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Modeling Hedonic Processing and Anhedonia in Depression

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Abstract

Depression is characterized by low positive emotion and a lack of pleasurable experiences, or anhedonia. Past studies have emphasized controlling negative affect, but there is an emerging trend in the depression literature to focus on positive emotion. The current study employed several psychophysiological tools, postauricular reflex, startle blink reflex, and event-related potential (ERP) components such as P3 and the late positive potential (LPP), to assess the dissociable components in positive emotion (consummatory and anticipatory processes). In addition, several different hypotheses of emotional dysfunction were evaluated to accurately model deficits in positive emotionality. A majority of the psychophysiological tools used supported the low positive emotionality model of depression. Results for the postauricular reflex and P3 amplitude to anticipatory emotional stimuli supported the theory of emotional dysfunction that emphasizes the lower levels of positivity in depression. Findings on LPP supported previous findings that show the measure reflects context insensitivity to emotional stimuli. In addition, the postauricular and startle blink reflex suggested consummatory processes but were not good measures of anticipatory processes. It is important for future studies to assess measures that can index anticipatory components of positive emotion.

Modeling Hedonic Processing and Anhedonia in Depression

Depression is estimated to affect 350 million people worldwide (WHO, 2012), and that number is rising. Around 1 million lives are lost yearly due to suicide, and for every person that commits suicide there are about 20 more who attempt suicide. According to the Disease Control Priorities Project (DCPP) and the World Health Organization (WHO), depression is ranked in the top ten diseases for global disease burden (Lopez, Mathers, Ezzati, Jamison, & Murray, 2006; Murray & Lopez, 1997). Some common symptoms of major depressive disorder include a persistent increase in negative affect and anhedonia, which is a loss of pleasure in previously enjoyable activities and reduced reactivity to reward (American Psychiatric Association, 2013).

There has been a greater emphasis on controlling the disturbances in negative emotion for mental disorders, but unlike mood disorders such as anxiety, clinical depression is characterized by a lack of positive emotion (Clark & Watson, 1991b). Progress has been made in terms of focusing on the enhancement of positive emotion in research and clinical settings through promoting positive functioning (Joseph & Wood, 2010) and using characteristically positive strengths (Wood, Linley, Maltby, Kashdan, & Hurling, 2011). Even though the increased emphasis on positive emotion is impactful, it is counterintuitive to overemphasize positive emotion and ignore negative emotion. It is imperative to understand the interactions of negative and positive affect on behavioral, cognitive, and physiological levels. Several models of emotional dysfunction indicate which psychophysiological tools may best measure arousal and emotional deficiencies. The identification of the best psychophysiological tools to detect these deficiencies is important as it has the potential to maximize the effectiveness of assessment and treatment outcomes for depression.

Underarousal

Physiological and behavioral measures of arousal characteristically display larger results for pleasant and aversive stimuli when compared to neutral stimuli. An early model of emotional dysfunction proposed deficits in processing arousal (Grossberg, 1972). This theory proposes an overactive fear or relief response, which causes an overall drop in mean reactivity. According to this model, those suffering from depression would be expected to exhibit a larger reaction to arousing pleasant and aversive stimuli when compared to neutral stimuli, but there would be an overall reduction in arousal across all valence types.

Studies on the reduction of mean P3 amplitude in depression have supported the underarousal model of depression. Several studies have utilized cognitively demanding tone discrimination tasks to observe P3 amplitude reductions in depressed participants (Bruder et al., 1995; Diner, Holcomb, & Dykman, 1985). Blackwood and colleagues (1987) investigated P3 amplitude in schizophrenia and depression. The results showed an attenuation of P3 amplitude in both disorders, but only schizophrenia displayed P3 latency. The postauricular reflex, a valid psychophysiological measure of positive emotion, displays potentiated mean magnitudes for pleasant stimuli when compared to neutral and aversive stimuli (Benning, Patrick, & Lang, 2004; Benning, 2011). Although most studies support the postauricular reflex as a reliable measure of positive emotion, some results also demonstrate the postauricular reflex to be a good measure of underarousal for subclinical depression (Sloan & Sandt, 2010).

Low Positive Emotionality

Depression is uniquely characterized by a lack of positive emotion, and internalizing disorders such as anxiety are associated with increased negative affect (Clark & Watson, 1991b). Low positive emotion may be attributable to an overall fear of positive affect (Beblo et al., 2012), and those suffering or recovering from depression are more likely to display a lack of control when presented with a controllable positive event (Kang & Gruber, 2013). Despite the different theories on what causes low positive emotion in depression, investigating the reduction is vital to understanding emotional dysfunction (Clark, Watson, & Mineka, 1994).

As mentioned above, the postauricular reflex is an appropriate measure of positive emotion based on previous studies reporting a potentiation of the reflex during pleasant stimuli contrasted to neutral and aversive stimuli (Benning, 2011; Benning, Patrick, & Lang, 2004; Sandt, Sloan, & Johnson, 2009). If depression were best described by low positive emotionality, depressed participants would exhibit their lowest mean results during the presentation of pleasant stimuli when compared to neutral and aversive stimuli in contrast to a healthy control group. Nondepressed participants would display the highest mean results during the presentation of pleasant stimuli when compared to neutral and aversive stimuli.

Several studies have utilized ERP measures to investigate deficits in positive emotion. According to feedback-negativity methods of recording ERP measures, deficits in processing reward have been shown to be highly related to low positive emotion in never-depressed adolescent girls (Bress, Foti, Kotov, Klein, & Hajcak, 2013). This study also linked deficiencies in processing reward using neural measures to make an association with the first onset of a major depressive episode. Cavanaugh and Geisler (2006) observed P3 amplitude in college students with subclinical depressive symptoms during happy and fearful faces. The study found a reduction in P3 amplitude only for happy faces, which supports a model of low positive emotionality.

Heightened Negative Emotionality

Alternate views on emotional dysfunction in major depressive disorder emphasize the prevalence of negative moods and emotion. In terms of personality traits, negative affectivity is integral to models of emotional dysfunction that highlight temperamental sensitivity (Tellegen, 1985). Beck (1976) proposed cognitive theories aligned with heightened negative emotionality, which claimed negative moods facilitate negative cognitive processes like schemas that catalyze patterns of negative emotion to stimuli. Cognitive vulnerabilities emerge during moments of high stress and may lead to onset, relapse, and recurrence of depression (Scher, Ingram, & Segal, 2005).

The startle blink reflex is a non-invasive tool that is useful in the investigation of various affective states and emotional processes across disorders (Grillon and Bass, 2003). As a psychophysiological measure, startle blink reflexes display potentiation of mean peak magnitude during aversive stimuli as opposed to neutral and pleasant stimuli (Cuthbert, Bradley, & Lang, 1996; Lang et al., 1990), and it may be a good biological indicator of heightened negative emotion found in depression. However, most of the research stands in opposition to the startle blink reflex as a measure of heightened negative emotionality. Multiple studies have found no significant differences across different valence types in depression (Forbes, Miller, Cohn, Fox, & Kovacs, 2005; Taylor-Clift, Morris, Rottenberg, & Kovacs, 2011), a finding better described as context insensitivity.

Emotion Context Insensitivity

The Emotion Context Insensitivity (ECI) model of emotional processes hypothesizes that deficits in emotional reactivity are, speaking in terms of evolution, an adaptive feature of depression (Nesse, 2000; Rottenberg, Gross, & Gotlib, 2005). As such, an emotional dysfunction would involve withdrawal from situations that require reactions to an emotional stimulus. If utilizing a psychophysiological measure for ECI, the mean results during pleasant stimuli would be similar to low positive emotionality, but during aversive stimuli, the measure would display the opposite of heightened negative emotionality. Unlike the underarousal model of emotional dysfunction, ECI would not display attenuation across pleasant, neutral, and aversive stimuli, but instead, depressed participants would display reduced mean results for stimuli meant to produce emotional reactivity.

The LPP is an event-related potential associated with selective attention allocation towards emotional stimuli (Weinberg & Hajcak, 2010). Kujawa, Hajcak, Torpey, Kim, and Klein (2012) investigated LPPs in children with maternal history of depression. The study showed that children at high risk for depression exhibited a reduction in emotional reactivity across all valence types, which is consistent with ECI theory. In addition, studies on the startle blink reflex in depressed participants support ECI for emotional stimuli at specific time points (Dichter and Tomarken, 2008; Dichter, Tomarken, Shelton, & Sutton, 2004). Similarly, participants suffering from severe depression fail to display potentiated startle blink for emotional stimuli (Kaviani et al., 2004).

The models of emotional dysfunction discussed propose hypotheses for how emotional reactivity will occur in line with specific stimuli. Deficits in positive and negative emotion may be measured psychophysiologically and interpreted through potentiation and attenuation of reflex magnitudes during stimuli of different valence types. Within positive and negative affect, there are dissociable processes that form each orthogonal emotion. Specifically, positive emotion incorporates motivation, hedonic processing, and learning (Berridge, 2009; Berridge & Kringelbach, 2008; Berridge & Robinson, 2003).

