AN EEG INVESTIGATION OF A DEPRESSIVE SELF-SCHEMA RELATED TO LEVELS OF PROCESSING IN INDIVIDUALS WITH HIGH DEPRESSIVE SYMPTOMATOLOGY

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ABSTRACT

Individuals with high depressive symptomatology have better memory for negative events than positive events. The preferential processing of negative information supports the theory of a depressive self-schema in individuals diagnosed with depression (Beck, 1979). Processing information through a depressive self-schema (or mindset) can perpetuate negative rumination and worsen the symptoms related to depression. Although it is well established that individuals with high depressive symptomatology remember more unpleasant information than positive or neutral information, not as much is known about whether or not these individuals possess a selective bias for processing depression-related unpleasant information (i.e., words such as lonely, sadness, lethargy) over other unpleasant information (i.e., words such as rotten, seasick, victim). To investigate this phenomenon, electroencephalography (EEG) was used to measure the temporal resolution of brain activity while individuals who score high and low in symptoms of depression participated in an event-related memory task involving unpleasant (depression-related and general) and neutral words. Contrary to the initial hypothesis, individuals with high depressive symptomatology did not show a selective memory benefit for unpleasant depression-related information over and above generally unpleasant and neutral information at all levels of processing. Nor did they exhibit within-group differences in event-related potential (ERPs) corresponding to processing depression-related content versus generally unpleasant content. However, individuals with high depressive symptomatology did exhibit between-group differences in mean reaction time, ERPs, and alpha band activity in comparison to individuals with low depressive symptomatology. These findings provide supporting evidence of a distinction in implicit processing (i.e. mean reaction time) and neural processing (i.e. ERPs related to unpleasant and neutral processing) between groups of high and low depressive symptomatology.

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CHAPTER 1

INTRODUCTION

1.1 Levels of Processing

Varying levels of processing (shallow versus deep processing) can influence the formation of long-term memories. Level of processing (LOP) effects were first investigated by Craik and Lockhart (1972) in reference to the notion that the depth of mental processing at encoding ultimately influences memory retrieval, such that deeper processing tends to result in better long-term memory retention, whereas shallow processing tends to result in poorer retention of long-term memories. When attempting to remember more than a single item of information, such as an item and its context, binding among those items is required to form a coherent memory representation. This kind of deep processing requires a greater level of cognitive demand due to the need to forge an association or relational binding of multiple items. According to Lockhart and colleagues (1976; 1990), the greater the relational binding, the better the retrieval of that information. In contrast, shallow processing does not involve the same degree of binding and only requires that an individual perceive the superficial and perceptual features of an item. Shallow processing can be beneficial in preserving cognitive resources but is often detrimental to the long-term memory formation process.

Deep processing involves actively manipulating information while considering the semantic meaning of the item (Hunt & Einstein, 1981; Humphreys, 1978). The prefrontal cortex (PFC) is involved in processing both item-specific (i.e. shallow processing) and associative (i.e. deep processing) information. More specifically, neuroimaging studies have found increased ventrolateral prefrontal cortex (VLPFC) activity during shallow processing and increased dorsolateral prefrontal cortex (DLPFC) activity during deep processing (Badre & Wagner, 2007;

D'Esposito et al., 1999; Wagner et al., 2001). These findings, and many others, suggest that the VLPFC and DLPFC have functionally distinct roles in regards to level of processing effects (Petrides, 1994; Owen, 1997; D'Espositio et al., 1999). Evidence provided from neuroimaging studies suggest that deeper processing, or the lack thereof, may be related to functions of the PFC. Importantly, the benefit of deeper processing resulting in better long-term memory may not be present in populations with neurological disorders that involve disorders in PFC activity, such as in depression.

1.2 Emotional Memory

In addition to the initial level of processing, the emotional valence of the content to be remembered can significantly influence memory formation. In fact, researchers have consistently found that emotional events tend to be remembered better than nonemotional events (Bradley et al., 1992). However, these effects tend to be more pronounced in females. More specifically, studies have shown that women tend to report more negative affect than men, whereas no gender differences are reported for positive affect (Fujita et al., 1991; Kessler et al., 2006). Prior research has also reported that women are more likely than men to ruminate about negative thoughts and experiences (Butler & Hoeksema, 1994). Although depression is more frequently diagnosed in women than in men (Kessler, 2003; Paykel, 1991), many underlying social factors may contribute to the higher prevalence of female depression. For instance, it is more socially acceptable for women in the United States to freely talk about their emotions, whereas men tend to be more reserved in identifying and discussing their emotions. Apart from gender, highly arousing content is more likely to be remembered than low arousing content despite the pleasantness of the emotion (Bradley et al., 1992). For this reason, all of the unpleasant words presented in the study were matched for levels of emotional valence and arousal.

Various neuroimaging techniques have been used to identify crucial brain regions involved in emotional processing (Cahill et al., 1996; Phelps & Anderson, 1997). The prefrontal cortex (PFC) and the amygdala have consistently been reported to be highly involved in emotional regulation and social behavior (i.e. two domains commonly impaired in individuals with high depressive symptomatology). However, other brain regions such as the ventral striatum, anterior cingulate, posterior parietal, and insula regions have also been reported to contribute to the evaluation of emotional content (David & Irwin, 1999; Lane & Nadel, 2000). The amygdala's role in emotional processing has long been investigated in both human and animal studies of emotional learning (Aggleton, 1992; Adolphs et al., 1994; Phelps, 2006; Wang et al., 2014). This region of the brain is responsible for processing a wide variety of emotions and does not discriminate towards a particular valence. For example, neuroimaging studies using positron emission topography (PET) and function magnetic resonance imaging (fMRI) have reported that the amygdala is involved in processing both pleasant and unpleasant stimuli (Morris et al., 1996; Schneider et al., 1997).

Additionally, a meta-analysis of emotional processing was conducted by Phan et al. (2002). Phan and colleagues reviewed 55 different neuroimaging studies (fMRI and PET) and concluded that the medial prefrontal cortex, amygdala, anterior cingulate, occipital lobe, and insula play a critical role in processing emotional information. Although the data suggested that most emotions are processed by a network of brain regions, some emotions such as sadness and fear appeared to be specific to particular regions. They found that fear was specifically engaged in the amygdala and sadness was specifically correlated with activation in the subcallosal cingulate. Relevant to the present study, Fossati and colleagues (2003) used an fMRI to distinguish processing differences between positive and negative words in healthy individuals. The authors

found that processing positive words produced greater activation in the right dorsomedial prefrontal cortex as compared to processing negative words. Fossati et al. also observed decreased activity in the insula, temporal regions, and inferior parietal regions when processing negative words. These findings suggest that emotional processing relies on a wide network of brain regions but that distinctions among different types of emotions (pleasant versus unpleasant) can be observed at a neural level.

Moreover, imaging studies using emotional stimuli have reported that the number of emotional items remembered is correlated with encoding activity in the amygdala and hippocampus (Cahill et al., 1996; Hamann et al., 1999). More recently, an event-related fMRI study found that left amygdala activity while encoding information predicted later memory performance for unpleasant pictures (Canli et al., 2000). A distinction of encoding between unpleasant depression-related items versus generally unpleasant, but not depression-related, items has not yet been examined to the best on my knowledge.

Electroencephalography (EEG) investigations of emotions commonly use a comparison of event-related potentials (ERPs) to assess different aspects of complex emotional processing. ERP studies of emotion have identified a consistent pattern of electrical potential in response to emotional stimuli. More specifically, ERPs for emotional stimuli (pleasant or unpleasant) tend to be more positive-going than ERPS for neutral stimuli (Cuthbert, et al., 2000; Vanderploeg et al, 1987). The greatest ERP effects related to emotional processing occur during the P300, N300, and the slow wave (SW) component. In general, researchers have found that the P300 component is more sensitive to emotion under intentional emotional processing, whereas the N300 component is more sensitive during incidental emotional processing (Carretie et al., 1997;

Diedrich et al., 1997). This study implemented an intentional emotional processing paradigm and assessed similar components of the ERP wave in relation to emotional memories.

