontal (Figure 14).

Midline Effects

The best-fit model for implicit processing, $\chi 2(12)=111.53$ ~(Table 12), for P3 latency predicted slower P3 by 45.455ms (19.800) for Happy than Neutral trials, $F(1,240)=2.296$, $p<.05$. Holding Emotion constant, Central electrodes were associated with P3 58.636ms (28.002) faster for Central than Frontal electrodes, $F(1,240)=-2.094$ $p<.05$. The best-fit model, $\chi 2(12)=111.614$, suggested slower P3 during Sad than Neutral trials by 40.818ms (20.818), $F(1,240)=2.023$ $p<.05$ (Figure 11).

Discussion

Experiment 2 examined the relationship between intentionality and emotion processing in depressed individuals as reflected by P3 component amplitude and latency. Task instructions guided the participants' attention to non-emotional or emotional features (sex and emotion, respectively) of happy, sad, and neutral faces, corresponding to implicit and explicit emotion processing (Rellecke, et al., 2012). Global effects reflected a larger P3 in parietal than frontal electrodes independent of task, group, and emotion. In contrast, midline electrodes showed effects of emotion during implicit but not explicit processing only in depressed individuals. This was associated with greater P3 for happy than neutral faces frontally and greater for neutral than happy faces parietally. The results do not support initial hypotheses regarding P3 amplitude: that it would be lower in response to happy and sad faces in depressed individuals compared to controls and that the effect would be more marked in implicit than explicit processing. In fact, the only effects of emotion and task present were in the opposite direction from that predicted.

Greater effects of Group and Emotion were found on P3 latency. Over midline electrodes, P3 was faster for neutral than happy expressions frontally during implicit processing and faster than sad expressions explicit processing, with no group differences predicted. Global effects reflected slower P3 for depressed than controls during explicit processing. On the implicit task, depressed individuals had a faster P3 for happy than neutral faces, while this pattern was only present over central electrodes and was reversed over frontal electrodes in controls. While this does not support the hypothesis of greater effects during explicit than implicit processing, it does match in that depressed individuals presented a slowed P3 overall compared to controls.

It is possible that the fully-randomized presentation of the two tasks, in which both blocks contained an equal number of gender and emotion discrimination trials, might have attenuated attention allocation to sex and emotion for both tasks. In an intentionality and emotion processing study with a greater number of conditions, Rellecke, et al. (2012) used a blocked presentation for each type of task in which each block of the experiment consisted of a single type of processing (task). Unfortunately, the authors did not report results regarding the P3 component and thus it is difficult to assess the effect of task design. To establish a better framework of reference for P3 effects in depressed individuals, a follow-up experiment might examine the two types of processing in a blocked design and in a larger sample of non-clinical participants.

Summary and Conclusions

The current study aimed to further our understanding of the cognitive deficits specific to depression, examine the nature of early stages of emotion processing in individuals with depressive symptoms compared to controls, and establish the viability of the dot-probe task and the P300 component in an emotion processing task as predictors of depression. The discrimination version of the dot-probe task was superior in identifying biases in depressed participants in orienting to and disengaging attention from emotional stimuli, independent of valence. Due to the long exposure time of emotional faces used in this study (1000ms), these findings provide further support to the view that differences in emotion processing are reflected in later stages of processing rather than initial arousal and attention to emotional stimuli. It is worth exploring the validity of this task in predicting depression and examining the presence biases for other emotions and other stimulus modalities (music, vocal sounds, and videos). Another critical comparison is within different manifestation of depressive mood: major depressive disorder, dysthymia, and medium- and short-duration depressive moods within the same study. Finally, a longitudinal study would allow for a better understanding on the time course and stability of these biases in depressed and non-depressed individuals: Do they really predate the onset of depressive symptoms, increasing its likelihood? Or do they become "activated" after exposure to stressors? Is it a combination of the two?

Consistent with previous literature, state affect and especially positive affect influenced biases both independently from and concurrent with depressive symptoms

As previously mentioned, mood induction studies have demonstrated that induced mood can influence all stages of emotion processing. However, most studies have established that positive and negative moods have different effects in the patterns which they elicit. It is possible that mood-congruency effects were absent due to the lack of induction of mood; participants were merely asked to report their mood before beginning the task. Another possibility is that the effects of different valence moods are more noticeable in later stages of information processing beyond attention not addressed in this experiment.

Intentionality of emotion processing appeared to have an effect on attention allocation during discrimination; however, this was in a direction opposite to that hypothesized: effects were most apparent during implicit than explicit processing. Differences between groups were mostly evident as interactions between emotion and caudality, as was the case for the greater P3 amplitude of neutral than happy faces only over parietal electrodes in depressed but not control individuals. The time course of processing conformed more to the original hypothesis of larger effects during explicit than implicit emotion processing. Depressed individuals presented slowed P3 for happy faces during implicit processing but slowed for sad faces during explicit; however, the prediction of shorter P3 specifically to happy faces was not supported.

The disagreement between these results and previously reported P3 differences in depressed individuals might be due to a variety of factors. First, the depressed participants in this study were not formally diagnosed with major depressive disorder but rather reported on their symptomatology in the week preceding the experiment. The self-reported depressive symptoms might have reflected transient moods as a result of life events rather than the “causeless” symptoms often observed in depressive disorder. Second, traditional research on the P3 in depression often consists of a single emotion processing task, while this experiment contained two tasks which were interspersed throughout the experiment instead of kept separate. A possibility would be to examine whether block vs. randomized organization of tasks within the experiment result in different P3 amplitude patterns.

In summary, while there were interesting differences in emotion processing associated with depressive mood, most relationships were not precise enough to be viable predictors in determining depression symptoms solely from performance in a task independent from self-report. Additional avenues of exploration have been discussed, including comparisons of a wider variety of emotions and typology of depressive moods and the use of a longitudinal study design. Further analyses will examine other ERP components to establish a more comprehensive description of the nature of emotion processing in depression. If an effective prediction tool were to be established, it would not only enhance the identification of individuals who might be at risk, improving the services that can be provided to them, but it could possibly be used as a tracking tool for improvement with psychotherapy and/or antidepressant treatment.

a)

b)

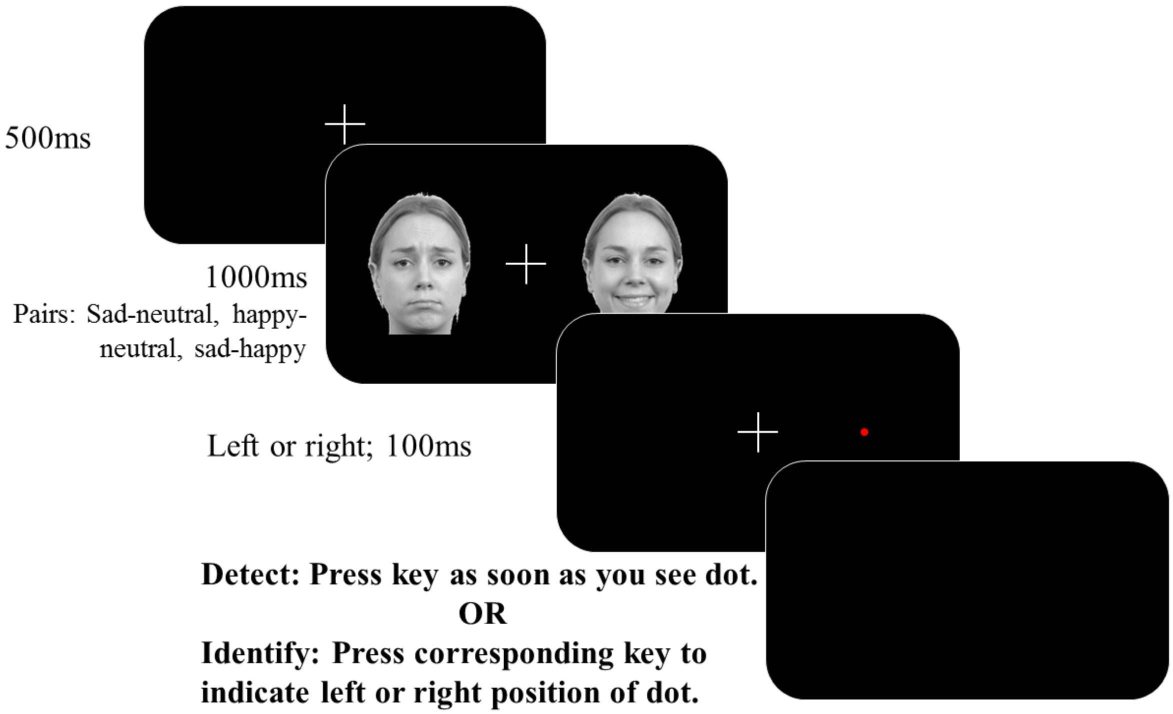


Figure 1. a) Sample happy, sad, and neutral emotional expressions for the same subject (from Radboud Faces Database (Langner, et al., 2010); b) Dot-detection task trials.

a)

b)