Consummatory and Anticipatory Processes

To fully comprehend how the lack of pleasure in anhedonia affects depression, it is necessary to expand on deficits in positive emotionality. Positive emotion consists of several components that are dissociable (Berridge, 2009; Berridge & Kringelbach, 2008; Berridge & Robinson, 2003). A tripartite model of depression may be derived from this organization of pleasure processing. One aspect of positive emotion is hedonic processing, which is consciously or unconsciously "liking" a stimulus, but the reaction is not necessarily stimulus specific. An example of a subjective experience of conscious "liking" would be enjoying the sweet taste of a pleasant dessert. The consumer is aware that the experienced pleasure derived from the tasty dessert. Unconscious "liking" may involve an automatic physiological reaction to a stimulus. For example, an immediate smile which stems from a pleasant stimulus (Berridge, Robinson, & Aldridge, 2009). In addition, motivation is an integral process of positive emotion. Before consumption of a pleasurable stimulus, there must be an attraction to approach the reward. Once attraction is established, motivational "wanting" can occur with or without "liking." An example of "wanting" occurring without "liking" would be a drug addict irrationally relapsing with a rational urge to abstain (Berridge & Kringelbach, 2008).

The current study observed the deficits in "liking" and "wanting" for people suffering from depression. To measure the consummatory process of "liking," participants were presented with pleasant, neutral, and aversive pictures and sounds. Anticipatory "wanting" was investigated by matching a neutral shape with either a pleasant, neutral, or aversive picture or sound. During stimulus presentation, psychophysiological measures, postauricular reflex, startle blink reflex, P3 amplitude, and LPP, were recorded to assess deficits in positive emotion. In addition, results were used to observe which model of emotional dysfunction was best supported.

Method

Participants

The current study consisted of 69 participants (62% female, *M* age = 26.9) comprising 32 depressed and 37 nondepressed participants. In terms of race and ethnicity, 39.1% were White, 13.0% were Black, 26.1% Asian, 20.3% Hispanic, and 1.4% Native American. Nineteen participants were excluded because they failed to show reactivity to the postauricular reflex (magnitude under 2 μV) leaving 29 control and 21 depressed participants. Similarly, nineteen participants were omitted because of insufficient reactivity of the startle blink reflex (magnitude under 1 μV), which left 33 control and 17 depressed participants. A total of 50 participants for postauricular and startle blink measurements remained for analysis. One participant was excluded from EEG analysis due to excessive noise in recorded data, leaving 68 participants for EEG analysis.

Depressed participants were recruited from the community through flyers and advertisements on the Internet and screened using the Inventory for Depressive Symptomatology-Clinician-rated (IDS-C; Rush, Gullion, Basco, Jarret, & Trivedi, 1996). For a participant to be considered depressed, a score of at least 24 was required. Nondepressed participants for the control group consisted of psychology students at the University of Nevada, Las Vegas (UNLV). Participants from the UNLV subject pool were screened with the Inventory for Depressive Symptomatology - Self-Report (IDS-SR; Rush et al., 1996). Nondepressed participants needed a score of 13 or below in order to take part in the study. Students who participated received course credit. Community participants received a payment of $100. This study was approved by the Institutional Review Board of UNLV.

Stimuli

The startle probe was a bilateral 50 ms, 105 dB white noise probe with nearly instantaneous rise time; probes were presented 3000, 4000, or 5000 ms after the onset of most picture stimuli. Forty-eight pictures were derived from the International Affective Picture System (IAPS; CSEA-NIMH, 1999) for this experiment. A total of twelve sound clips were supplied by the International Affective Database of Sounds (IADS; Bradley & Lang, 1999). The experiment included maximally intense exemplars of pleasant and aversive picture contents depicting stimuli that are directly or indirectly related to an organism's survival. All picture contents were gender balanced on dimensions of normatively related valence (median $t(6)$ between men and women = 0.35, $p = .735$) and arousal (median $t(6)$ between men and women = 0.13, $p = .897$).

The first three pictures (IAPS numbers 4650, 7080, and 9252) were probed at the beginning of the experiment to habituate abnormally large initial reflex magnitudes (Graham, 1979); data from these pictures were not analyzed. Probes were not presented during four pictures during the experiment (IAPS numbers 2220, 5460, 7233, and 8485); instead, probes were presented during the inter-trial interval (ITI) after these pictures to reduce the predictability of the startle probes. A total of eight run orders were used in this study: Four different serial positions of the pictures were used, with appropriate stimulus substitutions made for women and men in the study. In each run order, no more than two pictures of the same valence occurred contiguously, and pictures of the same content did not follow each other.

Self-Report Measures

Multidimensional Personality Questionnaire – Brief Form (MPQ-BF; Patrick, Curtin, & Tellegen, 2002). The MPQ is a valid measure used to analyze personality according to higher-order factors, which are comprised of primary trait scales. The higher-order factors are positive emotionality (PEM), trends of positive emotion across various settings, negative emotionality (NEM), which consists of stress, aggression, and poor coping, and constraint

(CON), tradition and tendency to choose low-risk situations. Primary trait scales within PEM are well-being, social potency, achievement, and social closeness. NEM consists of the primary trait scales: stress reaction, alienation, and aggression. CON involves (planful) control, harm-avoidance, and traditionalism. The measure contains 155 items, which are mostly true or false questions.

Inventory for Depressive Symptomatology – Clinician-Rated (IDS-C) and Self-Report (IDS-SR) (Rush et al., 1996). The IDS assesses the severity of depressive symptoms according to the symptom domains of a major depressive episode. In addition, items define other common symptoms like feelings of irritability and anxiety. Twenty-eight of the thirty items are used to score the completed responses. For appetite and weight changes, only the increase or decrease items are included in the final assessment. Coefficient α for IDS-SR total scores was .92 in this sample (M = 23.3, SD = 14.82).

Self-rating Depression Scale (SDS; Zung, 1965). The SDS assesses psychological and somatic symptoms and the severity of those complaints in participants diagnosed with depression. Twenty items (ten positive statements and ten negative statements) are rated on a Likert scale from 1 (a little of the time) to 4 (most of the time). Coefficient α for Zung total scores was .83 in this sample (M = 27.2, SD = 7.45).

Procedure

Depressed and nondepressed participants went through the informed consent process with a research assistant. Participants were then escorted to an experiment room where they were introduced to the psychophysiological tools and computers used in the experiment. During electrode placement, they filled out a participant information questionnaire on a computer, which asked for age, sex, race, ethnicity, and health problems. In addition, participants filled out a series of questionnaires (see Measures section). After the experimental set up and questionnaires were completed, participants were asked to sit as still as possible while completing the assigned tasks. Participants were recorded at rest for 4 minutes, and they spent 2 minutes with their eyes open and 2 minutes with eyes closed. There was a habituation period for the startle probe, which played the noise probe 3 times over a 30 second span.

Participants were told they would be presented with a series of images and sounds. Before the actual tasks, they were asked to rate their valence and arousal to three different shapes, which were a triangle, circle, or square. Valence was rated using the Self-Assessment Manikin (SAM; Bradley & Lang, 1994) on the computer. They were instructed to complete a training session for the actual experiment. The training session involved associating a random shape, either a circle, triangle, or square, to a specific stimulus valence (pleasant, neutral, or aversive). Participants were told that loud bursts of noise would play through their headphones, and they were told to ignore those sounds. During the inter-stimulus interval, participants were instructed to concentrate on a fixation cross in the center of the screen. They were presented with pleasant, neutral, or aversive picture or sound stimuli.

Psychophysiological Recordings

All physiological channels were recorded using Ag/AgCl electrodes and sampled at 2000 Hz with a Neuroscan SynAmps^2 bioamplifier at DC with a 500 Hz lowpass filter to avoid aliasing of the physiological signals. Following detailed instructions from O'Beirne and Patuzzi (1999), the postauricular reflex was measured by placing electrodes on the postauricular muscle and pinna. Startle blink reflex magnitude was recorded by placing electrodes on the orbicularis oculi muscle underneath the right eye. EEG data was recorded with a Neuroscan Quik-Cap.

Data Reduction

Offline, startle blink and postauricular reflex EMGs were epoched from 100 ms pre-probe onset to 250 ms post-probe onset. Postauricular EMGs were not filtered further, and startle blink reflex EMGs were bandpass filtered from 28-250 Hz (Blumenthal et al., 2005). Startle blink and postauricular reflex EMGs were then rectified; startle blink reflex data were additionally smoothed with a single-pole recursive infinite impulse lowpass 5th order Butterworth filter with a 10 ms time constant. EEG data were referenced to linked mastoids before being epoched from 250 ms pre-picture onset to 1550 ms post-picture onset. An ocular artifact correction was applied (Semlitsch, Anderer, Schuster, & Presslich, 1986) to correct for blinks before data were lowpass filtered at 20 Hz. All filters were applied at 24 dB/octave.