A previous study which measured ERPs during the encoding of emotional and neutral pictures found that the slow wave component of ERPs (600 – 900 ms) recorded from a parietal electrode was positively correlated with the number of subsequently remembered slides (Palomba et al., 1997). More recently, researchers have found similar ERP differences in the slow wave component when the participants were processing unpleasant information compared to when the participants were processing neutral information (Moser et al., 2006; Hajcak & Nieuwenhuis, 2006; MacNamara et al., 2009). In particular, neural activity during the slow wave component of an ERP increased in response to processing unpleasant pictures and decreased in response to processing neutral pictures (Foti & Hajcak, 2008).

As noted earlier, brain activity during encoding ultimately influences later memory retrieval. For this reason, a subsequent memory paradigm was used in conjunction with an EEG to determine which brain regions are critical for encoding information that is later remembered. In a subsequent memory paradigm, encoding trials are sorted according to whether the item presented in each trial (study session) was later remembered or forgotten in a subsequent memory test (long-term memory session). Using a subsequent memory paradigm in conjunction with an EEG can reveal if emotional events, particularly those associated with a depressive self-schema, are better remembered as a result of better encoding (Brewer et al., 1998). Additionally, research has shown that ERPs for items that are subsequently remembered tend to be more positive-going than ERPs for items that are subsequently forgotten (Sanquist et al., 1980).

Differences in ERP activity during the encoding phase of memory that correspond to information later remembered or forgotten is known as the subsequent memory effect.

Subsequent memory effects most commonly occur over the frontal and parietal regions of the brain. This effect can be detected as early as 300 – 400 ms and can persist beyond 1,200 ms (Rugg et. al., 1996). For this study, it was predicted that subsequent memory effects would be modulated by the emotional content (depression-related vs generally unpleasant) of the encoded stimuli in individuals with high depressive symptomatology but not in individuals with low depressive symptomatology.

1.3 Memory Impairments in Depression

Dysfunctions of memory are often found in symptoms of neurological and psychiatric disorders such as dementia, schizophrenia, Alzheimer's disease, amnesia and the focus of this proposal, major depressive disorders or individuals who have high depressive symptomatology (Nestor et. al., 2006; Ragland, 2012). A recent meta-analysis suggests that individuals with depression show impairments in long-term memory, but it is unclear whether these impairments are caused by a broad deficit in memory overall or are instead the result of a selective memory deficit (Austin et al., 1992; Austin et al., 2001; Burt et al., 1995; Iisley et al., 1995). Previous studies have successfully used an EEG to detect electrophysiological changes when investigating attention and memory in depression (Armitage & Hoffman, 2001; Brenner et al., 1986; Grimshaw et al., 2014).

Studies have consistently reported impairments in attentional and executive control among clinically depressed individuals, which suggests impairments in working memory (WM) (Beats et al., 1996; Raskin et al., 1982; Silberman et al., 1983). In addition, studies using rodent models and clinical studies of depressed patients have found impairments in associative memory (deep processing ability). This impairment may reflect a deficit in the ability to allocate the appropriate cognitive resources required for the more demanding tasks (Cohen et al., 1982; Roy-

Byrne et al. 1986). However, other studies have suggested that the memory impairments in depression may be independent of the inability to appropriately allocate cognitive resources during difficult tasks (Golinkoff & Sweeney, 1989). To address this unresolved issue, individuals who score high in symptoms of depression completed a shallow processing task and a deep processing task to determine if a selective depressive bias exists regardless of the level of cognitive demand required by the task.

A recent meta-analysis of cognitive performance in major depressive disorder reported consistent deficits in executive function which correlated with the severity of current depressive symptoms (Snyder, 2013). In addition, recent neuroimaging data have also supported the findings of impaired executive function in depression (Goeleven et al., 2006; Yao et al., 2010). Individuals with depression display impairments in planning, cognitive inhibition, attentional control and problem solving. Letkiewicz and colleagues (2014) found that poorer performance on executive function tasks involving set shifting, inhibition, and working memory predicted depressive symptoms in individuals at risk for depression. Furthermore, these deficits in executive function were accompanied by various abnormalities in neural activity and neurochemicals in individuals with major depressive disorder (Drevets et al., 2008). Some researchers have suggested that neurochemical alterations in the serotonergic and dopaminergic neural systems lead to the onset and development of depression (Chaudhury et al., 2013; Risch and Nemeroff, 1992; Shabbir et al., 2013).

Magnetic resonance imaging (MRI) studies have revealed structural abnormalities in individuals with depression (Drevets et al., 2008; Lorenzetti et al., 2009). Koolschijn et al. (2009) analyzed brain volume differences in 2,418 patients with major depressive disorder and observed decreased brain volume in the orbitofrontal prefrontal cortex and anterior cingulate

compared to healthy controls. More recently, Videbech and Ravnkilde (2015) analyzed MRI data from over 350 patients diagnosed with depression and observed reduced hippocampal volume in comparison to healthy subjects. The hippocampus is necessary for relational binding and the encoding of new information. Reduction in hippocampal volume may contribute to severe memory impairments commonly observed in depression. Additionally, EEG research has also provided evidence of functional abnormalities in depression (Fingelkurts et al., 2007; Knott et al., 2001; Pizzagalli et al., 2003). Fingelkurts and colleagues found dysfunctions in alpha and theta band activity in individuals with depression. Both alpha and theta bands have been shown play a critical role in semantic and episodic memory (Klimesch et al., 1994; Klimesch, 1999).

Other researchers have focused on the influence of default network activity and emotional processing in depression. Lesioning studies have revealed that the medial prefrontal cortex is critically involved in processing emotions (Hornak et al., 2003). In particular, researchers have suggested that abnormalities in the subgenual cingulate, a subregion of the medial prefrontal cortex, may underlie the poor emotional regulation and rumination often found in depression (Abler et al., 2008). Activity in the subgenual cingulate has also been reported to be positively correlated with the length of current depressive episodes in individuals with major depressive disorder (Greicius et al., 2007). Moreover, the subgenual cingulate, anterior cingulate, parietal cortex, temporal cortex, and other regions of the medial prefrontal cortex have been shown to be involved in the connectivity of a larger "default mode network". The default mode network remains active during the passive resting state of an individual (i.e. an individual is not focused on any particular task or event). Individuals with depression have been shown to have a hyperactive default network which contributes to impairments in executive control and emotional regulation (Sheline et al., 2009). Shelina and colleagues found that viewing negative

pictures elicited significantly greater activity in regions of the default mode network in individuals with depression as compared to healthy controls. These findings are interesting because activity in the default mode network typically decreases during goal-oriented tasks (Fox et al., 2005). It appears that an overactive default network may perpetuate symptoms of rumination and cognitive impairments commonly observed in depression. However, additional neuroimaging research is needed to fully understand the mechanism of depression and default mode network activity.

Bistricky and colleagues (2013) found supporting neural evidence of a negative information processing bias among individuals with major depressive disorder. Specifically, the ERP results of depressed individuals revealed a greater P300 amplitude following the presentation of a sad face compared to happy or neutral faces. More recently, Zhang and colleagues (2016) found similar results with greater P300 effects occurring during the unconscious processing of sad faces as compared to happy or neutral faces. Zhang and colleagues also detected differences in P100 and N200 effects between depressed individuals and healthy controls. These results suggest that an emotional processing bias toward negative information exists at an explicit and implicit level of processing. In addition, individuals with depression require a greater intensity of emotion to correctly identify happy faces but the same degree of emotional intensity is not required for accurately identifying sad and angry faces (Joorman & Gotlib, 2006). Moreover, individuals with depression display better recognition and longer reaction times when identifying sad faces as compared to happy faces (Gollan et al., 2008; 2010).

Additionally, studies have used emotional words to assess emotional processing in depression (Canli et al, 2004; Roiser et al., 2009). Recently, Dai and Feng (2011) used an EEG to

compare cognitive inhibition performance between individuals with major depressive disorder, subclinical depression, and healthy controls. The authors used a modified emotional Stroop task and found that individuals with major depressive disorder exhibited deficits in attentional inhibition for negative words at both a behavioral and neural level. In particular, individuals with major depressive disorder displayed greater interference effects for negative words which was accompanied by a decrease in N100 amplitude for negative words and a decreased P100 amplitude for positive words. Additionally, individuals with major depressive disorder, as well as individuals with subclinical depression, displayed greater N400 effects over parietal regions when processing negative words as compared to individuals without depression. The deficit task performance on an emotional Stroop task is consistent with prior findings related to cognitive inhibition and emotional disorders (Yovel & Mineka, 2005).