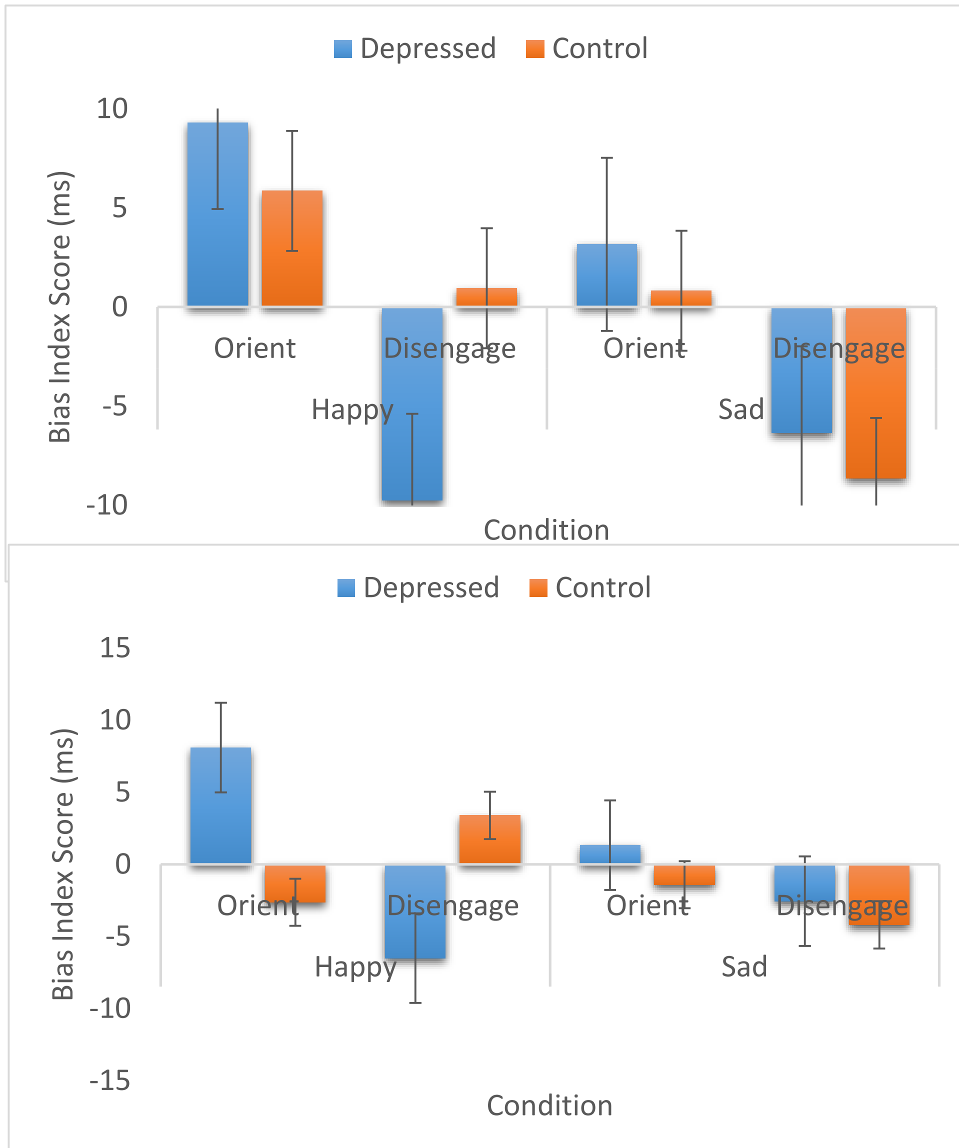


Figure 2. Orienting and Disengaging bias scores for Depressed v. Controls, Happy v. Sad emotions in a) Detection and b) Discrimination tasks.

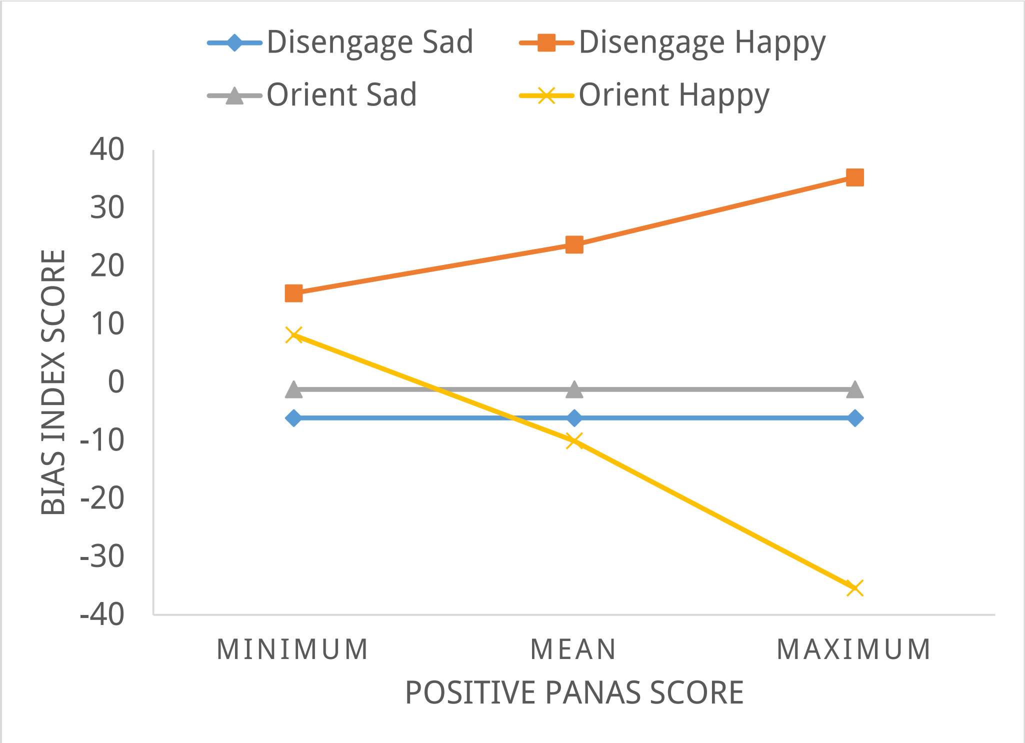
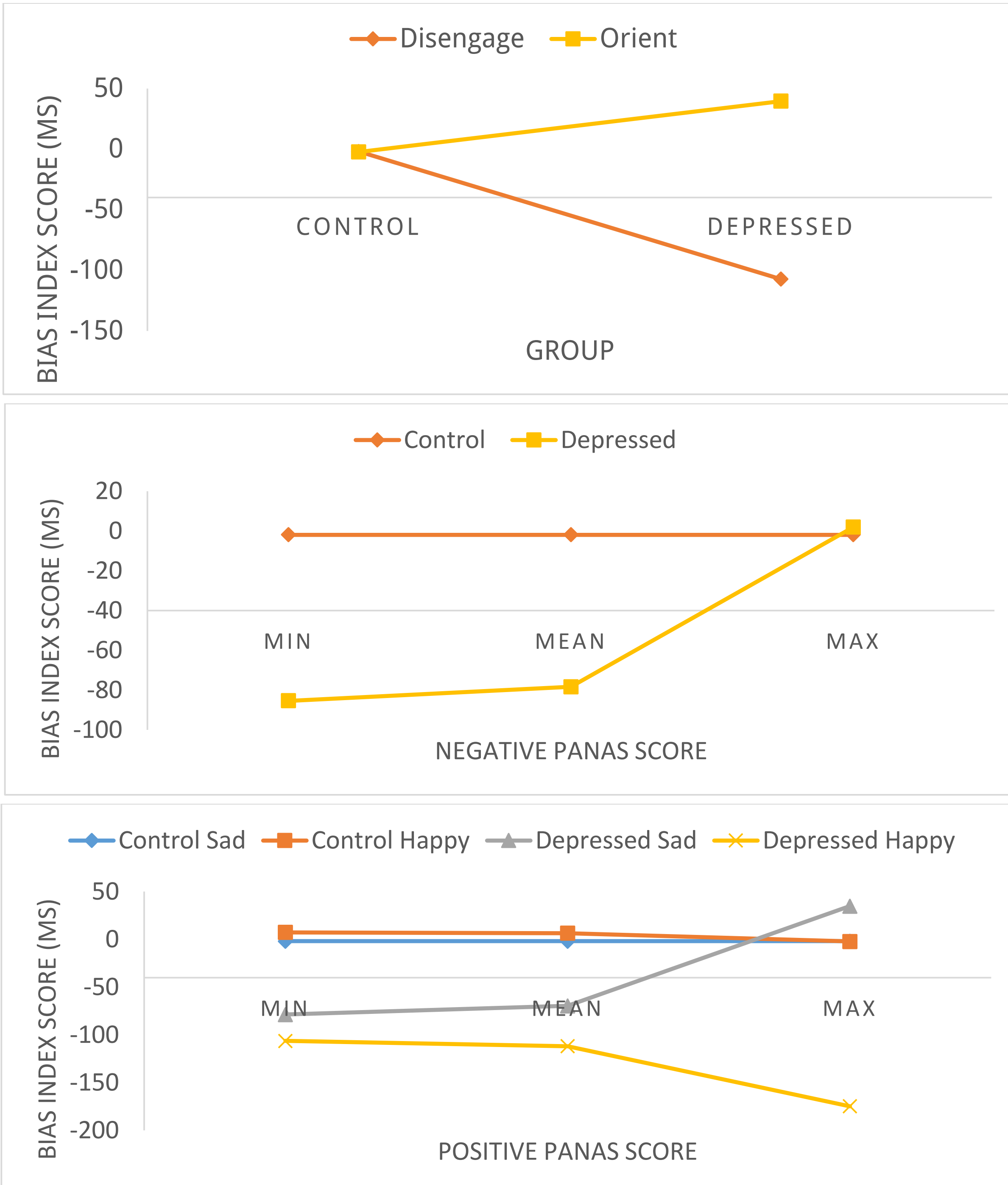


Figure 3. Significant interaction of Index Type, Emotion, and PANAS Positive Affect scores (Min=10, Mean=26.75, Max=50) during Detection Task. Higher index scores represent larger presence of processing bias.



a)
b)
c)

Figure 4. Significant interactions for Index during Discrimination task: a) Group*Index Type, b) Group*PANAS Negative, c) Group*PANAS Positive, and d) Group*Emotion*PANAS Positive. Higher index scores represent larger presence of processing bias.