Because the postauricular reflex is a microreflex, postauricular muscle activity was assessed using aggregate rectified waveforms. Postauricular EMG activity to noise probes was averaged across all pictures of a given valence, yielding average waveforms comprising 16 trials. In each aggregation, postauricular reflex magnitudes were assessed as the peak EMG activity occurring 8-35 ms after noise probe onset minus the mean 50 ms pre-probe EMG baseline activity (cf. Benning et al., 2004; Sloan & Sandt, 2010).

P3 amplitude was assessed using similar aggregate waveforms as the peak activity at PZ and LPP amplitude was similarly assessed at CZ (the only sites with group by valence effects in this study) as the maximum activity 250-500 ms after picture onset minus the mean 200 ms pre-picture baseline activity (Olofsson et al., 2008). For these measures, valid data from at least 8 out of 16 trials per valence were required for a participant to be included in further analyses. Prior to signal averaging, trials were excluded if baseline activity exceeded 100 μV. Startle blink reflexes were scored on a trial by trial basis as the maximum smoothed activity 30-120 ms after noise probe onset minus the mean 50 ms pre-probe EMG baseline activity. Trials were excluded if baseline activity exceeded 3 *SD* above the mean. For all non-ERP measures, negative peaks were set to 0 and included in the analyses. Postauricular reflex data were averaged across both ears prior to analysis.

Data Analysis

Independent samples *t* tests were conducted on IDS-SR and SDS scores to confirm that depressed and control participants differed in their levels of depressive symptomatology. These tests were also conducted on MPQ scores to examine how the two groups differed with respect to normal-range personality traits.

A series of 3 x 2 mixed ANOVAs was used to analyze the psychophysiological data. In each ANOVA, stimulus Valence (pleasant, neutral, or aversive) was included as the within-subjects factor, and Group (depressed or control) was included as the between-subjects factor. Huynh-Feldt corrections were applied to adjust the degrees of freedom of each within-subjects term for violations of sphericity. To clarify the modulation of each measure by valence in each group, main effects within the control and depressed groups were subsequently analyzed with separate within-subjects ANOVAs.

Finally, to investigate whether the severity of depressive symptomatology correlated with deficits in psychophysiological reactivity, IDS-SR and SDS scores were correlated with patterns of emotional modulation of each psychophysiological measure. All analyses were conducted using SPSS version 22. A critical α level of .05 was used for all statistical comparisons.

Results

Self-Reports

Table 1 displays the means and standard deviations of the control and depressed participants on the depression measures used in this study. As expected, depressed participants had higher scores on both measures of depression. They also had greater levels of anhedonia in addition to greater negative affective symptoms than controls.

Table 2 gives the means and standard deviations of the control and depressed participants on the primary trait and higher-order factor scales of the MPQ. Depressed participants had higher scores than controls on stress reaction, alienation, aggression, and negative emotion. They had lower scores than controls on well-being, social closeness, traditionalism, positive emotion, and constraint. Depressed and control participants did not differ in their scores on social potency, achievement, (planful) control, harm avoidance, and absorption.

Postauricular Reflex

Figure 1 displays the within-subjects *z* scores of postauricular peak magnitudes during pleasant, neutral, and aversive pictures for both control and depressed groups. There was a trend toward a Group x Valence interaction, $F(2,47) = 2.71$, $p = .077$, $\eta^2_p = .10$. Planned within-subjects contrasts revealed a significant linear Group x Valence effect, $F(1,48) = 4.55$, $p = .038$, $\eta^2_p = .09$, but not a significant quadratic Group x Valence effect, $F(1,48) = 1.38$, $p = .244$, $\eta^2_p = .03$. There was no main effect of Valence, $F(2,47) = 0.78$, $p = .462$, $\eta^2_p = .03$. Similarly, planned within-subjects contrasts did not show a significant linear, $F(1,48) = 1.42$, $p = .239$, $\eta^2_p = .03$, or quadratic Valence effect, $F(1,48) = 0.10$, $p = .749$, $\eta^2_p = .00$.

Separate multivariate ANOVAs performed for each group revealed a trend towards a significant Valence effect control group, $F(2,27) = 3.22$, $p = .056$, $\eta^2_p = .19$. Specifically, postauricular reflex magnitude was greater during pleasant than aversive pictures, linear $F(1,28) = 6.22$, $p = .019$, $\eta^2_p = .18$, and intermediate during neutral pictures, quadratic $F(1,28) = 0.43$, $p = .517$, $\eta^2_p = .01$. In the depressed group, there was no main effect of Valence, $F(2,19) = 0.55$, $p =$

.584, η^2_p = .05. Specifically, there were no significant linear, F(1,20) = 0.41, p = .527, η^2_p = .02, or quadratic main effects of Valence, F(1,20) = 0.99, p = .332, η^2_p = .05.

Figure 2 demonstrates within-subjects z scores for postauricular peak magnitudes during pleasant, neutral, and aversive sounds for both control and depressed groups. There was a significant Valence effect, F(2,33) = 5.08, p = .012, η^2_p = .23. Specifically, postauricular reflex magnitude was greater during pleasant than aversive sounds, linear F(1,34) = 8.74, p = .006, η^2_p = .21, and intermediate during neutral sounds, F(1,34) = 1.57, p = .219, η^2_p = .04. There was no significant Group x Valence interaction, F(2,33) = 1.21, p = .312, η^2_p = .07. In addition, planned within-subjects contrasts displayed no significant linear, F(1,34) = 0.93, p = .340, η^2_p = .03, or quadratic Group x Valence interactions, F(1,34) = 1.59, p = .215, η^2_p = .04.

Separate multivariate ANOVAs conducted for each group showed a trend towards a significant Valence depressed group, F(2,13) = 3.35, p = .067, η^2_p = .34. Postauricular reflex magnitude was greater during pleasant than aversive sounds, F(1,14) = 7.21, p = .018, η^2_p = .34, and intermediate during neutral sounds, quadratic F(1,14) = 0.00, p = .993, η^2_p = .00. The control group did not display a main effect of Valence, F(2,19) = 2.65, p = .096, η^2_p = .22. In addition, within-subjects contrasts showed no significant linear, F(1,20) = 2.24, p = .150, η^2_p = .10, or quadratic Valence effects, F(1,20) = 3.15, p = .091, η^2_p = .14, in the control group.

Figure 3 exhibits within-subjects z scores of postauricular peak magnitudes during pleasant, neutral, and aversive cues for both control and depressed groups. The 3 x 2 mixed ANOVA did not show a Group x Valence interaction, F(2,47) = 0.50, p = .952, η^2_p = .00. Planned within-subjects contrasts revealed no significant linear, F(1,48) = 0.07, p = .791, η^2_p = .00, or quadratic Group x Valence interactions F(1,48) = 0.03, p = .867, η^2_p = .00. There was no main effect of Valence, F(2,47) = 1.17, p = .318, η^2_p = .05. In addition, planned within-subjects contrasts displayed no significant linear, $F(1,48) = 0.08$, $p = .778$, $\eta^2_p = .00$, or quadratic Valence effect, $F(1,48) = 2.29$, $p = .136$, $\eta^2_p = .05$.

Separate multivariate ANOVAs revealed no Valence effect control, $F(2,27) = 0.80$, $p = .459$, $\eta^2_p = .06$. Specifically, there was no significant linear, $F(1,28) = 0.17$, $p = .685$, $\eta^2_p = .01$, or quadratic effect of Valence, $F(1,28) = 1.57$, $p = .221$, $\eta^2_p = .05$, within the control group. The depressed group displayed no significant Valence effect, $F(2,19) = 0.43$, $p = .654$, $\eta^2_p = .00$. There was neither a significant linear, $F(1,20) = 0.00$, $p = .991$, $\eta^2_p = .02$, or quadratic Valence effect, $F(1,20) = 0.88$, $p = .360$, $\eta^2_p = .04$.

Startle Blink Reflex

Figure 4 shows the within-subjects *z* scores of startle blink reflex peak magnitudes during pleasant, neutral, and aversive pictures for both control and depressed groups. There was a main effect of Valence, $F(2,47) = 5.90$, $p = .005$, $\eta^2_p = .20$. Planned within-subjects contrasts displayed a significant linear Valence effect, $F(1,48) = 11.91$, $p = .001$, $\eta^2_p = .19$, but there was no significant quadratic Valence effect, $F(1,48) = 0.95$, $p = .335$, $\eta^2_p = .02$. In addition, the 3 x 2 mixed ANOVA showed no significant Group x Valence interaction, $F(2,47) = 0.75$, $p = .480$, $\eta^2_p = .03$. Specifically, within-subjects contrasts showed no significant linear, $F(1,48) = 1.52$, $p = .224$, $\eta^2_p = .03$, or quadratic Group x Valence interactions, $F(1,48) = 0.76$, $p = .784$, $\eta^2_p = .00$.