Overall, it appears that emotional regulation is disrupted in individuals with depression. While the mechanism of emotional impairment is not entirely understood, Dannlowski and colleagues (2007) have argued that the dysregulation of emotional processing in depression may be caused by a hypoactive prefrontal cortex which results in a hyperactive amygdala. The prefrontal cortex is involved in higher mental processes such as cognitive inhibition and executive control. Typically, the prefrontal cortex will project to other regions of the brain to aid in cognitive control and inhibition. If the prefrontal cortex is hypoactive (as reported in depression), then less inhibitory inputs is communicated to the amygdala which leads to a lack of inhibition and emotional control. Functional MRI research has provided supporting evidence of dysfunctions in attentional control and emotional processing caused by abnormal activity in the prefrontal and amygdala (Kerestes et al., 2012; Meriau et al., 2006).

1.4 Depressive Self-Schema

A person's emotional state can also affect the encoding and retrieval process. Individuals with chronic depression are assumed to possess a depressive self-schema. The depressive self-schema is considered to play a critical role in the onset and continuation of depression (Dozois & Beck, 2008; Dozois et al., 2009). Individuals who possess a depressive self-schema have an exaggerated negative internal representation of the self that influences how they process and see the world. Processing information through a depressive self-schema (or mindset) can perpetuate negative rumination and worsen the symptoms related to depression (Brinker & Dozois, 2009). Evidence suggests that a depressive self-schema affects all aspects of information processing but is most influential for information processing related to the self.

Derry and Kuiper (1981) were among the first researchers to examine the effects of content-specific processing (i.e. specific processing for depression-related content) in individuals with clinical depression. Using a paradigm similar to Rogers and colleagues (1977), Derry and Kuiper asked individuals with clinical depression to make self-referent (does the word describes you?), semantic (does the word means the same as a given word?), and structural (does word contain small letters?) ratings in response to adjective words. Importantly, Derry and Kuiper added an additional component to assess for differences in content-specific processing by presenting non-depression (i.e. loyal, curious, amiable) and depression-related (i.e. helpless, weary, dismal) adjectives. The memory recall performance for the self-referent, semantic, and structural tasks was compared between individuals with clinical depression, individuals without depression, and individuals diagnosed with a psychiatric condition not related to depression. Consistent with previous research (Davis, 1979; Rogers et al., 1977), adjective recall was greatest for the self-referent task compared to the structural and semantic tasks for all of the

groups. However, individuals with clinical depression displayed a unique pattern of performance in the self-referent task that differed from individuals without depression and the psychiatric controls. Specifically, individuals with clinical depression recalled more of the depression-related adjectives than the non-depression related adjectives during the self-referent task. The preferential processing of negative information supports the theory of a depressive self-schema in individuals diagnosed with depression (Beck, 1979, 1988).

Beck argued that a depressive self-schema develops during early life and remains dormant until triggered by negative life events. Although a depressive self-schema is highly organized and efficient in encoding information, it can have a detrimental influence on the severity and duration of depression. In fact, studies have shown that a depressive self-schema is correlated with the severity of depressive episodes. Using an information processing task, Dozois and Dobsin (2001) found that individuals who had improved from a depressive episode also showed an increase in processing pleasant content and a decrease in processing unpleasant content. These findings suggest that a depressive self-schema is responsible for the rapid identification of depression-specific information. The rapid identification of negative information in with high depressive symptomatology increases the ease of memory retrieval and leads to faster reaction times when remembering unpleasant memories. Overall, it is easier for individuals with high depressive symptomatology to process and remember negative information than positive information.

Clark and Teasdale (1982) investigated the retrieval accessibility of negative and positive memories in individuals with clinical depression. In this study, participants were shown a series of neutral words and asked to try to recall a real-life experience brought to mind when hearing the neutral word. The authors found that participants who were in a more depressed state of mind

were more likely to recall unhappy experiences than happy experiences. Additionally, retrieval latency was faster when remembering unhappy experiences compared to happy experiences. On the other hand, when participants reported that they were in a less depressed state of mind they displayed a greater recall for happy experiences compared to unhappy experiences. These findings suggest that current mood, as well as a depressive self-schema, can influence the nature of memory formation and recall in depression.

In a more recent study, Lim and Kim (2005) compared cognitive processing performance of emotional information related to implicit and explicit memory between individuals with clinical depression, panic disorder, and somatoform disorder. For this study, participants were presented with 4 different types of words (physical threat, positive, negative, and neutral) during an emotional Stroop and tachistoscopic identification task (implicit memory) and a free recall task (explicit memory). For implicit memory, the authors reported a supraliminal interference for negative for individuals with depression but not for individuals with panic disorder or somatoform disorder. For explicit memory, both individuals with depression and individuals with panic disorder displayed a memory benefit for negative words but not for individuals with somatoform disorder. These findings are interesting because they reveal that self-schemas and cognitive processing deficits are not consistent across individuals with different emotional disorders. Importantly, a depressive self-schema has been consistently reported in individuals diagnosed with depression.

The most effective method of treatment for individuals with a depressive self-schema involves cognitive restructuring. Cognitive restructuring can be achieved through cognitive-behavior therapy (CBT) and cognitive therapy (CT). CBT and CT are two types of psychotherapy that help individuals identify negative and unhealthy mental processes that are

contributing to their disorder and offer an action oriented plan of how to restructure and change the way the individual thinks. Pharmacotherapy has also been shown to be an effective treatment for individuals with a depressive self-schema. However, a study conducted by Segal and Colleagues (1999) reported that CBT was more effective at reducing negative mood and decreased the potential risk for later depressive relapse in comparison to pharmacotherapy.

Although it is well established that individuals with depression tend to remember more unpleasant information, not as much is known about whether or not these individuals possess a selective bias for processing depression-related unpleasant information over generally unpleasant (but not depression-related) information. To investigate this phenomenon, an electroencephalography (EEG) was used to measure the temporal resolution of brain activity while individuals who scored high and low in symptoms of depression participated in an event-related memory task involving unpleasant (depression-related and general) and neutral words. A subsequent memory paradigm was used to determine which brain regions were critical for successfully encoding information.

Using a measure of temporal resolution (ERPs), electrophysiological correlates related to the encoding of unpleasant and neutral words were compared between groups of high and low depressive symptomatology. All words were selected from the Affective Norms for English Words (ANEW) database. Unpleasant words were divided into two categories: (1) depression-related unpleasant words (i.e. lonely, sadness, lethargy) and (2) generally unpleasant words (i.e. rotten, seasick, victim). The two unpleasant word categories were matched for emotional arousal and valence and only differed with respect to their association with depression-related content. The neutral words were selected based on normative data indicating that they had moderate levels of valence and arousal.

1.5 Research Aims

The primary aim of this study was to determine if there was a selective bias for remembering depression-related information (i.e. a depressive self-schema) over generally unpleasant information in individuals with high depressive symptomatology. Additionally, the possible influence of a depressive self-schema in individuals with high depressive symptomatology was assessed at both a superficial and deep level of processing. It was predicted that individuals with high depressive symptomatology would display better memory for depression-related material over generally unpleasant and neutral information. In contrast, it was predicted that individuals with low depressive symptomatology would display better memory for unpleasant information over neutral information, but without showing a selective bias for depression-related content. To address this prediction, a memory paradigm using depression-related words, generally unpleasant (but not depression-related) words, and neutral words was developed. Moreover, a shallow and deep processing memory paradigm was used among individuals with high and low depressive symptomatology while the participant's corresponding behavioral and electrophysiological responses were monitored.

The secondary aim of this study was to determine whether brain activity during encoding could be used to predict later memory performance (i.e. subsequent memory effects). It was expected that individuals with high depression would exhibit differences in the event-related potentials (ERPs) associated with depression-related content compared to generally unpleasant but non-depression related content. In contrast, it was not expected that the same pattern of ERP performance would be exhibited between the unpleasant content for individuals with low depressive symptomatology because they do not possess a depressive self-schema. For this experiment, ERPs refer to evoked potentials in response to either depression-related words,

generally unpleasant but non-depression related words, and neutral words. Subsequent memory ERPs were measured by averaging the EEG brain activity associated with correctly remembering or forgetting a particular word.