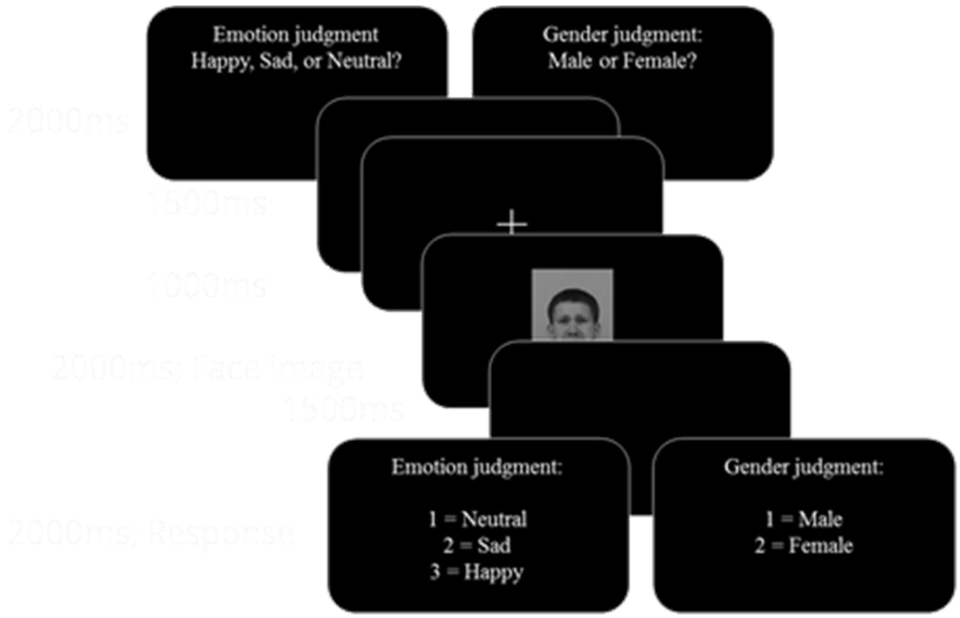


Figure 5. Implicit-explicit emotion processing task trial.

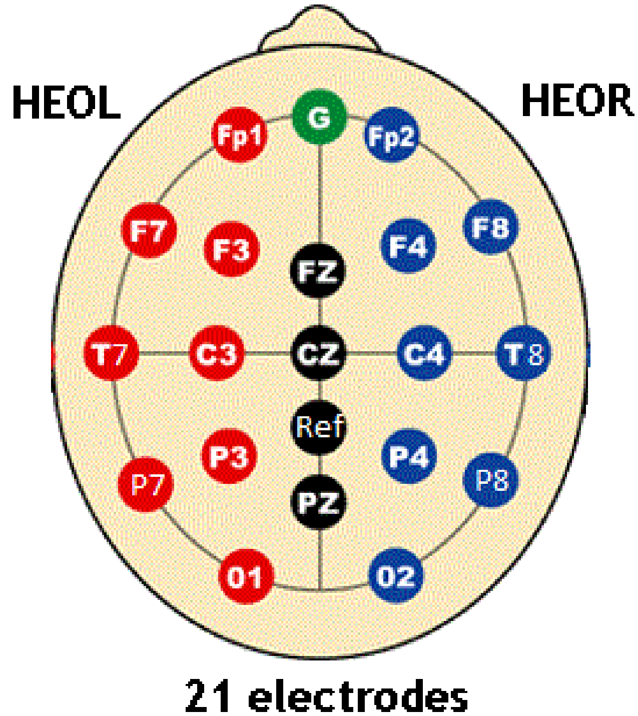


Figure 6. Electrode placement according to 10-20 system depicting electrodes used during EEG acquisition. G = ground electrode, Ref = reference electrode.

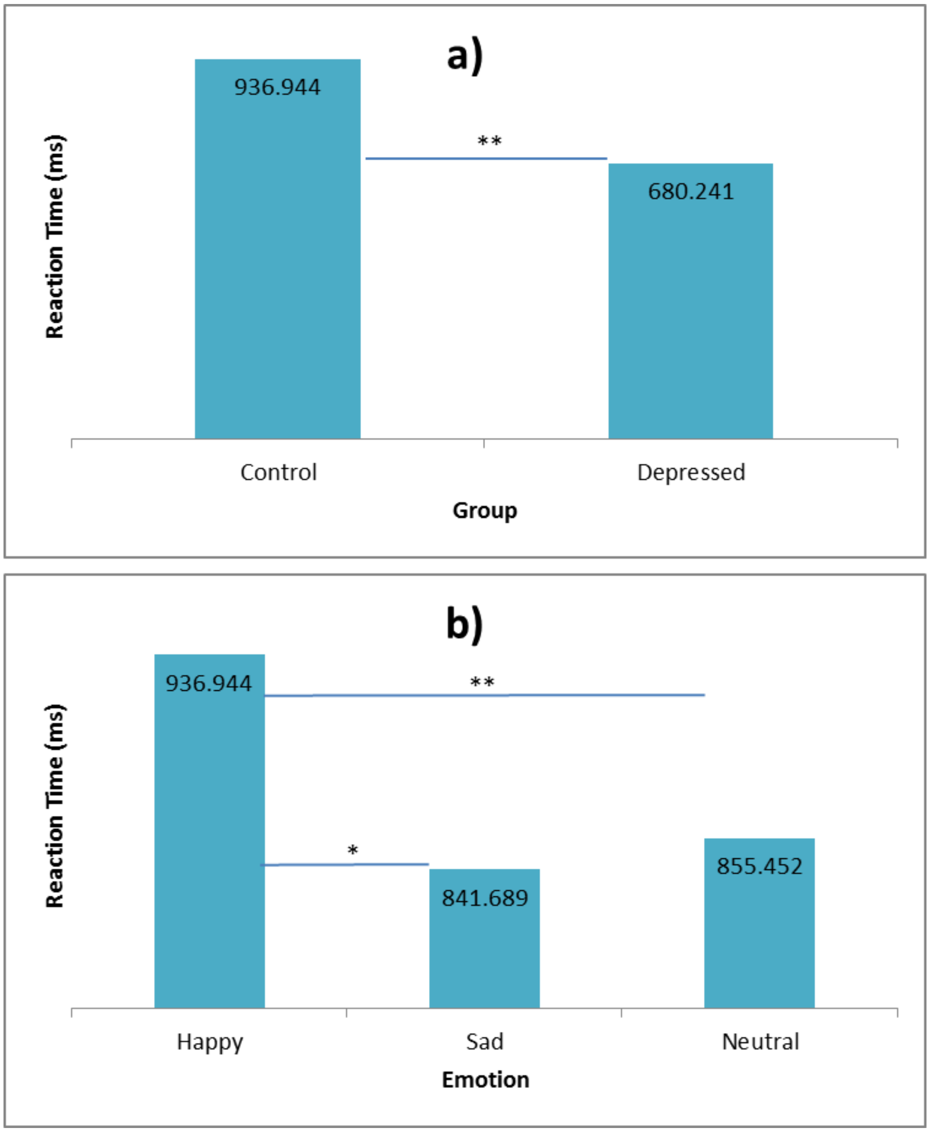


Figure 7. Significant effects of a) Group and b) Emotion on reaction time. *Significant at α=0.05; **trending toward significance (α<.08).