Separate multivariate ANOVAs performed for each group showed a significant Valence effect control group, $F(2,31) = 9.03$, $p < .001$, $\eta^2_p = .37$. Specifically, startle blink reflex magnitudes were greater for aversive than pleasant pictures, linear $F(1,32) = 18.49$, $p < .001$, $\eta^2_p = .37$, and intermediate during neutral pictures, quadratic $F(1,32) = 1.11$, $p = .299$, $\eta^2_p = .03$. There was no significant effect of Valence for the depressed group, $F(2,15) = 0.84$, $p = .451$, η^2_p

= .10. In addition, the depressed group did not show a significant linear, $F(1,16) = 1.49$, p = .240, $\eta^2_p = .09$, or quadratic Valence effect, $F(1,16) = 0.19$, $p = .662$, $\eta^2_p = .01$.

Figure 5 displays the within-subjects *z* scores of startle blink reflex magnitudes during pleasant, neutral, and aversive sounds for both control and depressed groups. The 3 x 2 mixed ANOVA revealed a significant Valence effect, $F(2,32) = 8.97$, $p = .001$, $\eta^2_p = .36$. Specifically, startle blink reflex magnitude was greater during aversive than pleasant sounds, linear $F(1,33)$ = 15.52, $p < .001$, $\eta^2_p = .32$, and intermediate during neutral sounds, quadratic $F(1,33) = 3.35$, p = .076, $\eta^2_p = .09$. There was no significant Group x Valence interaction, $F(2,32) = 1.06$, $p = .358$, $\eta^2_p = .06$. There was also no significant linear, $F(1,33) = 2.06$, $p = .160$, $\eta^2_p = .06$, or quadratic Group x Valence interaction, $F(1,33) = 0.09$, $p = .759$, $\eta^2_p = .00$.

Separate multivariate ANOVAs conducted for each group revealed a significant Valence effect control group, $F(2,22) = 12.23$, $p < .001$, $\eta^2_p = .53$. Specifically, startle blink reflex magnitude was greater for aversive than pleasant sounds, linear $F(1,23) = 24.67$, $p < .001$, η^2_p = .52, and intermediate for neutral sounds, quadratic $F(1,23) = 1.86$, $p = .186$, $\eta^2_p = .08$. In the depressed group, there was no significant effect of Valence, $F(2,9) = 1.78$, $p = .224$, $\eta^2_p = .28$. Within-subjects contrasts showed no significant linear, $F(1,10) = 1.98$, $p = .190$, $\eta^2_p = .16$, or quadratic Valence effect $F(1,10) = 1.63$, $p = .231$, $\eta^2_p = .14$.

Figure 6 shows the within-subjects *z* scores of startle blink reflex magnitudes during pleasant, neutral, and aversive cues. There was no significant Valence effect, $F(2,46) = 0.75$, p = .477, $\eta^2_p = .03$. Planned within-subjects contrasts revealed no significant linear, $F(1,47) = 0.43$, $p = .514$, $\eta^2_p = .01$, or quadratic Valence effect, $F(1,47) = 1.28$, $p = .262$, $\eta^2_p = .03$. The Group x Valence interaction was not significant, $F(2,46) = 0.36$, $p = .700$, $\eta^2_p = .02$. Similarly, planned within-subjects revealed no significant linear, $F(1,47) = 0.22$, $p = .641$, $\eta^2_p = .01$, or quadratic Valence effect, $F(1,47) = 0.41$, $p = .525$, $\eta^2_p = .01$.

Separate multivariate ANOVAs conducted for each group showed no significant Valence effect control group, $F(2,30) = 1.36$, $p = .272$, $\eta^2_p = .08$. There was no linear, $F(1,31) = 0.04$, $p = .842$, $\eta^2_p = .00$, or quadratic Valence effect, $F(1,31) = 2.68$, $p = .112$, $\eta^2_p = .08$. There was also no significant effect for the depressed group, $F(2,15) = 0.14$, $p = .874$, $\eta^2_p = .02$. Specifically, within-subjects contrasts showed no linear, $F(1,16) = 0.28$, $p = .601$, $\eta^2_p = .02$, or quadratic Valence effect, $F(1,16) = 0.07$, $p = .792$, $\eta^2_p = .00$.

P3 Amplitude

Figure 7 displays mean P3 amplitudes at PZ for pleasant, neutral, and aversive cues for control and depressed groups. The 3 x 2 mixed ANOVA showed a significant Group x Valence interaction, $F(2,65) = 3.78$, $p = .028$, $\eta^2_p = .10$. Planned within-subjects contrasts revealed no significant linear Group x Valence effect, $F(1,66) = 0.43$, $p = .514$, $\eta^2_p = .10$, but there was a significant quadratic Group x Valence effect, $F(1,66) = 5.57$, $p = .021$, $\eta^2_p = .08$. Main effect of Valence was not significant, $F(2,65) = 0.51$, $p = .600$, $\eta^2_p = .02$. Within-subjects contrasts exhibited no linear, $F(1,66) = 0.02$, $p = .318$, $\eta^2_p = .01$, or quadratic Valence effect, $F(1,66) = 5.57$, $p = .887$, $\eta^2_p = .00$.

Separate multivariate ANOVAs showed a significant Valence effect control group, $F(2,35) = 3.95$, $p = .028$, $\eta^2_p = .18$. Specifically, within-subjects contrasts did no display a significant linear, $F(1,36) = 1.85$, $p = .182$, $\eta^2_p = .05$, or quadratic Valence effect control group, $F(1,36) = 2.74$, $p = .107$, $\eta^2_p = .07$. The depressed group did not show a significant main effect of Valence, $F(2,29) = 1.37$, $p = .269$, $\eta^2_p = .09$. Within-subjects contrasts showed there was no significant linear, $F(1,30) = 0.05$, $p = .831$, $\eta^2_p = .00$, or quadratic Valence effect, $F(1,30) = 2.83$, $p = .103$, $\eta^2_p = .09$.

LPP

Figure 8 exhibits mean LPP at CZ during pleasant, neutral, and aversive pictures for control and depressed groups. There was a significant Group x Valence interaction, $F(2,65) = 4.51$, $p = .015$, $\eta^2_p = .12$. Planned within-subjects contrasts did not show a significant linear Group x Valence interaction, $F(1,66) = 1.10$, $p = .297$, $\eta^2_p = .02$, but it did reveal a significant quadratic Group x Valence interaction, $F(1,66) = 9.02$, $p = .004$, $\eta^2_p = .12$. In addition, the 3 x 2 ANOVA revealed a significant main effect of Valence, $F(2,65) = 40.89$, $p < .001$, $\eta^2_p = .56$. Specifically, within-subjects contrasts did no exhibit a significant linear Valence effect, $F(1,66) = 0.46$, $p = .502$, $\eta^2_p = .01$, but there was a significant quadratic Valence effect, $F(1,66) = 80.89$, $p < .001$, $\eta^2_p = .55$.

Separate multivariate ANOVAs revealed a significant main effect of Valence for the control group, $F(2,35) = 44.81$, $p < .001$, $\eta^2_p = .72$. Specifically, within-subjects contrasts did not exhibit a significant linear Valence effect, $F(1,36) = 1.32$, $p = .259$, $\eta^2_p = .03$, but there was a significant quadratic Valence effect, $F(1,36) = 90.31$, $p < .001$, $\eta^2_p = .71$. The multivariate ANOVA showed a significant Valence effect depressed group, $F(2,29) = 7.53$, $p = .002$, $\eta^2_p = .34$. Within-subjects contrasts revealed there was no significant linear Valence effect, $F(1,30) = 0.91$, $p = .765$, $\eta^2_p = .00$, but there was a significant quadratic Valence effect, $F(1,30) = 14.32$, $p < .001$, $\eta^2_p = .32$.

Correlations between Depressive Symptomatology and Psychophysiology

Correlations were performed in the depressed group to investigate the relationship between depressive symptomatology and several psychophysiological measures. Table 3 shows correlations between depressive symptomatology and postauricular reflex magnitude. The correlations between depressive symptomatology and startle blink reflex magnitude are shown in Table 4. Table 5 and Table 6 display the correlations between depressive symptomatology and ERP measures.

Discussion

Self-reports showed expected results in both control and depressed groups. Depressed participants displayed more symptoms related to anhedonia and negative affect in comparison to the control group. In addition, depressed participants scored lower on MPQ scales on well-being and positive emotion. Most of our results support the low positive emotionality model of emotional dysfunction. Both the postauricular reflex and P3 measured at PZ displayed a reduced magnitude during pleasant stimuli. To further support the low positive emotionality model, correlations between depressive symptomatology and the postauricular reflex showed a negative correlation during pleasant stimuli. Further correlations were performed with startle blink reflex and ERP measures, but there were no significant findings. Results for LPP during pictures aligned with literature on ECI, which supports an emotional withdrawal hypothesis (Nesse, 2000).