A third post-hoc research aim was added to the study. The tertiary aim of this study was to determine if a Fourier transformation of brain activity (i.e. a power spectrum analysis) during encoding corresponded to later memory performance. It was expected that individuals with high depressive symptomatology would display differences in brain wave frequency corresponding to processing depression-related content versus generally unpleasant but non-depression related content. However, this same pattern of brain wave frequency was not expected for the low depressive symptomatology group due to the lack of a depressive-schema.

H1: It was predicted that individuals with high depressive symptomatology would have better memory for unpleasant content over neutral content compared to individuals with low depressive symptomatology.

H2: It was predicted that individuals with high depressive symptomatology would show a greater selective bias for depression-related unpleasant content over generally unpleasant but non-depression related content compared to individuals with low depressive symptomatology. Specifically, this selective bias would be expected to be greater during the deep processing task.

H3: It was predicted that individuals with high depressive symptomatology would exhibit differences in event-related potentials (ERPs) corresponding to processing depression-related content versus generally unpleasant but non-depression related content. However, the same ERP pattern was not expected for individuals with low depressive symptomatology.

H4: It was expected that individuals with high depressive symptomatology would display differences in brain wave frequency corresponding to processing depression-related content versus generally unpleasant but non-depression related content. The same frequency pattern was not expected for individuals with low depressive symptomatology.

CHAPTER 2

EXPERIMENTAL METHODS

2.1 Participants

40 young adults were recruited from the University of Texas at Arlington to participate in the study. Each participant completed a prescreen questionnaire that included the Center of Epidemiological Studies Depression Scale (CES-D), a measure which was used to identify groups of high and low depressive symptomatology. According to the standardized criteria used for scoring the CES-D scale, individuals with scores 25 or higher are considered to have moderate to severe symptoms of depression whereas individuals with scores 10 or below are considered to have minimal or no symptoms of depression (Radloff, 1977; Weissman et al., 1977). For this study, the same standardize criteria was used such that individuals with CES-D scores of 25 or higher were eligible to be part of the "high depressive symptomatology" group, which served as the experimental group. In contrast, individuals with CES-D scores of 10 and below were eligible to be part of the "low depressive symptomatology" group, which served as the control group. The low depressive symptomatology group served as a normal control group because the group did not meet the standardized criteria for mild, moderate, or severe depression..

A total of 40 individuals (20 individuals with low depressive symptomatology, 20 individuals with high depressive symptomatology) were included in this experiment. All

participants signed an informed consent form prior to participating in the study. Participants were excluded if they were 18 or younger, a non-native English speaker, had a serious mental or physical health problems, were pregnant, had taken medications/drugs within the past 6 months that affect the central nervous system, and/or if they had a major medical condition or psychiatric illness. After completion of the experiment, each participant was debriefed about the experiment and given a debriefing form which included information regarding the purpose of the study and contact information for any additional concerns or questions that may have occurred after the conclusion of the experiment. All participants were granted research credit for his or her participation.

An initial G Power calculation of a 2 group (high depressive symptomatology, low depressive symptomatology) x 2 level of processing (shallow, deep) x 3 word type (depression-related, unpleasant non-depression related, and neutral) mixed model ANOVA was performed to determine the ideal sample size and power. Power was calculated using a G Power Statistical Power Analysis 3.1.9.2 software developed by Erdfelder and colleagues (2007, 2009). The G Power analysis revealed an ideal sample size of 70 to derive a strong effect size of at least 0.80. In an ideal setting, this study would have included all 70 individuals. However, a smaller sample size is often used in neuroimaging studies because of the large amount of data collected at different time points (i.e. increasing intra-subject variability) for each condition of interest. For example, 32 channels of EEG data were collected for each participant in this study and the EEG data were combined across multiple trials (60 trials) to create an average ERP for each word condition (i.e. depression-related, unpleasant non-depression related, and neutral). After each individual ERP was created, the ERPs were then average between-subjects in regard to groups of high and low depressive symptomatology.

Other EEG studies which have assessed cognitive processing in individuals with depression have used similar sample sizes ($n \leq 20$) (Debener et al., 2000; Finglekurts et al., 2007; Ruchsow et al., 2006). In particular, Debener and colleagues (2000) used an EEG to detect resting anterior EEG alpha asymmetry as a potential biomarker for depression using a sample size of only 13 subjects. Additionally, Finglekurts and colleagues (2007) observed impaired functional connectivity of alpha and theta band activity in individuals with major depression using an EEG comparison of 12 depressed individuals and 10 control individuals. Moreover, Ruchsow and colleagues (2006) observed impairments in inhibition processing in individuals with major depression by comparing ERP data for hits between 10 individuals diagnosed with depression and 10 control individuals. For each of these studies, EEG data were collected at multiple time points and across many different locations (32 channels) for each participant. Numerous neuroimaging studies, which used a similar experimental design as this project, used a sample size of 20 or less for each group. Despite these results, it is still important to consider that a small sample size typically has low statistical power which reduces the chance of detecting a true effect within a study and decreases the generalizability of the results. On the other hand, too large of a sample size can increase the probability of rejecting the null hypothesis and increases type I error (i.e. detecting a false positive). In fact, the effects observed in a smaller sample size would presumably be observed in a larger sample size. Given this consideration, significant effects found in a small population should not be disregarded on the sole basis of sample size.

2.2 Procedures

Shallow vs Deep Processing

Both a shallow and a deep processing memory task were developed using unpleasant and neutral words. For this experiment, a total of 270 words were selected from the Affective Norms

for English Words (ANEW) database. Unpleasant words were divided into two categories: (1) depression-related unpleasant words (i.e. lonely, sadness, lethargy) and (2) nondepression-related unpleasant words (i.e. rotten, seasick, victim). A total of 135 words were used for the shallow processing task and a total of 135 words were used for the deep processing task. The words in the two unpleasant word categories were matched for their emotional arousal (M = 5.32, SD = 0.07) and valence (M = 2.56, SD = 0.05) and only differ by the association with depression-related content. The neutral words were selected to have a moderate level of arousal (M = 5.13, SD = 1.03) and valence (M = 4.80, SD = 0.88). The shallow and deep processing tasks were matched on all measures and only differed by the amount of cognitive effort required by the tasks. Experimental schematics are shown in Figures A.3 – A.6.

The shallow processing task was divided into two separate sessions: a study (encoding) and test (retrieval) session. During the study session of the shallow processing task, participants were instructed to read a series of words on a computer screen while determining how many syllables were in the word (ranging from 1 to 3 syllables). For each trial, one word was presented for 2000 milliseconds (ms), followed by an interstimulus screen for 500 ms. Each participant was instructed to make responses related to syllable count for 90 separate trials (30 depression-related (DR), 30 generally unpleasant but not depression related (U-NDR), and 30 neutral). Counting syllables did not require processing the semantic meaning of a word and was considered to represent a superficial or shallow form of processing.

During the test session of the shallow processing task, a randomized mixture of previously studied and new words was presented on a computer screen. The participants were asked to make a memory judgment as to whether they recognize a word as being ‘old’ (i.e. I remember studying the word) or new (i.e. I do not remember studying the word, it must be new).

Each word was presented for 2000 ms, followed by an interstimulus screen for 500 ms and a subsequent screen for providing confidence rating for 1500 ms. The participants were asked to make a memory judgment as to whether they recognize a word as being 'old' or 'new', followed by a confidence rating in that decision. The confidence ratings ranged from 1 to 3 and represented low, medium, and high confidence. Objective measurements of memory accuracy and subjective measurements of confidence ratings were collected and analyzed to determine the relationship between memory accuracy and memory strength. A total of 135 trials (30 depression-related, 30 generally unpleasant but not depression-related, 30 neutral, 45 new) were presented during the test session.