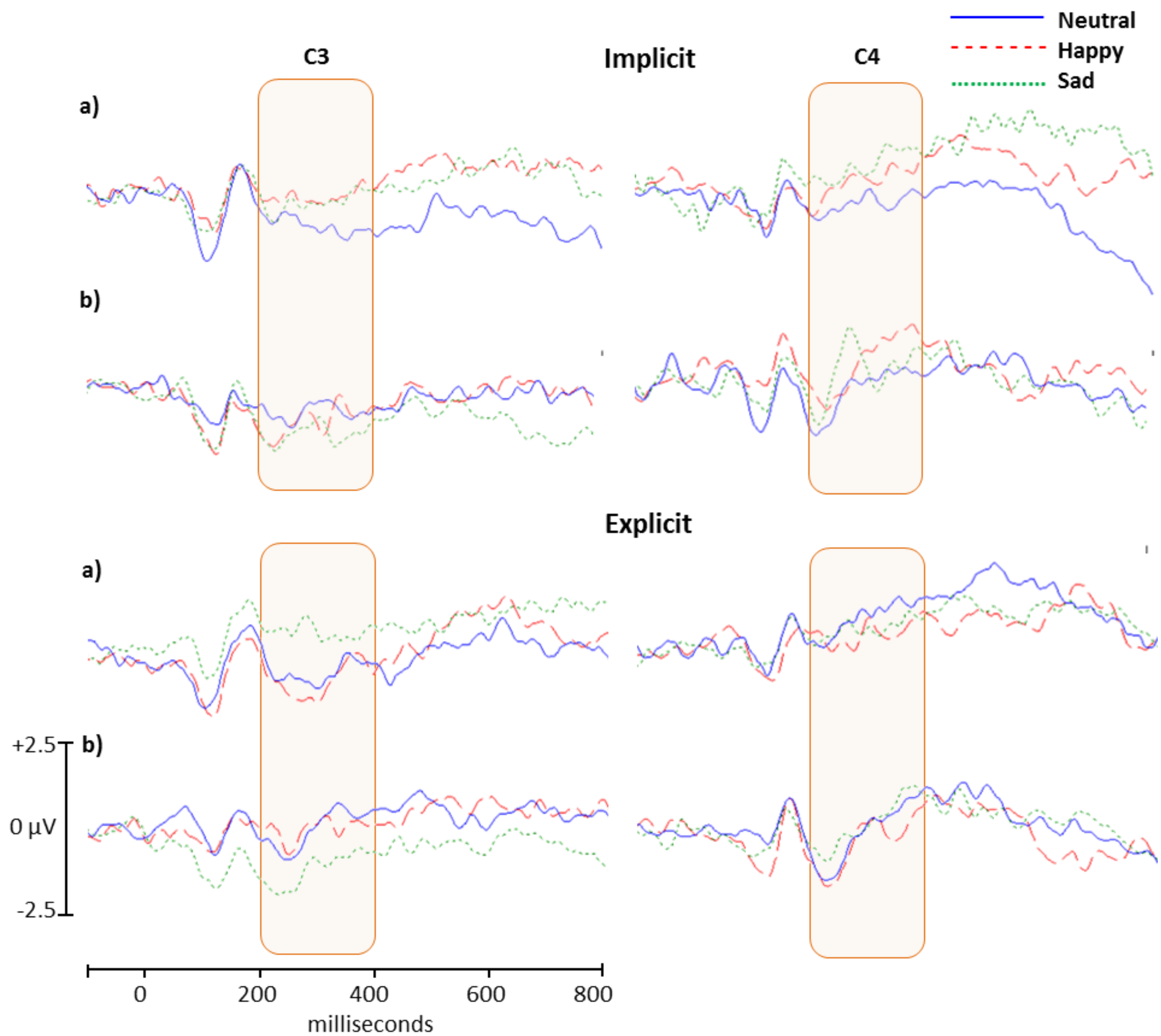


Figure 8. Global ERPs over Central Electrodes for a) Controls and b) Depressed, with P3 area highlighted.

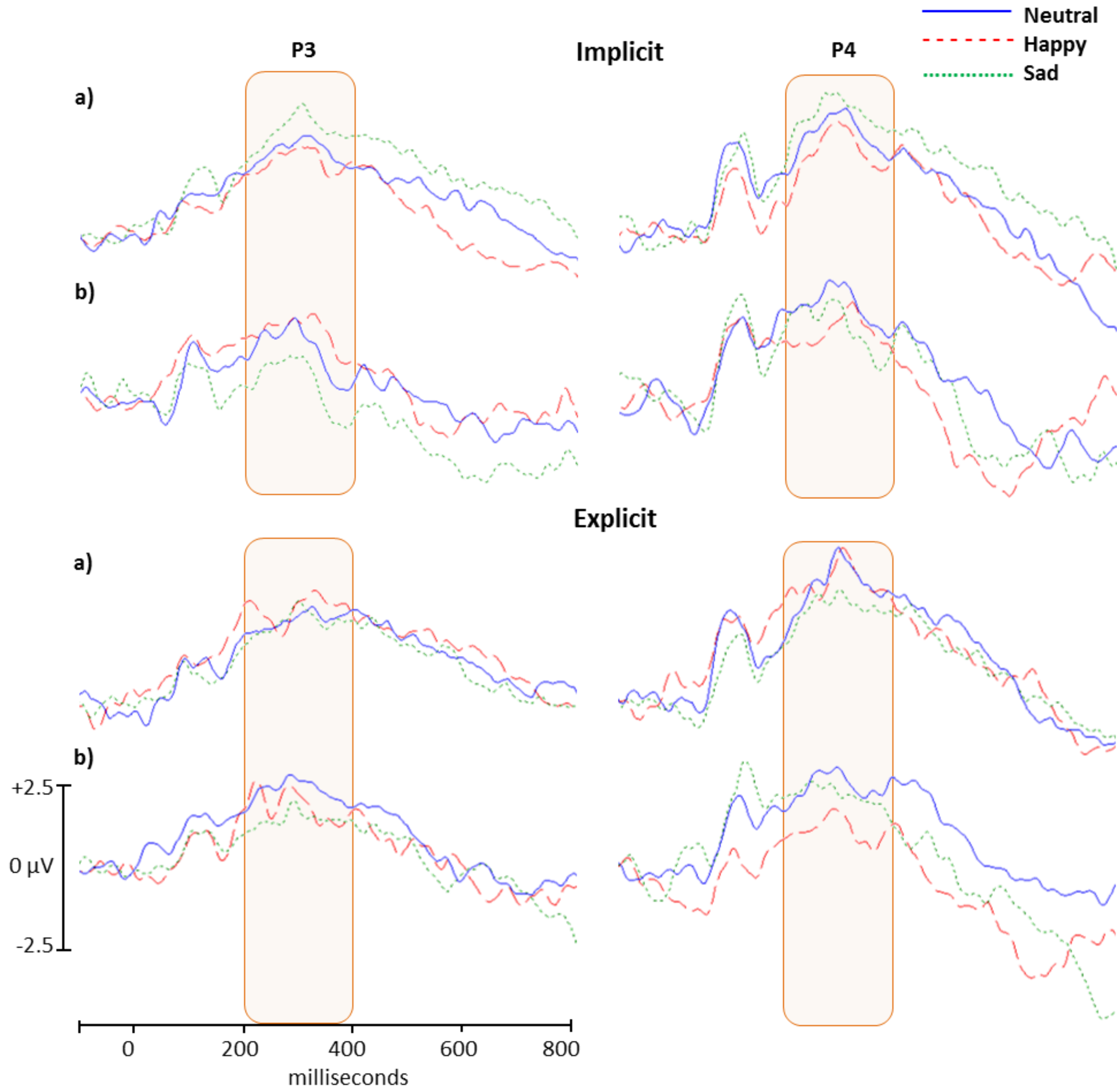


Figure 9. Global ERPs over Parietal Electrodes for a) Controls and b) Depressed, with P3 area highlighted.