As expected, our results were aligned with previous studies on the postauricular reflex, which demonstrated a potentiation of the reflex for pleasant stimuli when compared to neutral and aversive stimuli and an attenuation of mean magnitude during aversive stimuli in comparison to neutral stimuli (Benning, 2011; Benning, Patrick, & Lang, 2004; Sandt, Sloan, & Johnson, 2009). The postauricular reflex is a valid psychophysiological measure of positive emotion, so it would be a useful tool for identifying any deficits in positive affect in depression.

In this study, the postauricular reflex identified reductions in emotional reactivity to pleasant stimuli for the depressed group when compared to the control group. These findings also support the low positive emotionality model of emotional dysfunction, which emphasizes the lack of positive affect that characterizes depression (Clark, Watson, & Mineka, 1994). In further support of low positive emotionality, depressive symptomatology in our depressed group was negatively correlated with postauricular reflexes to pleasant stimuli (see Table 3). Measures specific to the dampening of positive affect may be better predictors of depression than tools focusing on negative affect (Raes, Smets, Nels, & Schoofs, 2012).

Deficits in motivational “wanting” and hedonic “liking” are common symptoms associated with anhedonia in depression (Berridge, 2009; Berridge & Kringelbach, 2008; Berridge & Robinson, 2003; Treadway, Buckholtz, Schwartzman, Lambert, & Zald, 2009). During pictures and sounds, which were used to investigate “liking,” the results for the postauricular reflex showed trends aligning with theories on low positive emotionality, and our findings for the startle blink reflex exhibited patterns agreeing with ECI. But during cues, which measured motivational “wanting,” neither psychophysiological measure displayed consistent trends. It is possibly due to the postauricular and startle blink reflexes being good measures of hedonic “liking,” but inadequate measures of motivational “wanting.” Based on these assumptions, the postauricular and startle blink reflexes index consummatory processes and are poor measures of anticipatory processes.

Results for P3 amplitude to cues at PZ were similar to Cavanaugh and Geisler (2006), which found reduced P3 amplitude in participants with subclinical depression during the presentation of happy faces, and the study also found that P3 latencies were highly correlated with happy faces and showed a weaker correlation with fearful faces. The current study expands the attenuation of P3 amplitude to pleasant stimuli to motivational "wanting" in clinical depression. In contrast with the postauricular and startle blink reflex measures, ERP components like P3 may be better tools to measure motivational "wanting." Low positive emotionality is also supported by these results based on the reduction in amplitude specific to pleasant stimuli.

Previous findings support LPP reflecting selective attention allocation towards emotional stimuli of several valence types (Schupp, Flasisch, Stockburger, & Junghofer, 2006), and consistent with Kujawa and colleagues (2012), LPP displayed reduced reactivity to pleasant, neutral, and aversive stimuli supporting ECI theory. Even though both studies support ECI theory, the current study has some major differences to the study conducted by Kujawa and colleagues. Our participants were adults and LPP results were specific to reactivity during pleasant, neutral, and aversive pictures at CZ, and the latter study was specific to emotional modulation in the occipital regions for children. With those differences aside, both results support the ECI hypothesis that emotional withdrawal may have been evolutionary adaptive in depression, which led to avoidance of threat or harm (Nesse, 2000).

The current study focused on hedonic "liking" and motivational "wanting" in processes of positive emotion. The psychophysiological tools investigated in this study are potential biomarkers for identifying deficits in processing pleasure. Specifically, low magnitude of the postauricular reflex during pleasant pictures may be a good indicator of anhedonia in depression. Using this tool in the assessment of depression can potentially improve assessment and provide comprehensive treatment, but much more research is needed before this is possible. We found that integral psychophysiological tools used in this study were not good measures of the anticipatory processes involved with motivational "wanting." It will be important to further assess measures that index anticipatory processes or implement stimuli that more accurately reflects "wanting." All picture and sound stimuli derived from IAPS and IADS. Therefore, future studies should employ different databases of stimuli to investigate possible differences in outcomes.

The current study had a control group limited to UNLV undergraduates and depressed participants were recruited from the community over the Internet. Future studies with a community-based control and depressed group may produce stronger effects. The sample size did not have a desirable number of participants, so further research will need to include larger sample sizes to make more accurate conclusions. The current study excluded those diagnosed with bipolar disorder, substance abuse problems, and traumatic brain injuries. Future studies should implement psychophysiological tools in these populations. In addition, the mean age of participants was twenty-six. Additional studies will be needed to investigate if similar effects are found in older control and depressed groups.

Conclusion

The postauricular reflex, startle blink reflex, and ERP components such as P3 and LPP are useful tools for investigating anhedonia in depression for several models of emotional dysfunction. A majority of the psychophysiological measures utilized in the current study support the hypothesis that depression is characterized by a lack of positive emotion, which is different from other internalizing disorders like anxiety. LPP results for this study support previous findings that depression leads to context insensitivity to emotional stimuli, but there were significant differences between the current study and previous findings. Our findings follow the trend in the depression literature to emphasize the importance of positive emotion in assessment and treatment of this illness, and it supports the movement to implement a holistic clinical and research process that utilizes both behavioral and psychophysiological tools to improve assessment and treatment of depression.

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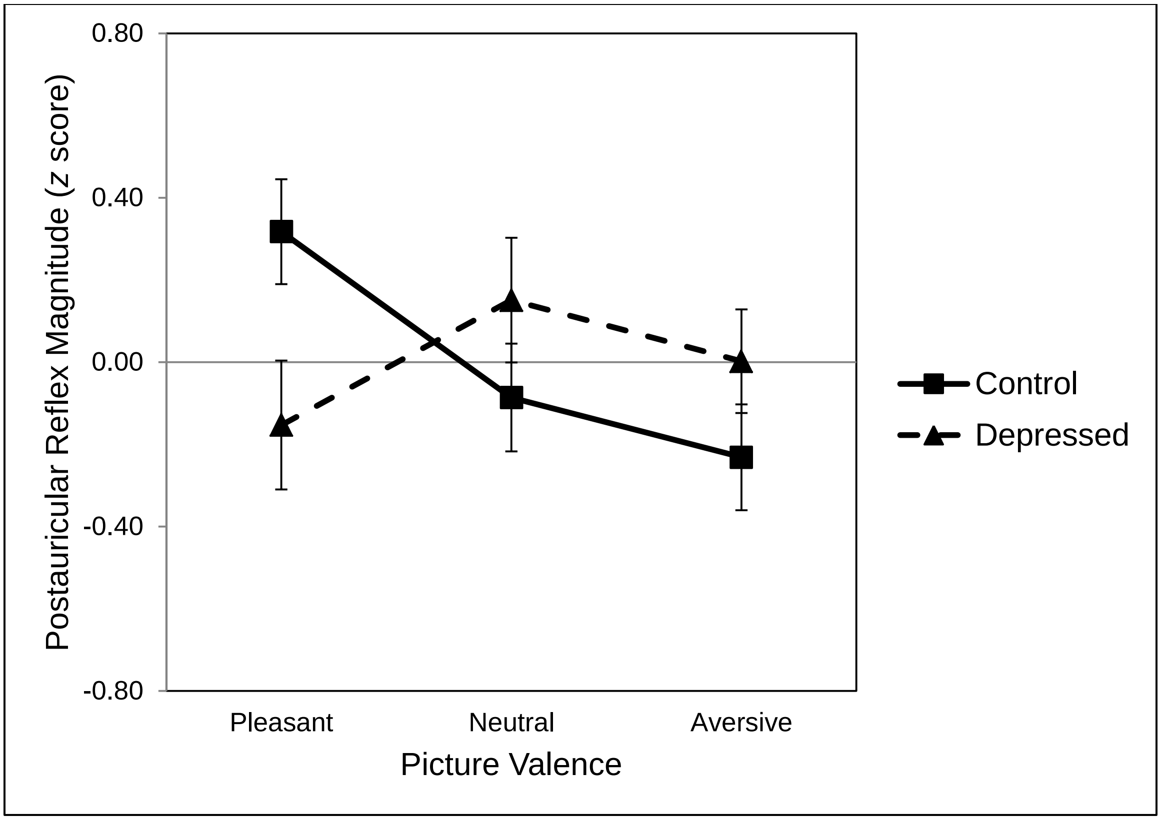

Figure 1. Postauricular reflex magnitudes during pleasant, neutral, and aversive pictures. Error bars represent standard errors of the mean.