The deep processing task was also divided into two separate sessions: a study session and a test session. During the study session of the deep processing task, participants were instructed to read a different series of words on a computer screen, but this time they were asked to decide if the word was either concrete or abstract. Concrete referred to terms that possessed a tangible property (i.e. objects, animals, locations, etc.), whereas abstract referred to terms that did not possess a tangible property (i.e. actions, ideas, states of mind, etc.). Determining if a word was concrete or abstract required semantic processing and was considered to represent an elaborative and deep form of processing. For each trial, one word was presented for 2000 ms followed by an interstimulus screen for 500 ms. Each participant was instructed to make responses related to the semantic meaning of the word for 90 trials (30 depression-related, 30 generally unpleasant but not depression-related, and 30 neutral).

During the test session of the deep processing task, a randomized mixture of previously studied and new words was presented on a computer screen. Each word was presented for 2000 ms, followed by an interstimulus screen for 500 ms and a subsequent screen for making a

confidence rating for 1500 ms. Identical to the shallow processing task, the participant will be asked to make a memory judgment as to whether they recognize a word as being 'old' or 'new', followed by a confidence rating in that decision. The confidence ratings ranged from 1 to 3 and represented low, medium, and high confidence. Objective measurements of memory accuracy and subjective measurements of confidence ratings were collected and analyzed to determine the relationship between memory accuracy and memory strength. A total of 135 trials (30 depression-related, 30 generally unpleasant, 30 neutral, 45 new) were presented during the test session.

Group Comparisons

Behavioral performance (d' and reaction time) and brain activity (EEG signals) were recorded during the memory tasks and compared between groups of high and low depressive symptomatology. An EEG recorded brain activity while the participants completed both a shallow and deep processing task involving words which varied in emotional content. A subsequent memory paradigm was used to examine the influence of a depressive self-schema on emotional memory.

2.3 EEG acquisition

An EEG records the brain's electrical activity (i.e. ERPs) occurring along the scalp. An EEG is sensitive enough to detect the electrophysiological changes that occur when a person processes emotional information. Emotional processes in the brain can occur within a fraction of a second, so an imaging device with high temporal resolution is needed to detect these changes. Compared to an EEG, other imaging devices such as an fMRI or PET have very high spatial resolution and relatively poor temporal resolution. Moreover, an EEG is cost effective in comparison to other imaging devices and enables accurate examination of the temporal changes

in brain activity. Data were acquired at the University of Texas at Arlington using a Brain Vision EEG system. EEG data were recorded from 32 electrodes mounted and gelled onto the participant's scalp in accordance with the international 10-20 system. The EEG device and channel setup is depicted in Figures A.1 and A.2. Cortical regions such as the PFC and centro-parietal regions play a significant role in emotional processing. For this reason, it was anticipated that the effects of emotional processing would be reflected in the PFC and centro-parietal regions through the modulation of the P300, N400 and slow wave (SW) components of an ERP. Mean amplitude differences within an ERP, as well as the power spectrum analysis associated with the ERP, was assessed for the present research study.

2.4 Behavioral data analysis

Objective measurements of memory recognition were collected and analyzed to determine recognition accuracy for both the shallow and deep processing tasks. Long-term memory recognition accuracy (d') was calculated based on a z-score transformations of false alarm rates and hit rates for each individual. D-prime is a commonly used discriminability measure of accuracy proportions that is based on the signal detection theory (Macmillan & Creelman, 1991). The z-scores for the d' measures were determined by subtracting standardized false alarm rates (i.e. the participant mistakenly claimed to "remember" a word that was not presented during the study session) from standardized hit rates (i.e. the participant correctly "remembered" a word that was actually presented during the study session). The accuracy proportions account for any missing data (i.e. no responses) by assessing the hits and false alarm rates in relation to the total number of responses made by the participant.

Overall reaction time and behavioral memory performance for DR, U-NDR, and neutral content was compared in a mixed 2 (high vs. low depression) x 2 (shallow vs. deep) x 3

(depression-related, generally but depression-related unpleasant, vs. neutral) mixed model ANOVA (Analysis of Variance). Additionally, histogram plots and frequency distributions tables were developed to ensure that no potential outliers were included in the analysis. Data were considered outliers if the score was greater than two standard deviations from the mean. Post-hoc analyses were also conducted to assess any potential differences or interactions between groups of high and low depressive symptomatology, level of processing, and/or differences in emotional memory performance.

In regard to confidence ratings and memory performance, memory performance was collected as a function of low, medium, and high confidence. However, memory performance scores (d-prime) cannot be reliably calculated for participants according to each of these confidence ratings. The scores cannot be reliably calculated because not all of the participants rated words with low or medium confidence. In some cases, participants rated words with low or medium confidence but failed to correctly remember (i.e. 'hit') any of these words during the long-term memory test. Given that d-prime is calculated based on a proportion of hit and false alarm responses, memory performance cannot be reliably calculated for word conditions that do not contain a 'hit' response rate. For this reason, memory performance cannot be reported as a function of low, medium, and high confidence.

On the other hand, all of the participants did provide high confidence ratings for each of the word conditions, so memory performance was compared between overall memory performance (regardless of confidence) and high confidence memory performance. High confidence memory and overall memory performance was compared using a 2 x 2 x 2 x 3 ANOVA of confidence (high, overall), group (high depressive symptomatology, low depressive

symptomatology), level of processing (shallow, deep) and word type (depression-related, unpleasant non-depression related, and neutral) mixed model ANOVA.

2.5 EEG data analysis

EEG data were acquired by the Brain Vision Inc. EEG system. All data were preprocessed using MATLAB software equipped with EEGlab and ADJUST toolbox. The ADJUST toolbox uses an automated algorithm which identifies and rejects noise and artifacts within the raw EEG data. Using the ADJUST toolbox eliminates any experimenter bias when preprocessing the data. During the preprocessing analysis, EEG data were down sampled to 256 hz, cleaned and corrected for artifacts, movement, and eye blinks with the aid of the ADJUST toolbox and ICA (Independent Component Analysis) application of EEGlab. In addition, all EEG data were filtered using a high-pass Buttersworth filter (0.1 Hz). Based on the standardized 10-20 system, the electrodes t9 and t10 served as common reference points during analysis. Using MATLAB equipped with ERPlab, processed EEG data were epoched 200 ms before the presentation of each visual stimuli and continued until 2000 ms after each event. Averaged ERPs were computed and compared among contrasts for DR, U-NDR, and neutral content between groups of high and low depressive symptomatology. The ERP contrasts were developed for both the shallow and deep processing memory tasks. Measures related to mean amplitude differences between ERP waves for each word type were extracted and statically analyzed using SPSS.

An ERP wave comprises various components (P100, N100, P200, N200, P300, N400, and LPC) which correspond to different cognitive processes. The ERP components are determined by the amplitude potential (positive = ‘P’ or negative = ‘N’) and latency of a wave. For example, P100 refers to a positive deflection in the ERP wave which can be detected approximately 100 ms after stimuli onset. The ERP amplitude reflects the degree of brain

activation required by a task, whereas the latency reflects the speed at which the information is perceived and processed (Olofsson et al., 2008). Moreover, the timing of the ERP wave components can vary depending on the individual and cognitive task. For instance, researchers have found that P100 effects occur around 60 – 140 ms after the onset of a stimuli. The P100 component is considered to be involved in the initial encoding of low-level sensory information (Pierson et al., 1996). The N100 component can detected approximately 100 – 200 ms after the onset of a stimuli and is considered to be involved in discriminating information and maintaining attention (Dai et al., 2011). The P200 component can be detected around 160 – 210 ms after the onset of a stimuli and is thought to be involved in the initial processing of task-relevant and task-relevant information (Hegerl et al., 1993). The N200 component can be detected around 250 – 430 ms after the onset of a stimuli and is considered to reflect cognitive control, mismatching information, and affective experiences (Folstein et al., 2008).

The P300 and N400 component, which are of particular interest for the present study, occur around 300 – 600 ms after the onset of a stimuli and mediate emotional processing, executive control, semantic processing and updating information in working memory (Brown & Hagoort, 1993; Dunn et al, 1998). Because these components are involved in emotional processing, it was expected that these components would reflect differences in emotional word processing (DR, U-NDR, neutral). In particular, it was expected that the P300 and N400 components would differ between groups of high and low depressive symptomatology due to fundamental differences in emotional processing caused by a depressive self-schema. Lastly, the late positive component (LPC) wave that occurs approximately 400 – 800 ms after the onset of a stimulus is involved in updating information in working memory during the late stage of

evaluation processing (Donchin & Coles, 1988). All components of the ERP wave were assessed for the shallow and deep processing memory tasks.