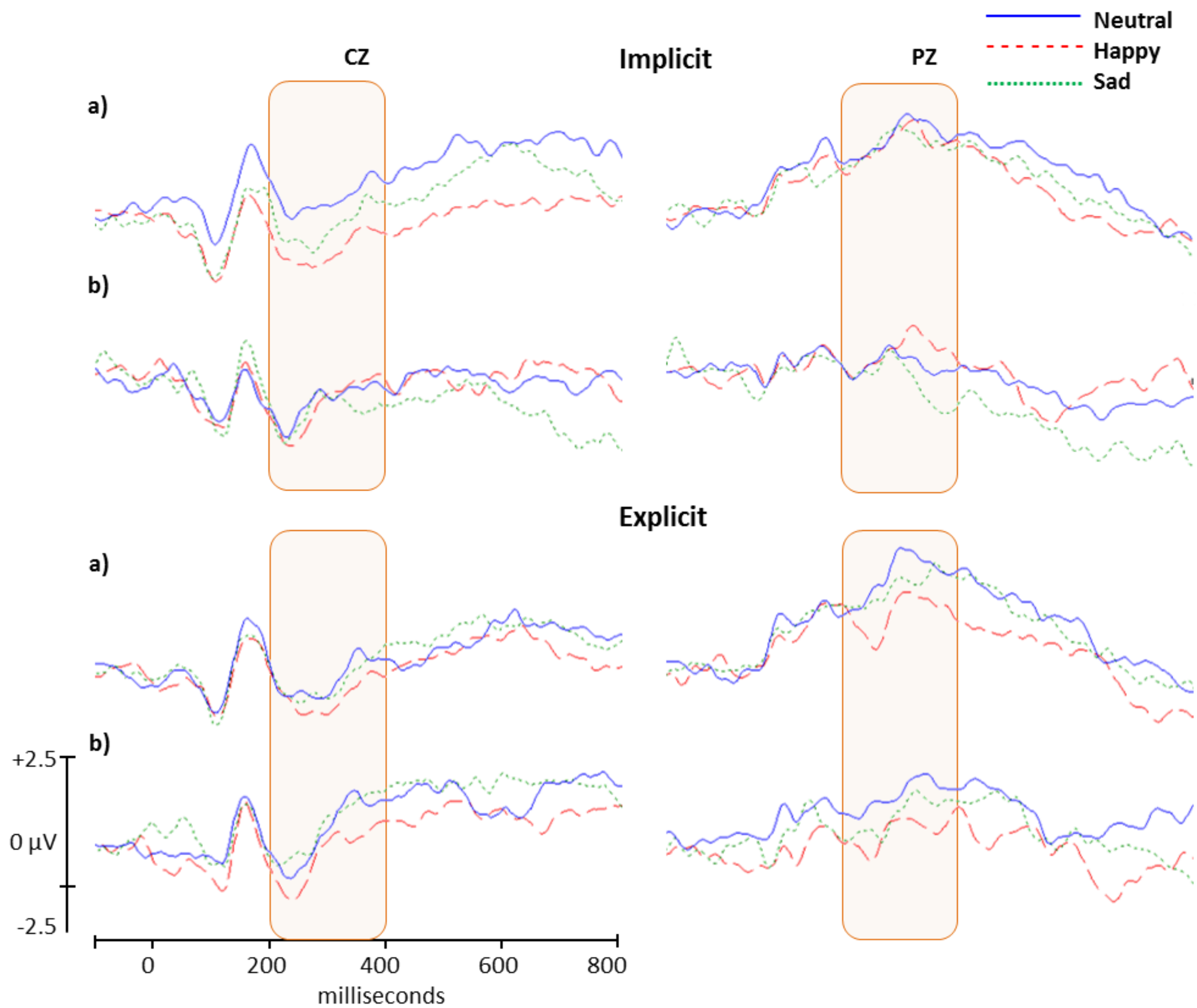


Figure 10. Midline ERPs over Central and Parietal electrodes for a) Controls and b) Depressed, with P3 area highlighted.

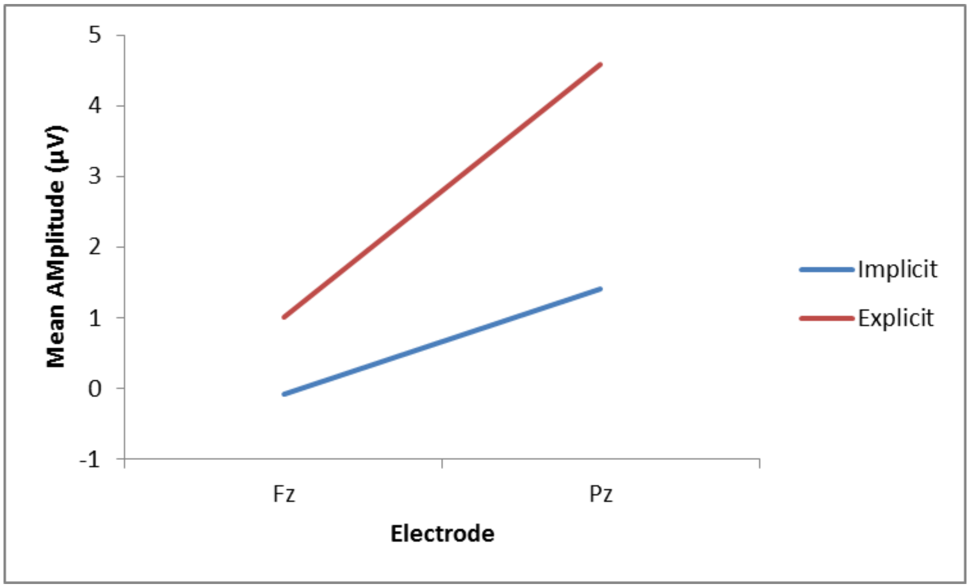


Figure 11. Significant effects and interactions for global P3 amplitude.

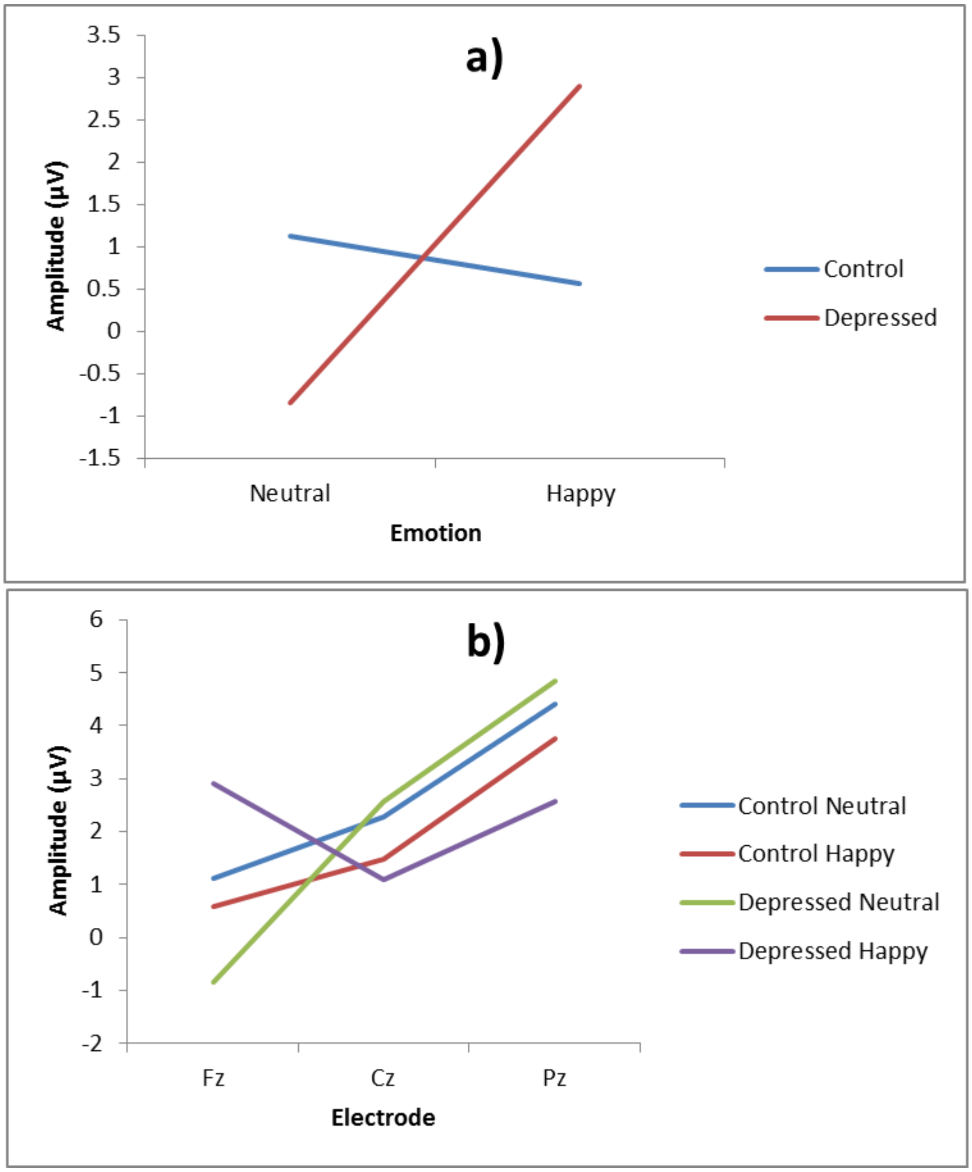


Figure 12. .Significant effects and interactions for midline P3 amplitude on Implicit task: a) Group*Emotion, and b) Group*Electrode*Emotion for Happy faces and α=0.05. No significant effects on Explicit task.