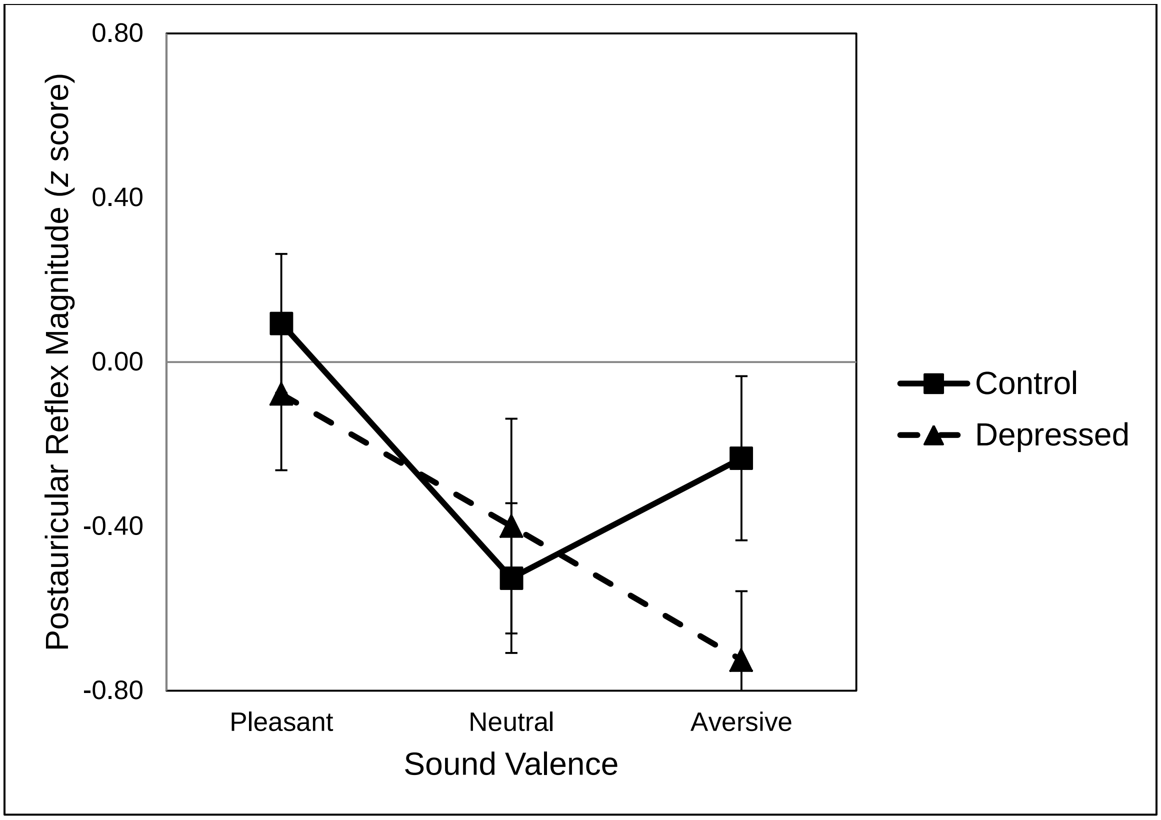

Figure 2. Postauricular reflex magnitude during pleasant, neutral, and aversive sounds. Error bars represent standard errors of the mean.

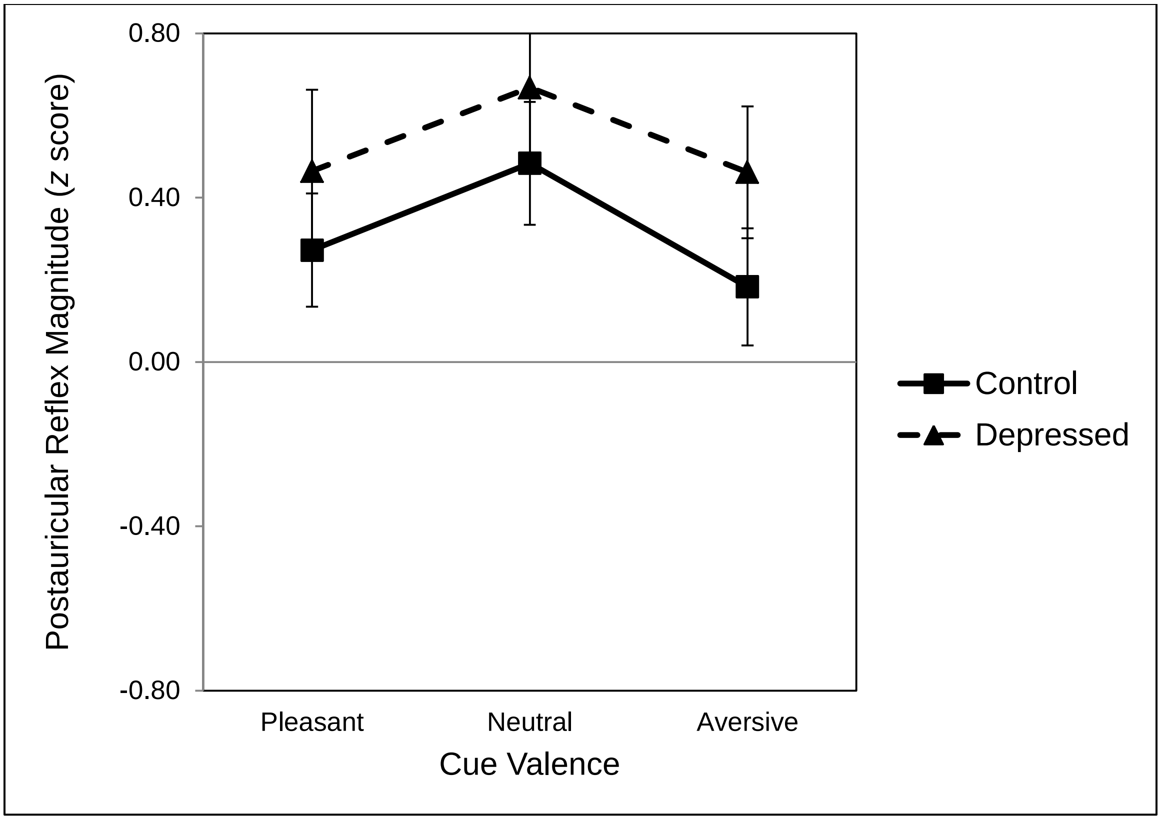

Figure 3. Postauricular reflex magnitude during pleasant, neutral, and aversive cues. Error bars represent standard errors of the mean.

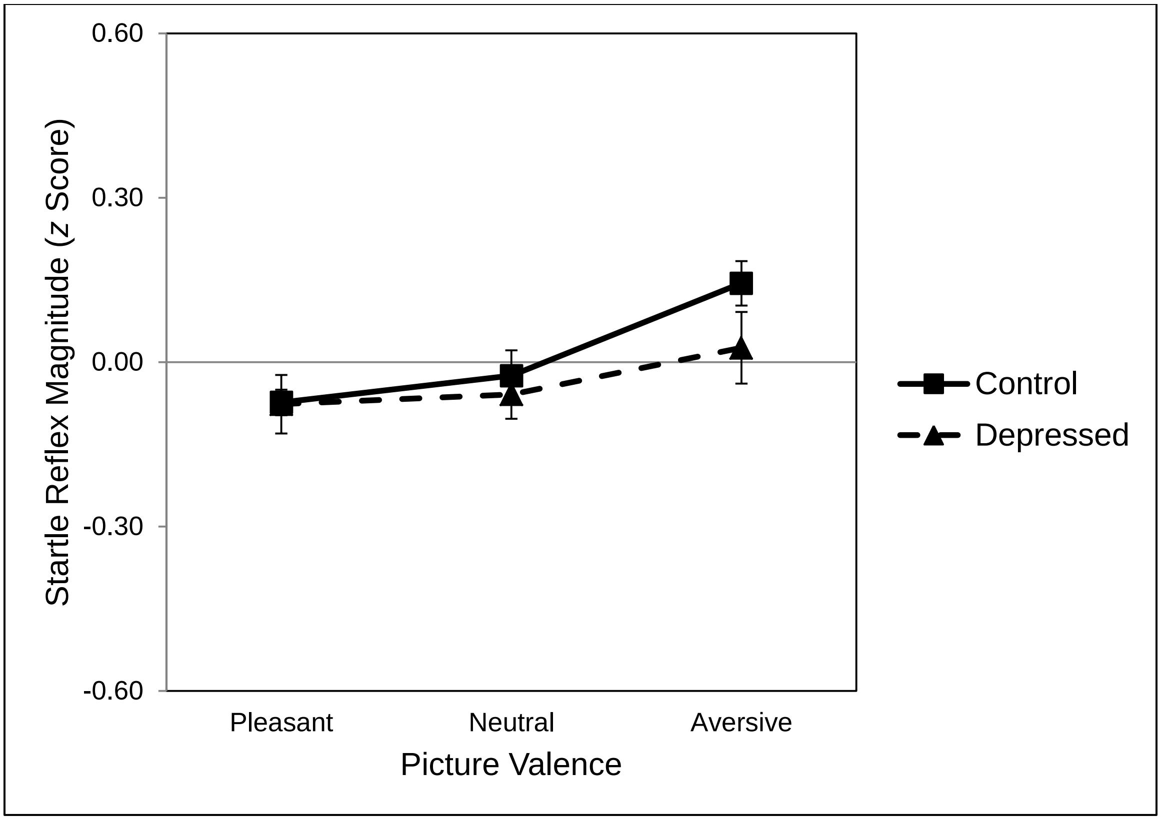

Figure 4. Startleblink reflex magnitude during pleasant, neutral, and aversive pictures. Error bars represent standard errors of the mean.