A Fourier transform of brain activity (i.e. a power spectrum analysis based on the ERP data) was also conducted to determine if brain wave frequencies mediated emotional processing in groups of high and low depressive symptomatology. The power spectrum analysis is sensitive to the oscillatory components contributing to an EEG signal. The oscillatory components of an EEG signal can vary based on frequency bands. In particular, delta waves are assessed from 0.1 – 3 Hz, theta waves are assessed from 4 - 7 Hz, alpha waves are assed from 8 – 15 Hz, beta waves are assessed from 16 – 30 Hz, and gamma waves are assessed from 31 – 100 Hz. Prior literature has reported that increases in theta band activity and decreases in alpha band activity are associated with better cognitive performance (Klimesch, 1999; Meltzer et al., 2009). For this reason, these two frequency bands were of particular interest for the present study. However, all frequency bands were also analyzed to assess for any differences in brain activity between groups of high and low depressive symptomatology. Data were analyzed in MATLAB equipped with EEGLAB and epoched according to the same time window as the ERP data (-200 ms to 1000 ms) for each of the word conditions and for each memory task. Scalp maps were plotted for delta (2 Hz), theta (6 Hz), alpha (10 Hz), beta (22 Hz), and gamma (40 Hz) bands with a plotting frequency range of 1 to 40 Hz. The statistical data analysis was conducted on the full range of delta (0.1 Hz – 3 Hz), theta (4 – 7 Hz), alpha (8 – 15 Hz), beta (16 – 30 Hz), and gamma (31 – 100 Hz) bands using a 5 (frequency band: delta, theta, alpha, beta, gamma) x 3 (word type: DR, U-NDR, neutral) x 2 (group: high, low depressive symptomatology) mixed model ANOVA.

CHAPTER 3

3. EXPERIMENTAL RESULTS

3.1 Behavioral Results

Forty participants (25 female) with ages ranging from 18 to 35 were recruited at the University of Texas at Arlington and offered research credit for participation. All of the participants were right-handed and native English speakers. Twenty individuals met the criterion of having high depressive symptomatology with an average CES-D score of 31.6 (1.37) and twenty individuals met the criterion of having low depressive symptomatology with an average CES-D score of 5.30 (0.54). Given the small size of this study and the consideration that multiple comparisons were tested, a more stringent p-value of significant was adopted for statistical analysis ($p \leq .025$). A more stringent p-value decreased the chance of type I error (i.e. a false positive).

The results of a 2 x 2 x 3 ANOVA of group (high depressive symptomatology, low depressive symptomatology), level of processing (shallow, deep) and word type (depression-related, unpleasant non-depression related, and neutral) revealed main effects of level of processing ($F[1,38] = 35.09$, $p < .001$, $\eta^2 = .480$) and word type ($F[1, 38] = 4.76$, $p < .025$, $\eta^2 = .205$) on memory accuracy performance. Histogram charts and data frequency tables revealed that there were no outliers in the dataset. Additionally, the interaction between the level of processing and word type was also significant ($F[1, 38] = 6.26$, $p < .025$, $\eta^2 = .253$). Refer to Appendix B for a graph of descriptive statistics related to memory accuracy.

Follow-up t-tests revealed that overall memory accuracy (d') did not differ by word type for either of the groups during the shallow processing task. Moreover, memory accuracy did not differ by word type during the deep processing task for individuals with low depressive

symptomatology. In contrast, individuals with high depressive symptomatology displayed better memory accuracy for U-NDR and neutral words as compared to DR words during the deep processing task ($t[19] = 4.16$, $p < .025$; $t[19] = 3.58$, $p < .025$).

Additionally, the results of a 2 x 2 x 3 ANOVA of group (high depressive symptomatology, low depressive symptomatology), level of processing (shallow, deep) and word type (depression-related, unpleasant non-depression related, and neutral) revealed main effects of level of processing ($F[38] = 91.58$, $p < .001$, $\eta^2 = .707$) and word type ($F[38] = 8.70$, $p < .025$, $\eta^2 = .320$) on mean reaction time performance. Furthermore, there was a significant interaction between word type and group ($F[38] = 5.41$, $p < .025$, $\eta^2 = .226$). Refer to Appendix B for a graph of descriptive statistics related to mean reaction time.

Follow-up t-tests revealed that individuals with high depressive symptomatology displayed slower mean reaction times when correctly remembering DR words as compared to U-NDR for both the shallow and deep processing task ($t[19] = 2.64$, $p < .025$; $t[19] = 3.85$, $p < .025$). Individuals with low depressive symptomatology displayed slower mean reaction times when correctly remembering U-NDR as compared to neutral words during the shallow processing task ($t[19] = 2.62$, $p < .025$) and slower mean reaction times when correctly remembering DR words as compared to neutral words for the deep processing task ($t[19] = 2.50$, $p < .025$). Regardless of word type or group, the overall mean reaction time was faster during the deep processing task as compared to the shallow processing task ($t[39] = 9.70$, $p < .001$).

Overall memory performance and high confidence memory performance were also statistically analyzed. The results of a 2 x 2 x 2 x 3 ANOVA of confidence (high, overall), group (high depressive symptomatology, low depressive symptomatology), level of processing (shallow, deep) and word type (depression-related, unpleasant non-depression related, and

neutral) revealed a main effect of confidence on memory performance for the shallow processing task ($F[38] = 60.51$, $p < .025$, $\eta^2 = .621$) and the deep processing task ($F[38] = 47.125$, $p < .025$, $\eta^2 = .560$). However, the large main effects are likely due to dramatic differences in the number of available trials used to calculate d prime measures for high confidence responses versus overall responses. As previously mentioned, d prime is based on memory proportions derived from responses to old and new items.

For the shallow processing task, the high depressive symptomatology group made an average of 18.48 (0.72) high confidence responses and 29.60 (0.13) overall responses for old items. In addition, the high depressive symptomatology group made an average of 23.2 (2.38) high confidence responses and 43.95 (0.22) for new items. The low depressive symptomatology group displayed a similar pattern of performance with an average of 18.41 (0.64) high confidence responses made and an average of 29.30 (0.18) overall responses for old items. In addition, the low depressive symptomatology group made an average of 26.9 (2.11) high confidence responses and 43.50 (0.37) overall responses for new items. For the deep processing task, the high depressive symptomatology group made an average of 23.93 (0.60) high confidence responses and 29.65 (0.17) overall responses for old items. In addition, the high depressive symptomatology group made an average 25.00 (2.41) high confidence response and 44.15 (0.31) overall responses for new items. The low depressive symptomatology group displayed a similar pattern of performance with an average of 23.36 (0.71) responses and 29.35 (0.21) overall responses. In addition, the low depressive symptomatology group made an average of 30.1 (1.94) high confidence responses and 43.95 (0.37) overall responses for new items.

3.2 EEG Results

ERP Results

For the EEG analysis, brain activity during the encoding phase (i.e. words encoded during the study session) was averaged into ERPs based on the participant's long-term memory performance (i.e. words that were either successfully remembered or forgotten during the long-term memory session). For the shallow processing task, no main effects relating to the encoding of different word types was observed in comparison of groups of individuals with high and low depressive symptomatology. Refer to Appendix B for ERP graphs, including bar graphs which depict significant differences in mean amplitude. Please note no ERP effects were found beyond 1000 ms following the onset of the stimuli. For this reason, all graphs display ERP waves from -200 ms to 1000 ms for visual purposes.