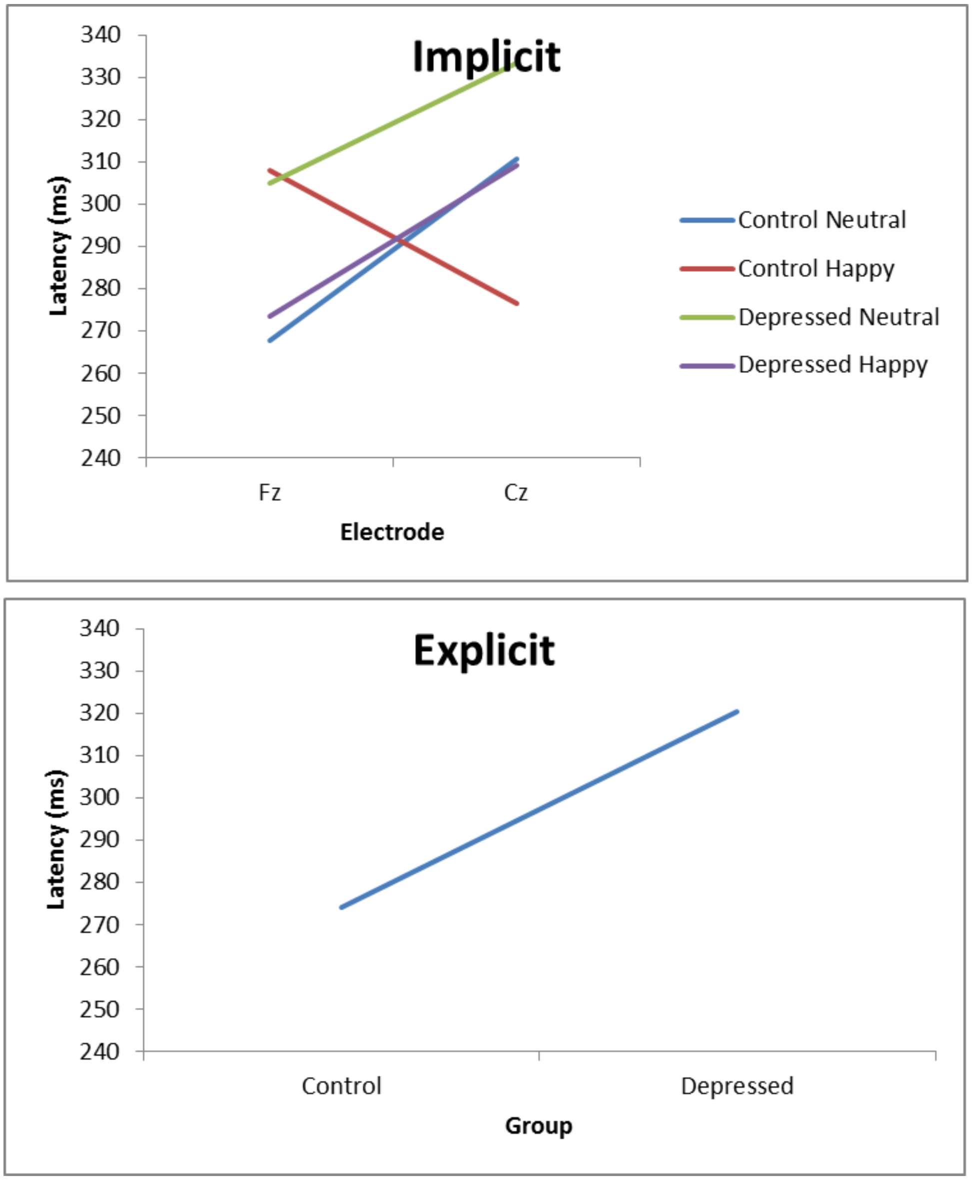


Figure 13. Significant effects and interactions for global P3 latency.

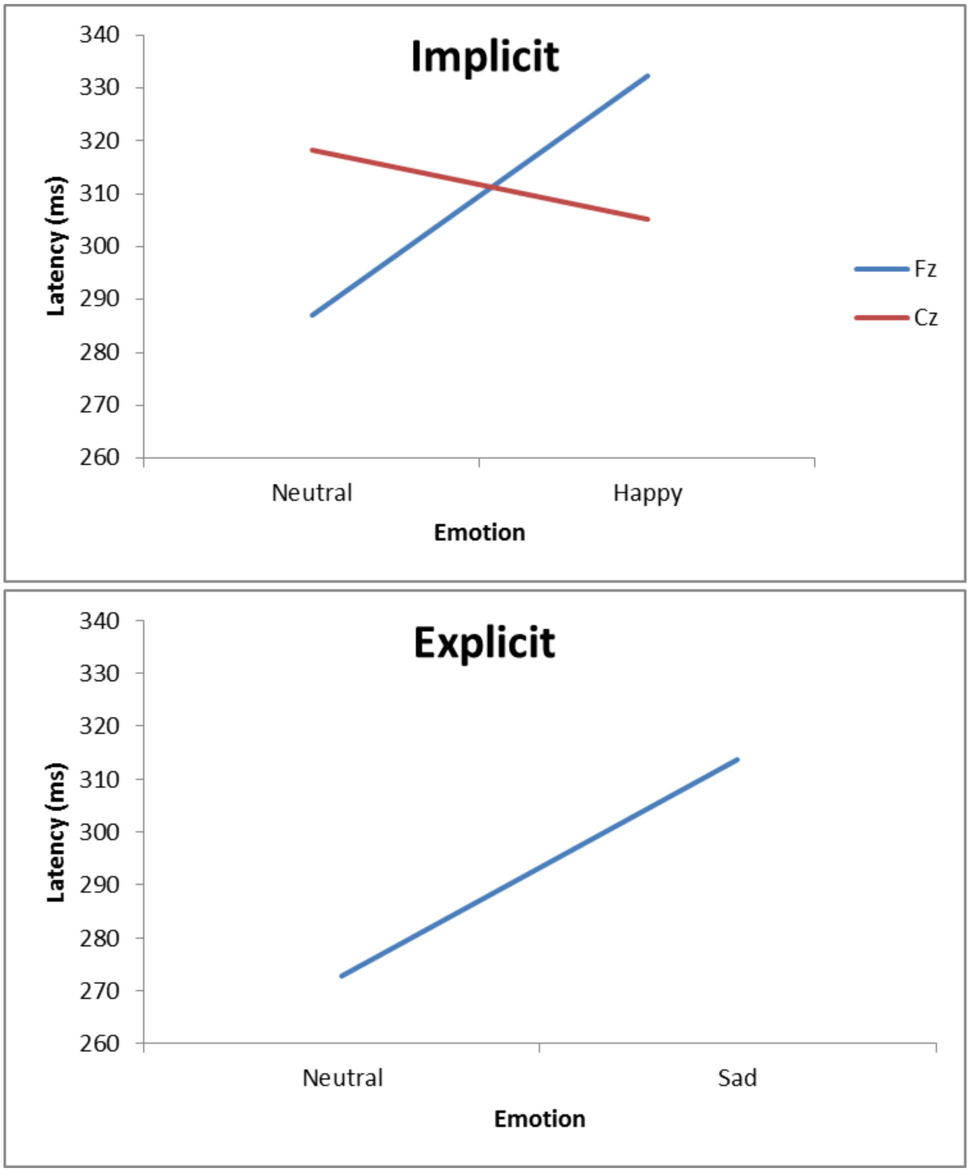


Figure 14. Significant effects and interactions for midline P3 latency.

Table 1
Validation information for face stimuli subset from RadBoud face database.

Rating	Emotion		
	Happy	Sad	Neutral
Percent Agreement (0-100)	99.35(1.599)	93.45(6.739)	94.25(6.172)
Intensity (1-5)	4.28(0.304)	3.57(0.322)	3.66(0.206)
Clarity (1-5)	4.59(0.178)	3.97(0.288)	3.92(0.213)
Genuineness (1-5)	3.90(0.482)	2.94(0.331)	4.13(0.190)
Valence (1-5)	4.35(0.222)	2.07(0.141)	3.18(0.211)

Note. Standard deviations appear in parentheses next to means.

Table 2
Experiment 1 participants' demographic information.

Variable	Group		Mean Difference
	Control	Depressed	
N	61	27	N/A
CES-D Score	7.62(3.882)	23.04(7.983)	-15.42
Age	19.64(2.058)	20.19(2.185)	-0.546
Reaction Time	285.86(90.284)	286.73(85.258)	-0.871
PANAS – Positive	27.64(9.171)	23.00(7.494)	-4.107*
PANAS – Negative	11.97(2.401)	16.07(5.546)	4.639*

Note. *p<0.05. Standard deviations appear in parentheses next to means.

Table 3
Reaction time in dot-probe tasks by Group, Congruency, and Task Type.

Task by Trial Type	Control		Depressed	
	Incongruent	Congruent	Incongruent	Congruent
Detection Task				
Neutral-Neutral*	289.173(104.228)		294.407(93.242)	
Neutral-Sad	282.161(90.370)	287.630(89.216)	285.503(84.496)	291.738(91.994)
Neutral-Happy	288.627(100.274)	284.775(89.152)	288.627(100.274)	280.116(90.783)
Discrimination Task				
Neutral-Neutral*	358.900(84.965)		400.909(141.721)	
Neutral-Sad	356.946 (93.561)	361.227 (90.290)	356.946 (93.561)	361.227 (90.290)
Neutral-Happy	359.504 (96.101)	359.711 (95.828)	359.504 (96.101)	359.711 (95.828)

Note. *Congruency only applicable to emotional trials. Standard deviations appear in parentheses next to means.

Table 4

Contribution of relevant variables to Bias scores on Detection task.

Predictor Variable	Model	
	A	B
Fixed Effects		
Intercept	-7.28(5.156)	-15.15(10.122)
Depressed	0.2(6.153)	2.34(13.492)
Orient	7.58(4.929)	15.89(13.098)
Happy	6.31(4.929)	18.81(13.098)
PANASPos	-0.04(0.284)	1.45(0.627)*
PANASNeg	-0.34(0.628)	-2.98(3.309)
Depressed * Orient		2.42(18.283)
Depressed * Happy		-19.2(18.283)
Depressed * PANASNeg		3.5(3.446)
Depressed * PANASPos		-2.13(1.011)*
Orient * Happy		-14.24(14.477)
Orient * PANASNeg		3.24(3.944)
Orient * PANASPos		-2.29(0.849)*
Happy * PANASNeg		0.68(3.944)
Happy * PANASPos		-0.74(0.849)
Depressed * Orient * Happy		26.9(23.442)
Depressed * Orient * PANASNeg		-5.08(3.979)
Depressed * Orient * PANASPos		2.82(1.168)*
Depressed * Happy * PANASNeg		-0.91(3.979)
Depressed * Happy * PANASPos		1.17(1.168)
Orient * Happy * PANASNeg		1.01(2.393)
Orient * Happy * PANASPos		0.27(1.083)
Variance Components		
Level-1	1336.01(127.383)	1212.15(115.574)
Level-2	0(0)	0(0)
Goodness-of-fit		
-2LL	2207.77	2186.37

Note. *$p<0.05$, ** $p<0.10$), $\chi2(14)=13.739$.*

Table 5

Contribution of relevant variables to Bias scores on Discrimination task.