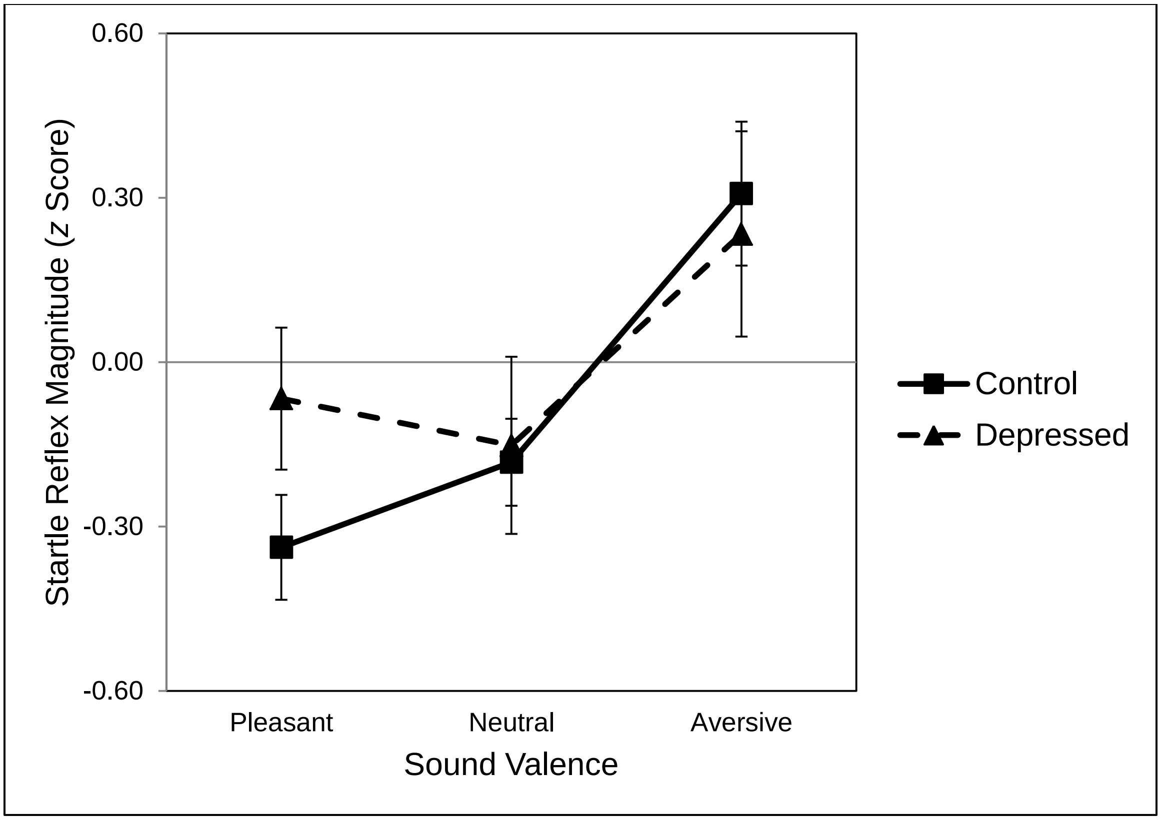

Figure 5. Startle blink reflex magnitude during pleasant, neutral, and aversive sounds. Error bars represent standard errors of the mean.

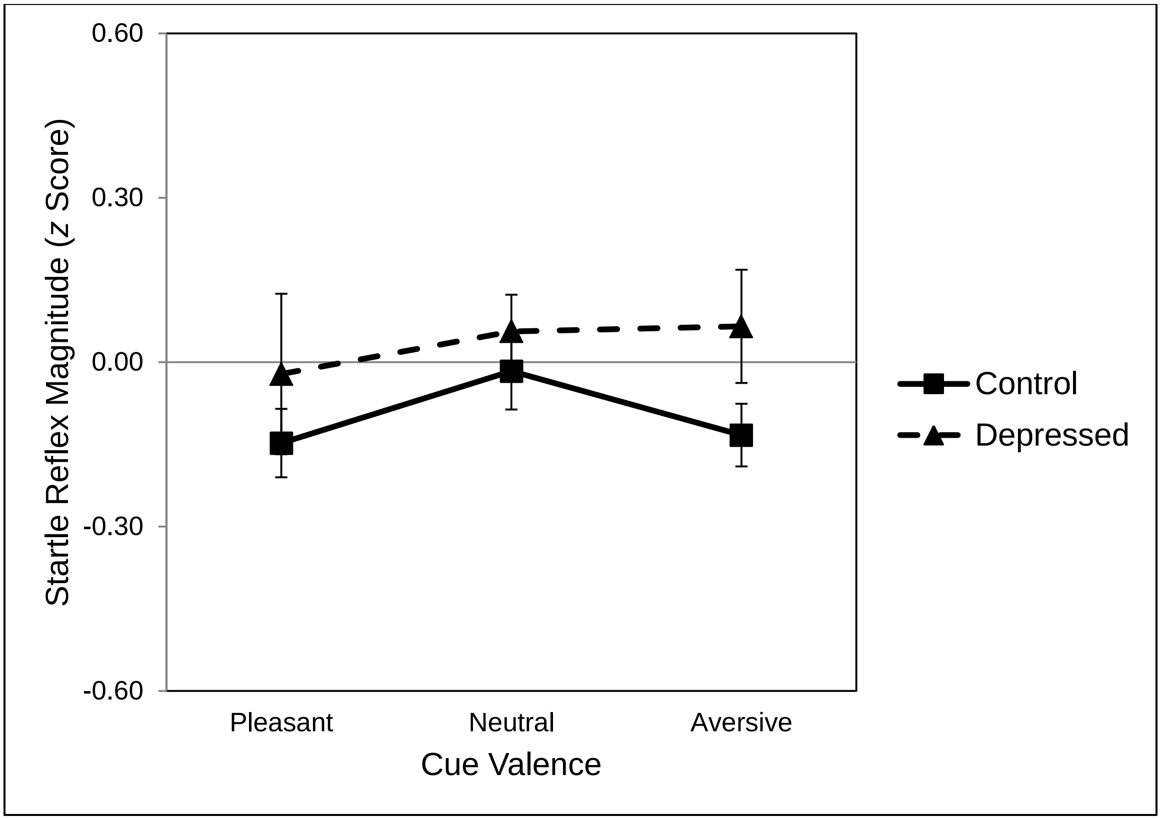

Figure 6. Startle blink reflex magnitude during pleasant, neutral, and aversive cues. Error bars represent standard errors of the mean.