For the deep processing task, significant encoding differences in the left prefrontal regions (electrodes f3, f7, fz, fc1) were observed in comparison of groups of individuals with high and low depressive symptomatology when comparing the ERPs of hits (i.e. successfully remembered information) for DR words ($F[38] = 5.73$, $p < .025$, $\eta^2 = .645$) and hits for U-NDR words ($F[38] = 6.19$, $p < .025$, $\eta^2 = .679$) but not when comparing hits for neutral words ($F[38] = 1.69$, $p > .05$, $\eta^2 = .245$. Moreover, significant encoding differences were also observed in the left centro-parietal regions (electrodes c3, cz, cp1, cp5) when comparing ERPs for hits for U-NDR words between groups of high and low depressive symptomatology ($F[38] = 5.86$, $p < .025$, $\eta^2 = .655$) but not when comparing hits for DR words ($F[38] = 2.89$, $p > .05$, $\eta^2 = .382$) or hits for neutral words ($F[38] = 2.02$, $p > .05$, $\eta^2 = .283$). The significant electrophysiological differences in prefrontal and centro-parietal regions occurred during the 350 – 600 ms following the presentation of the stimuli. Consistent with prior literature, the ERP waves related to processing unpleasant information (DR or U-NDR) tended to be more positive going than when processing neutral information.

Power Spectrum Analysis Results

Furthermore, a power spectrum analysis based on the ERP data was also conducted to determine if brain wave frequencies significantly differed by word type condition between groups of high and low depressive symptomatology. Statistical power spectrum data were extracted using EEGLAB from the EEG.chanlocs variable. All EEG data were epoched at -200 ms to 2000 ms for overall hits and for hits by each word condition. No main effect of word type was found within groups of high and low depressive symptomatology ($F[38] = 1.89$, $p > .05$, $\eta^2 = .237$). Additionally, no main effect of word type was found between groups of high and low depressive symptomatology ($F[38] = 2.16$, $p > .05$, $\eta^2 = .316$). However, the results did reveal a main effect of group during the deep processing task when analyzing brain activity which corresponded to overall successful hits, regardless of the emotional word type ($F[38] = 3.87$, $p < .025$, $\eta^2 = .433$). Follow up t-test revealed that individuals with high depressive symptomatology displayed greater alpha activity during the deep processing task compared to individuals with low depressive symptomatology ($t[19] = 5.66$, $p < .025$). Refer to Appendix B for power spectrum plots (delta, theta, alpha, beta, and gamma bands) for overall hits during the shallow and deep processing tasks for individuals with high and low depressive symptomatology.

CHAPTER 4

DISCUSSION

The influence of a depressive self-schema was assessed at both a shallow and deep level of processing in individuals with high or low depressive symptomatology. Shallow processing involves structural and phonemic encoding that typically leads to weak memories that are prone to be forgotten. In contrast, deep processing involves relational binding and semantic encoding that helps form long lasting memories. The behavioral results from this study revealed a similar

pattern of findings such that overall memory accuracy was worse for the shallow processing task as compared to the deep processing task regardless of word type.

Word type was not an important factor in the shallow processing task due to the fact that shallow processing is not influenced by the semantics of a word. For the shallow processing task, the participants were given a short amount of time (2 seconds) to determine the syllable count of a word (i.e. perceptual processing) which resulted in weak memory traces that were later forgotten. In contrast, overall memory accuracy was higher during the deep processing task for both groups. Inconsistent with our hypothesis, memory accuracy did not differ by word type for individuals with low depressive symptomatology during the deep processing task. Moreover, individuals with high depressive symptomatology did not show better memory performance for unpleasant words (DR or U-NDR) as compared to neutral words. In fact, these individuals displayed worse memory recall for depression-related words than for either generally unpleasant or neutral words.

The influence of type I and type II error was also considered for the statistical analysis of the data. The difference between the two types of errors depends on the null hypothesis. For instance, type 1 error refers to the incorrect rejection of a true null hypothesis, also known as a false positive. Type 1 errors can lead researchers to detect effects or relationships which do not actually exist. Conducting a large number of comparisons can increase the likelihood of type 1 error. In contrast, type II error refers to the failure to correctly reject a false null hypothesis, also known as a false negative. Type II errors can cause researchers to fail to detect effects or relationships which do actually exist.

It is important to understand that all inferential statistical tests have a probability of making a type 1 and type II error. Moreover, the two types of errors are negatively correlated

with each other (as one type of error decreases, the other inadvertently increases and vice versa). Researchers typically adopt a p-value of .05 to provide an adequate balance of type I and type II error. In order to decrease type 1 error which can occur when running a large number of t-tests, a more stringent p-value of significance was adopted for the statistical analysis of the present study ($p \leq .025$). The p-value of .025 refers to a 2.5% chance of the observed effects occurring due to random sampling error (i.e. type 1 error).

The pattern of memory performance displayed by both groups of high and low depressive symptomatology is interesting because it is inconsistent with prior research that has reported that unpleasant information is typically better remembered than neutral information (Dolcos et. al., 2002) and that individuals with high depressive symptomatology are especially likely to remember depression-related words (Bentall et. al., 1995; Rinck & Becker, 2005; Watkins et. al., 1992). To make sense of these findings, it is important to consider the influence of using pictures instead of words to manipulate emotion and also the influence of selecting appropriate words to accurately assess emotional processing.

The majority of studies that have reported better memory recall for emotional information over neutral information tend to use pictures instead of words as stimuli (Bradley et. al., 1992; Bradley et. al., 2001; Hamann et. al., 1999; Hayes et.. al., 2010, Palomba et. al., 1997). Consistent with the dual code theory proposed by Allan Paivio (1971), pictures are more influential on memory because of their ability to be encoded at multiple levels. A picture provides a concrete depiction of information that contains both a visual and a verbal component. For example, consider being shown a picture of an apple. Even though the picture contains no verbal words you would still automatically encode the visual aspects of the picture as well as the verbal aspect of the picture (i.e. the associated verbal label, ‘apple’). Thus, the memory of that

picture is encoded in two separate forms which improves the memory strength and recall of that information. For the present study, emotional words were chosen instead of pictures so that a clear distinction could be made between unpleasant depression-related words and unpleasant non-depression related words. The lack of improved memory for unpleasant information over neutral information for the shallow and deep processing tasks in this study may have been influenced by the fact that words are not remembered as well as pictures.

On the other hand, there have also been prior studies which have reported enhanced memory for emotional words over neutral words (Kensinger & Corkin, 2003; Liu et. al, 2012; Matthews & Barch, 2006). However, previous studies which have used emotional words to investigate memory tend to select words that are counterbalanced based on ratings of imaginability (referring to an individual's ease of forming a mental image) and give special consideration to the number of abstract and concrete words used in a memory paradigm. In general, concrete words possess a higher rating of imaginability because they easily form a mental image that is familiar to the individual. Being able to form a mental image is beneficial to memory for the same reasons that pictures are beneficial to memory (i.e. dual coding). In contrast, abstract words possess a lower rating of imaginability because they do not readily form a mental image. For this reason, concrete words are easier to recall than abstract words (Kroll and Merves, 1986; Walker & Hulme, 1999).

Unfortunately, words most commonly associated with depression are abstract (i.e. lonely, burdened, sadness). For the present study, approximately 99% of the DR words were abstract, approximately 80% of the U-NDR words were abstract, and approximately 43% of the neutral words were abstract. However, a definite percentage of abstract words could not be determined for each word condition because of the subjective interpretation of some words. For example,

words presented in the experiment such as ‘watch’ or ‘console’ could be considered either abstract or concrete depending on the context. Given this limitation, the percentage of abstract and concrete words could not be reliably determined for each condition. Although the percentage of abstract and concrete words cannot be statistically tested, the consideration of the approximate percentage of abstract words used in the experiment may explain why individuals with high depressive symptomatology displayed poorer memory accuracy for the DR words as compared to the U-NDR and neutral words during the deep processing task. Although not statistically significant, a similar pattern of memory performance was also observed for the low depressive symptomatology group. A reliable percentage of abstract words could not be determined based on the participants’ individual responses because they did not rate all 270 words used in the experiment as being abstract or concrete. Decisions of a word being abstract or concrete were only made during the study session of the deep processing task (90 trials). For this reason, the degree of abstract or concrete ratings could not be considered as a covariate for memory performance.