Predictor Variable	Model		
	A	B	C
Fixed Effects			
Intercept	-3.18(3.627)	1.99(4.412)	1.2(7.281)
Depressed	-0.93(4.868)	-1.05(4.837)	15.34(12.036)
Orient	3.31(3.817)	3.31(3.791)	1.09(9.859)
Happy	2.38(3.817)	2.38(3.791)	2.7(9.859)
PANASPos	0.02(0.224)	0.04(0.223)	0.51(0.448)
PANASNeg	0.64(0.535)	0.77(0.826)	0.96(1.739)
PosPos		-0.06(0.026)*	-0.05(0.052)*
NegNeg		-0.05(0.082)	0.19(0.386)
Depressed * Orient			-31.88(15.61)*
Depressed * Happy			3.04(15.61)
Depressed * PANASNeg			1.79(2.909)
Depressed * PANASPos			0.78(1.059)
Depressed * PosPos			-0.3(0.112)
Depressed * NegNeg			-0.31(0.431)
Orient * Happy			-2.82(12.614)
Orient * PANASNeg			-1.78(2.347)
Orient * PANASPos			-1.01(0.613)*
Orient * PosPos			-0.01(0.071)
Orient * NegNeg			-0.19(0.461)
Happy * PANASNeg			-1.03(2.347)
Happy * PANASPos			-0.66(0.613)
Happy * PosPos			0(0.071)
Happy * NegNeg			-0.03(0.461)
Depressed * Orient * Happy			6.02(17.41)
Depressed * Orient * PANASNeg			1.76(3.359)
Depressed * Orient * PANASPos			-1.05(1.223)
Depressed * Orient * PosPos			0.62(0.129)
Depressed * Orient * NegNeg			0.1(0.498)

Contribution of relevant variables to Bias scores on Discrimination task.

Predictor Variable	Model A	Model B	Model C
Depressed * Happy * PANASNeg			0.02(3.359)
Depressed * Happy * PANASPos			-0.09(1.223)
Depressed * Happy * PosPos			-0.04(0.129)
Depressed * Happy * NegNeg			0.01(0.498)
Orient * Happy * PANASNeg			1.12(2.974)
Orient * Happy * PANASPos			1(0.803)
Orient * Happy * PosPos			0.03(0.093)
Orient * Happy * NegNeg			-0.06(0.294)
Variance Components			
Level-1	1282.16(96.647)	1264.87(95.343)	1024.24(77.205)
Level-2	0(0)	0(0)	0(0)
Goodness-of-fit			
-2LL	3517.95	3513.17	3438.89

*Note. *p<0.05, ** p<0.10),* $\chi^2(12)=39.372$.

Table 6

Experiment 2 participant s' demographic information.

Variables	Group: Control	Group: Depressed	Mean Difference
Age	19.95(2.655)	21.33(2.739)	-1.38
Reaction Time	891.71(328.136)	670.77(247.802)	220.94
PANAS – Positive	11.55(2.373)	14.50(3.071)	-2.95*
PANAS – Negative	28.75(9.67)	24.88(8.741)	3.87

Note. * $p<0.05$. Standard deviations appear in parentheses next to means.

Table 7

Reaction time on emotion processing tasks by Group, Task, and Emotion.

Task	Group	
	Control	Depressed
Implicit		
Neutral	789.89(265.125)	607.63(240.368)
Sad	822.99(286.323)	642.32(239.011)
Happy	918.25(395.555)	680.24(232.029)
Explicit		
Neutral	898.23(330.479)	709.86(256.938)
Sad	798.29(261.707)	635.03(291.694)
Happy	908.13(379.112)	697.44(303.978)

Note. **p*<0.05. Standard deviations appear in parentheses next to means.

Table 8

Contribution of relevant variables to reaction time on emotion processing tasks.

Predictor Variable	Model			
	A	B	C	D
Fixed Effects				
Intercept	917.73(75.127)*	939.152(77.147)*	936.944(77.912)*	932.955(76.167)*
Depressed	-219.854(124.372)	-262.753(128.7)	-256.703(131.884)	-252.714(131.055)
Explicit	27.173(19.46)	9.586(36.707)	13.952(42.422)	22.16(24.523)
Sad	-83.043(23.552)*	-98.78(37.697)*	-95.255(41.883)**	-107.044(29.521)*
Neutral	-43.286(23.737)	-84.496(38.318)**	-81.492(42.792)	-57.385(29.878)
Depressed*Explicit		15.297(40.725)	3.247(70.13)	-4.961(60.828)
Depressed*Sad		67.13(49.512)	57.338(69.805)	69.128(63.009)
Depressed*Neutral		38.122(49.719)	29.697(72.052)	5.601(65.051)
Explicit*Sad		-16.529(47.289)	-23.579(59.232)	
Explicit*Neutral		53.531(47.974)	47.524(60.561)	
Depressed*Explicit*Sad			19.903(99.937)	-3.666(80.234)
Depressed*Explicit*Neutral			16.686(100.73)	64.2(80.234)
Variance Components				
Level-1	1282.162(96.647)*	1264.868(95.343)*	1128.627(85.073)*	1024.239(77.205)*
Level-2	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)
Goodness-of-fit				
-2LL	1860.654	1809.201	1787.323	1808.512

Note. *p<0.05, **p<.010, $\chi^2(7)$=73.331. Standard errors appear in parentheses below means.

Table 9

Contribution of relevant variables to P3 amplitude over global electrodes on emotion processing tasks.

Predictor Variable	Model			
	A	B	A	B
	Implicit Task		Explicit Task	
Fixed Effects				
Intercept	-0.235(0.35)	-0.089(0.602)	0.196(0.412)	1.012(0.739)
Depressed	0.59(0.423)	0.775(0.994)	0.2(0.468)	-1.234(1.216)
Right	0.638(0.231)	-0.334(0.777)	0.874(0.284)	0.119(0.969)
Cz	1.929(0.283)	1.493(0.793)	1.147(0.348)	-0.079(0.989)
Pz	4.761(0.283)	4.539(0.793)	4.297(0.348)	3.564(0.989)
Happy	0.161(0.283)	0.224(0.793)	0.121(0.348)	-0.213(0.989)
Sad	-0.081(0.283)	0.139(0.793)	0.28(0.348)	-0.409(0.989)
Depressed*Right		-0.58(1.117)		0.638(1.393)
Depressed*Cz		-0.129(1.223)		1.585(1.525)
Depressed*Pz		-0.226(1.223)		1.509(1.525)
Depressed*Happy		0.775(1.223)		-0.059(1.525)
Depressed*Sad		-0.615(1.223)		1.195(1.525)
Right*Cz		1.769(1.054)		0.77(1.314)
Right*Pz		1.835(1.054)		0.848(1.314)
Right*Happy		-0.045(1.054)		0.369(1.314)
Right*Sad		0.833(1.054)		0.355(1.314)
Happy*Cz		-0.349(1.088)		0.699(1.357)
Sad*Cz		0.326(1.088)		0.712(1.357)
Happy*Pz		0.632(1.088)		0.35(1.357)
Sad*Pz		-0.207(1.088)		0.584(1.357)
Depressed*Right*Cz		0.003(1.223)		-0.255(1.525)
Depressed*Right*Pz		0.526(1.223)		-0.296(1.525)
Depressed*Right*Happy		1.846(1.223)		1.011(1.525)
Depressed*Right*Sad		0.641(1.223)		-0.787(1.525)
Depressed*Happy*Cz		-0.856(1.498)		-0.428(1.868)
Depressed*Sad*Cz		-0.089(1.498)		-0.716(1.868)
Depressed*Happy*Pz		-2.377(1.498)		-0.399(1.868)

Contribution of relevant variables to P3 amplitude over global electrodes on emotion processing tasks.

Predictor Variable	Model			
	A	B	A	B
	Implicit Task		Explicit Task	
Depressed*Sad*Pz		0.324(1.498)		-0.622(1.868)
Right*Happy*Cz		-0.403(1.389)		-0.26(1.732)
Right*Sad*Cz		-1.412(1.389)		0.466(1.732)
Right*Happy*Pz		-1.571(1.389)		-1.266(1.732)
Right*Sad*Pz		-2.243(1.389)		-0.66(1.732)
Variance Components				
Level-1	7.676(0.468)	7.713(0.481)	11.636(0.709)	11.998(0.748)
Level-2	0.802(0.318)	0.8(0.318)	0.859(0.391)	0.839(0.391)
Goodness-of-fit				
-2LL	2841.117	2783.307	3071.471	3016.508

Note. * p<0.05, ** p<.010; *Implicit task, χ2(25)=57.81*; *Explicit task,* $\chi^2(25)=54.963$. Standard errors appear in parentheses below means.

Table 10

Contribution of relevant variables to P3 amplitude over midline electrodes on emotion processing tasks.