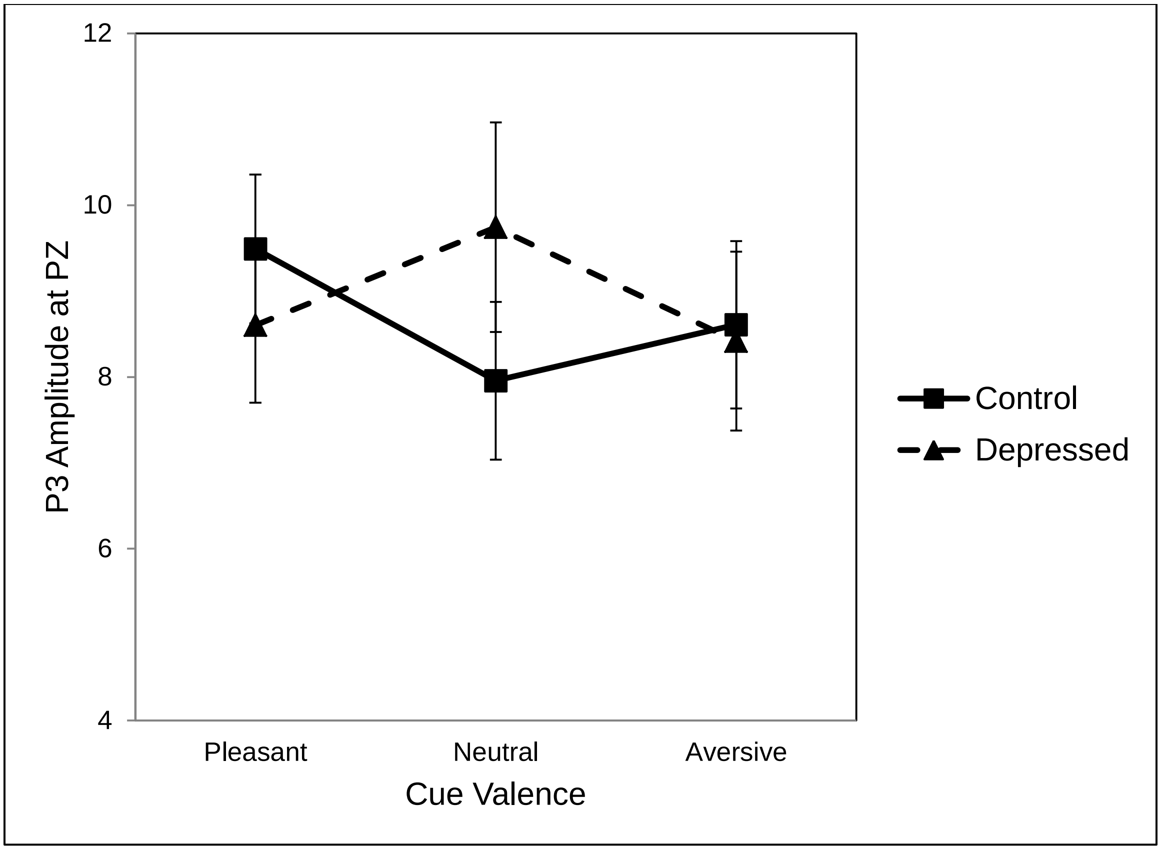

Figure 7. Mean P3 amplitudes at PZ during pleasant, neutral, and aversive cues. Error bars represent standard errors of the mean.

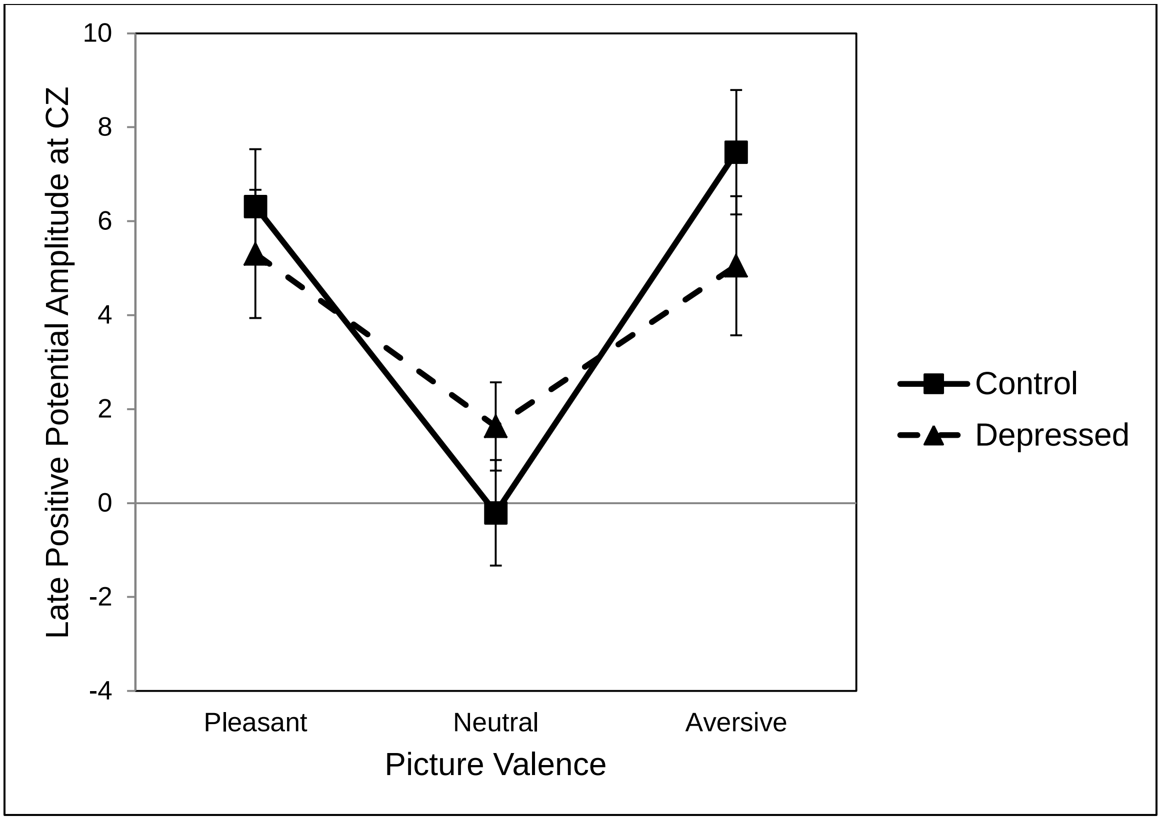

Figure 8. Mean Late Positive Potential (LPP) at CZ during pleasant, neutral, and aversive pictures. Error bars represent standard errors of the mean.

Table 1.

Independent-samples t-tests between for MPQ scores between the control and depressed group.

Measure	Control	Depressed	*t*	*df*	*p*
Well-being	52.4 (9.24)	32.7 (10.81)	7.73	60	<.001
Social Potency	54.9 (7.37)	51.2 (9.54)	1.71	60	.092
Achievement	54.23 (8.27)	49.5 (10.40)	1.97	60	.053
Social Closeness	52.7 (8.28)	40.1(10.83)	5.18	60	<.001
Stress Reaction	48.1 (7.80)	64.3 (5.08)	-9.68	60	<.001
Alienation	54.7 (8.60)	64.6 (8.15)	-4.67	60	<.001
Aggression	49.1 (9.07)	55.0 (10.85)	-2.29	60	.025
(planful) Control	50.4 (8.76)	46.6 (11.90)	1.43	60	.157
Harm Avoidance	45.6 (9.52)	44.7 (8.12)	0.40	60	.689
Traditionalism	45.5 (7.21)	40.3 (8.68)	2.61	60	.011
Absorption	55.1 (7.64)	56.2 (8.87)	-0.52	60	.604
Positive Emotion	56.1 (7.89)	40.0 (11.21)	6.52	60	<.001
Negative Emotion	51.6 (7.67)	63.9 (6.67)	-6.75	60	<.001
Constraint	45.8 (8.90)	41.1 (8.09)	2.19	60	.032

Note. Standard deviation listed in parenthesis. n = 31 for control group, n = 31 for depressed group.

Table 2.

Independent-Samples T-Tests for Depressive Symptomatology Between Control and Depressed Groups.

Measure	Control	Depressed	*t*	*df*	*p*
IDS total	9.3 (2.73)	44.3 (8.83)	-20.92	54	<.001
Zung total	35.2 (7.12)	57.4 (7.24)	-11.49	54	<.001
Zung positive	19.4 (5.72)	30.1 (3.77)	-8.06	54	<.001
Zung negative	10.1 (2.97)	21.4 (4.43)	-11.44	54	<.001

Note. Standard deviation listed in parenthesis. n = 31 for control group, n = 25 for depressed group.

Table 3

Correlations Between Depressive Symptomatology and Postauricular Reflex Magnitude

Measure	Pleasant - Neutral	Aversive - Neutral	Pleasant - Aversive
IDS Total	-.56*	.49*	.08
Zung Total	-.13	.05	.10
Zung – Positive Subscale	-.24	.18	.06
Zung – Negative Subscale	-.18	-.04	.28

Note. * $p < .05$. $n = 17$

Table 4

Correlations Between Depressive Symptomatology and Startle Blink Reflex Magnitude

Measure	Pleasant - Neutral	Aversive - Neutral	Pleasant - Aversive
IDS Total	.05	-.34	.41
Zung Total	-.42	-.03	.27
Zung – Positive Subscale	-.45	.02	.11
Zung – Negative Subscale	-.29	-.19	.27

Note. * $p < .05$. $n = 14$

Table 5

Correlations Between Depressive Symptomatology and P3 Amplitude

Measure	Pleasant - Neutral	Aversive - Neutral	Pleasant - Aversive
IDS Total	-.19	-.02	-.18
Zung Total	-.09	.10	-.02
Zung – Positive Subscale	-.11	.12	-.13
Zung – Negative Subscale	-.23	-.15	-.13

Note. * $p < .05$. $n = 25$

Table 6

Correlations Between Depressive Symptomatology and LPP Amplitude

Measure	Pleasant - Neutral	Aversive - Neutral	Pleasant - Aversive
IDS Total	-.12	-.18	-.26
Zung Total	-.15	-.11	-.33
Zung – Positive Subscale	-.12	-.03	-.23
Zung – Negative Subscale	-.26	-.25	-.34

Note. * $p < .05$. $n = 25$