	Model			
Predictor Variable	A	B	A	B
	Implicit Task		Explicit Task	
Fixed Effects				
Intercept	1.029(0.439)	1.119(0.635)	1.595(0.658)	1.648(0.988)
DEP	0.01(0.504)	-1.957(1.136)	0.11(0.708)	-1.818(1.767)
Cz	1.181(0.412)	1.156(0.854)	0.297(0.645)	0.725(1.358)
Pz	3.14(0.412)	3.298(0.854)	2.159(0.645)	1.798(1.358)
Happy	-0.461(0.412)	-0.546(0.854)	-0.287(0.645)	0.849(1.358)
Sad	-0.067(0.412)	-0.107(0.854)	-0.046(0.645)	0.33(1.358)
DEP * Cz		2.239(1.527)		1.705(2.43)
DEP * Pz		2.37(1.527)		3.353(2.43)
DEP * Happy		4.28(1.527)		-0.069(2.43)
DEP * Sad		1.156(1.527)		0.504(2.43)
Happy * Cz		-0.265(1.207)		-2.553(1.921)
Sad * Cz		0.148(1.207)		-1.035(1.921)
Happy * Pz		-0.118(1.207)		-0.877(1.921)
Sad * Pz		-0.602(1.207)		-0.75(1.921)
DEP * Happy * Cz		-4.925(2.159)		1.28(3.436)
DEP * Sad * Cz		-1.178(2.159)		0.978(3.436)
		-5.874(2.159)		-1.002(3.436)
		-0.454(2.159)		-0.386(3.436)
Variance Components				
Level-1	8.157(0.727)	8.015(0.732)	19.949(1.777)	20.29(1.852)
Level-2	0.843(0.459)	0.858(0.459)	1.225(0.91)	1.187(0.912)
Goodness-of-fit				
-2LL	1437.743	1396.976	1683.407	1640.202

Note. **p*<0.05, ***p*<.010; *Implicit task, $\chi^2(12)=40.767$; Explicit task, $\chi 2(12)=43.205$*. Standard errors appear in parentheses below means.

Table 11

Contribution of relevant variables to P3 latency over global electrodes on emotion processing tasks.

Predictor Variable	Model			
	A	B	A	B
	Implicit Task		Explicit Task	
Fixed Effects				
Intercept	284.647(7.811)	267.602(13.896)	276.211(7.814)	274.044(13.828)
Depressed	10.197(8.5)	37.275(22.862)	4.092(8.761)	46.261(22.769)
Right	12.924(5.546)	11.888(18.321)	11.646(5.446)	-13.996(18.142)
Cz	25.792(6.792)	43.104(18.686)	32.156(6.67)	27.323(18.504)
Pz	7.354(6.792)	39.909(18.686)	11.563(6.67)	11.637(18.504)
Happy	-4.719(6.792)	40.282(18.686)	8.438(6.67)	-0.261(18.504)
Sad	-4.01(6.792)	3.458(18.686)	-2(6.67)	-1.597(18.504)
DEP * Right		-14.24(26.324)		0.388(26.067)
DEP * Cz		-14.733(28.836)		-47.233(28.555)
DEP * Pz		-60.909(28.836)		-39.639(28.555)
DEP * Happy		-71.703(28.836)		-19.564(28.555)
DEP * Sad		12.933(28.836)		-21.691(28.555)
Right * Cz		12.064(24.843)		33.627(24.6)
Right * Pz		-9.727(24.843)		41.271(24.6)
Right * Happy		-7.928(24.843)		25.795(24.6)
Right * Sad		9.902(24.843)		20.557(24.6)
Happy * Cz		-74.341(25.647)		37.173(25.397)
Sad * Cz		-30.335(25.647)		2.403(25.397)
Happy * Pz		-47.506(25.647)		11.702(25.397)
Sad * Pz		-5.04(25.647)		16.841(25.397)
DEP * Right * Cz		8.994(28.836)		21.594(28.555)
DEP * Right * Pz		33.127(28.836)		-23.467(28.555)
DEP * Right * Happy		32.37(28.836)		7.455(28.555)

Contribution of relevant variables to P3 latency over global electrodes on emotion processing tasks.

Predictor Variable	Model			
	A	B	A	B
	Implicit Task		Explicit Task	
DEP * Right * Sad		-39.485(28.836)		13.418(28.555)
DEP * Happy * Cz		81.691(35.317)		8.045(34.973)
DEP * Sad * Cz		36.473(35.317)		-1.091(34.973)
DEP * Happy * Pz		63.418(35.317)		-8.845(34.973)
DEP * Sad * Pz		-10.473(35.317)		-23.491(34.973)
Right * Happy * Cz		15.5(32.74)		-61.437(32.42)
Right * Sad * Cz		-0.875(32.74)		-25.625(32.42)
Right * Happy * Pz		-4.625(32.74)		-31.312(32.42)
Right * Sad * Pz		-6.375(32.74)		-33.5(32.42)
Variance Components				
Level-1	4428.454(269.757)	4287.586(267.452)	4270.306(260.124)	4222.729(264.438)
Level-2	250.692(129.124)	258.518(129.11)	290.474(137.019)	293.118(137.045)
Goodness-of-fit				
-2LL	6448.02	6212.126	6430.235	6161.907

Note. * p<0.05, ** p<.010, *Implicit Emotion Processing task,* $\chi^2(25)=235.894$. *Explicit Emotion Processing task,* $\chi2(25)= 227.083$. Standard errors appear in parentheses below means.

Table 12

Contribution of relevant variables to P3 latency over midline electrodes on emotion processing tasks.

Predictor Variable	Model			
	A	B	A	B
	Implicit Task		Explicit Task	
Fixed Effects				
Intercept	299.644(10.75)	286.91(15.165)	281.89(10.442)	272.73(15.097)
DEP	-2.438(13.353)	-4.31(27.127)	5.48(12.263)	40.47(27.007)
Cz	7.687(9.474)	19.27(19.8)	22.83(9.647)	33.18(20.177)
Pz	2.167(9.474)	31.45(19.8)	18.67(9.647)	27(20.177)
Happy	10.583(9.474)	45.45(19.8)	-0.08(9.647)	-16.36(20.177)
Sad	17.146(9.474)	31.27(19.8)	16.21(9.647)	40.82(20.177)
DEP * Cz		7.33(35.42)		-41.78(36.093)
DEP * Pz		-10.25(35.42)		-35(36.093)
DEP * Happy		-25.45(35.42)		4.76(36.093)
DEP * Sad		-3.47(35.42)		-48.42(36.093)
Happy * Cz		-52.09(28.002)		13.91(28.534)
Sad * Cz		-16.55(28.002)		-18.36(28.534)
Happy * Pz		-58.64(28.002)		39(28.534)
Sad * Pz		-27.73(28.002)		-33.09(28.534)
DEP * Happy * Cz		56.89(50.092)		10.09(51.044)
DEP * Sad * Cz		29.55(50.092)		30.16(51.044)
DEP * Happy * Pz		39.04(50.092)		-37.4(51.044)
DEP * Sad * Pz		-13.07(50.092)		43.49(51.044)
Variance Components				
Level-1	4308.163(383.802)	4312.64(393.689)	4466.98(397.95)	4478.15(408.798)
Level-2	747.08(319.351)	746.58(319.499)	537.49(270.57)	536.25(270.77)
Goodness-of-fit				
-2LL	3214.2	3102.7	3218.2	3106.59

Note. * p<0.05, ** p<.010 *Implicit Emotion Processing task,* $\chi^2(12)=111.53$. *Explicit Emotion Processing task,* $\chi^2(12)=111.614$.. Standard errors appear in parentheses below means.

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Appendix I: Center for Epidemiological Studies Depression Scale

Below is a list of the ways you might have felt or behaved <u>in the past week</u>.

Indicate how often you have felt this way during the past week.

0	1	2	3
Rarely or none of the time(<1 day)	Some or a little of the time(1-2 days)	Occasionally or a moderate amount of time(3-4 days)	Most or all of the time(5-7 days)

During the past week...					
1.	I was bothered by things that usually don't bother me.	0	1	2	3
2.	I did not feel like eating; my appetite was poor.	0	1	2	3
3.	I felt that I could not shake off the blues even with help from my family or friends.	0	1	2	3
4.	I felt I was just as good as other people.	0	1	2	3
5.	I had trouble keeping my mind on what I was doing.	0	1	2	3
6.	I felt depressed.	0	1	2	3
7.	I felt that everything I did was an effort.	0	1	2	3
8.	I felt hopeful about the future.	0	1	2	3
9.	I thought my life had been a failure.	0	1	2	3
10.	I felt fearful.	0	1	2	3
11.	My sleep was restless.	0	1	2	3
12.	I was happy.	0	1	2	3
13.	I talked less than usual.	0	1	2	3
14.	I felt lonely.	0	1	2	3
15.	People were unfriendly.	0	1	2	3
16.	I enjoyed life.	0	1	2	3
17.	I had crying spells.	0	1	2	3
18.	I felt sad.	0	1	2	3
19.	I felt that people dislike me.	0	1	2	3
20.	I could not get "going".	0	1	2	3

Appendix II: Positive and Negative Affect Scales

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the appropriate answer in the space next to that word. Indicate to what extent you feel this way right now. Use the following scale to record your answers.

1	2	3	4	5
Very slightly or not at all	A little	Moderately	Quite a bit	Extremely

1. Interested ____
2. Distressed ____
3. Excited ____
4. Upset ____
5. Strong ____
6. Guilty ____
7. Scared ____
8. Hostile ____
9. Enthusiastic ____
10. Proud ____
11. Irritable ____
12. Alert ____
13. Ashamed ____
14. Inspired ____
15. Nervous ____
16. Determined ____
17. Attentive ____
18. Jittery ____
19. Active ____
20. Afraid ____