The words used for the present study were selected from the ANEW database, which only provided normative ratings for stimulus words in regard to valence (ranging from pleasant to unpleasant), arousal (ranging from calm to exciting), and dominance (ranging from a high degree of control to a low degree of control). Unfortunately, normative rating measures related to concreteness and imaginability are not available for the ANEW database making it not possible to statistically determine if long-term memory performance was mediated by such factors in the present study. The lack of psycholinguistic indexes (familiarity, imaginability, and concreteness) for words included in the ANEW database is an unresolved issue that has been raised by several researchers (Janschewitz, 2008; Montefinese et. al., 2013; Redondo et al., 2007). A follow-up

study should be conducted using the same 270 words from the present study to obtain self-reported ratings from participants related to concreteness and imaginability of the words. Measures of such ratings would make it possible to statistically control for the effect of the stimulus words' concreteness and imaginability in relation to the research hypotheses of this study.

In regards to imaginability and emotional words, Altarriba and Bauer (2004) found that emotional abstract words tend to have a higher rating of imaginability as compared to non-emotional abstract words, but overall emotional abstract words tend have lower ratings of imaginability and concreteness compared to concrete words themselves. The authors argue that emotional words tend to be imagined and recalled better than non-emotional abstract words because emotional words can more readily elicit an associated visual aid or feeling which improves encoding. For example, the emotional word 'sadness' may elicit an image of a sad facial expression (contributing to dual encoding) whereas a non-emotional abstract word such as 'fact' may not as easily elicit an associated mental image. Ultimately, it apparently was the imaginability related to concrete and abstract words that influenced the results related to explicit memory.

However, the results related to implicit memory (i.e. reaction time) and EEG data provided supporting evidence of differential processing related to a depressive self-schema. For instance, individuals with high depressive symptomatology displayed slower reaction times when correctly remembering DR words as compared to U-NDR words for both the shallow and deep processing task. In contrast, individuals with low depressive symptomatology did not display this same pattern of reaction time performance related to depression-related words. Reaction time performance can provide useful insight about the mental processes related to

memory (Sternberg, 1969). The reaction time performance displayed by individuals with high depressive symptomatology when processing depression-related information suggests that a depressive self-schema (i.e. processing information through a negative mind set) is present in individuals who possess a high number of symptoms related to depression. These findings are consistent with previous findings related to depression-prone individuals that have reported differences in implicit processing for depression-related content (Hartlage et. al., 1993; Lappanen et. al, 2004).

The slowed reaction time for depression-related content may reflect a deficit in attentional resources needed to process emotional information. Consistent with this idea, numerous studies have shown overall attentional deficits in individuals diagnosed with depression (Paelecke-Habermann et al., 2005; Sevigny et al., 2003). Moreover, impairments in attention have also been observed in individuals at risk for depression (Ingram and McLaughlin, 1994). On the other hand, more evidence exists in support of attentional biases for negative information in depression, a finding which is inconsistent with an overall attention deficit in depression (Bradeley et al., 1997; Donaldson et al., 2007; Gotlib et al., 2004; Leyman et al., 2007; Macleod et al., 1986) It is more likely the case that the slowed reaction time for depression-related words in this study may represent a propensity for rumination in depression. It may be the case that when processing negative information, individuals with depression spend more time ruminating on the depressive content as compared to positive content. These findings are consistent with literature that has reported delayed reaction time and sustained pupil dilation when processing negative content as compared to positive content in individuals with depression (Siegle et al., 2003).

In the present study, the EEG data were analyzed using a subsequent memory paradigm which involved assessing brain activity during encoding based on long-term memory performance. An automatic algorithm was used to preprocess the data to remove any artifacts in the data. For the shallow processing task, no main effect of encoding was observed in comparison of individuals with high depressive symptomatology and individuals with low depressive symptomatology. The lack of encoding differences between the two groups during the shallow processing task is not surprising because shallow processing is not an area of impairment for individuals with high depressive symptomatology. For this reason, it was not expected that the mental processes involved in this task would differ for groups of high and low depressive symptomatology.

However, brain activity when encoding DR words and U-NDR words did differ between groups of high and low depressive symptomatology during the deep processing task. Specifically, electrophysiological response to DR word and U-NDR words significantly differed during the 350 – 600 ms following the onset of the stimuli in the left prefrontal (electrodes f3, f7, fz, fc1) and left centro-parietal regions (electrodes c3, cz, cp1, cp5). These findings are consistent with those of prior neuroimaging studies that have reported differences in emotional processing in these same regions (Dolcos & Cabez, 2002; Dolcos et. al., 2004). The electrophysiological responses did not differ between hits for DR and hits for U-NDR in individuals with high depressive symptomatology as initially predicted, but the ERP results do show a clear distinction of processing differences between groups of high and low depressive symptomatology. These differences in electrophysiological responses between groups may be mediated a depressive self-schema which is common in individuals with high depressive symptomatology.

The results from the Fourier transform analysis did not reveal any significant encoding differences corresponding to processing different emotional words for either group. It was not expected that brain wave frequencies would differ during the shallow processing task because not much attentional resources were needed to successfully complete the task. Neither group displayed encoding different for emotional words during the deep processing task as well. However, a comparison of overall hits (regardless of the type of emotional word) revealed differences in alpha band activity over the prefrontal region between groups of high and low depressive symptomatology. In particular, individuals with depression displayed greater alpha band activity which corresponded to overall memory performance. Although these findings did not support any of the initial hypotheses for this study, they do provide helpful insight into the functional activity that may be underlying cognitive processing abnormalities in individuals with high depressive symptomatology. These findings are consistent with prior research which has shown that individuals with depression exhibit dysfunctions in alpha band activity when completing tasks involved in executive function (Fingelkurts et al., 2007). In addition, researchers have also found that individuals with depression tend to display less theta band activity when processing complex information as compared to healthy controls. The results from this study failed to replicate these findings related to theta band activity but the lack of theta activity may have been related to the monotony of the shallow and deep processing task.

Additionally, no significant differences were detected among delta or gamma bands between groups of high and low depressive symptomatology for the shallow and deep processing task. These results are not surprising because delta bands are most commonly associated with deep non-REM sleep (Genzel et al., 2014). The cognitive tasks from this study required activate participation from the subjects so it was not expected that frequency bands associated with deep

sleep would significantly differ between groups of high and low depressive symptomatology. It is also not surprising that no differences were found among gamma bands between groups of depressive symptomatology. Gamma bands are most commonly associated with basic sensory processing associated with vision (Gold, 1999; Swettenham et al., 2009). The cognitive tasks in this study involved viewing words which were presented in the same location on the computer screen across all of the different trials. Since gamma bands are most commonly associated with detecting differences in motion and complex visual processing, it was not expected that gamma bands would differ between groups of depressive symptomatology when completing a cognitive task involving words.

In conclusion, individuals with high depressive symptomatology did not show enhanced explicit memory for depression-related items over generally unpleasant and neutral items as initially predicted. Nor did they show ERP differences in support of distinguishing depression-related processing over generally unpleasant processing. However, these results are most likely due to a limitation in the experimental paradigm related to the high percentage of abstract words used for the depression-related word condition. On the other hand, individuals with high depressive symptomatology did reveal significant differences in mean reaction performance and neural activity related to processing depression-related content compared to individuals with low depressive symptomatology.

Clearly, a distinction exists related to implicit processing (i.e. mean reaction time) and neural processing (i.e. ERPs related to unpleasant and neutral processing) in comparison of individuals with high depressive symptomatology to individuals with low depressive symptomatology. However, additional research is needed to better understand the nature of these differences. One limitation of this study was the relatively small sample size which led to

underpowered results. However, low statistical power is a common limitation in a majority of neuroimaging studies (Button et al., 2013). Future research related to depressive-self schema and memory in depression should account for the imaginability of emotional words and only use abstract words to avoid any potential confounds. If using emotional words selected from ANEW database, self-report measures related to concreteness, familiarity, and imaginability should also be collected from the participants to account for any potential confounds or covariate influences. Future research should analyze ERP data to determine if biomarkers of depression can be detected. Kemp and colleagues (2009) have shown promise in identifying biomarkers of depression but additional research is needed to confirm these results. Future diagnosis of depression and recommended treatment could use biomarkers of ERP data to discriminate between varying degrees of depression, improving our overall understanding and prognosis of major depressive disorder.

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APPENDIX A

EEG SETUP AND MATERIALS

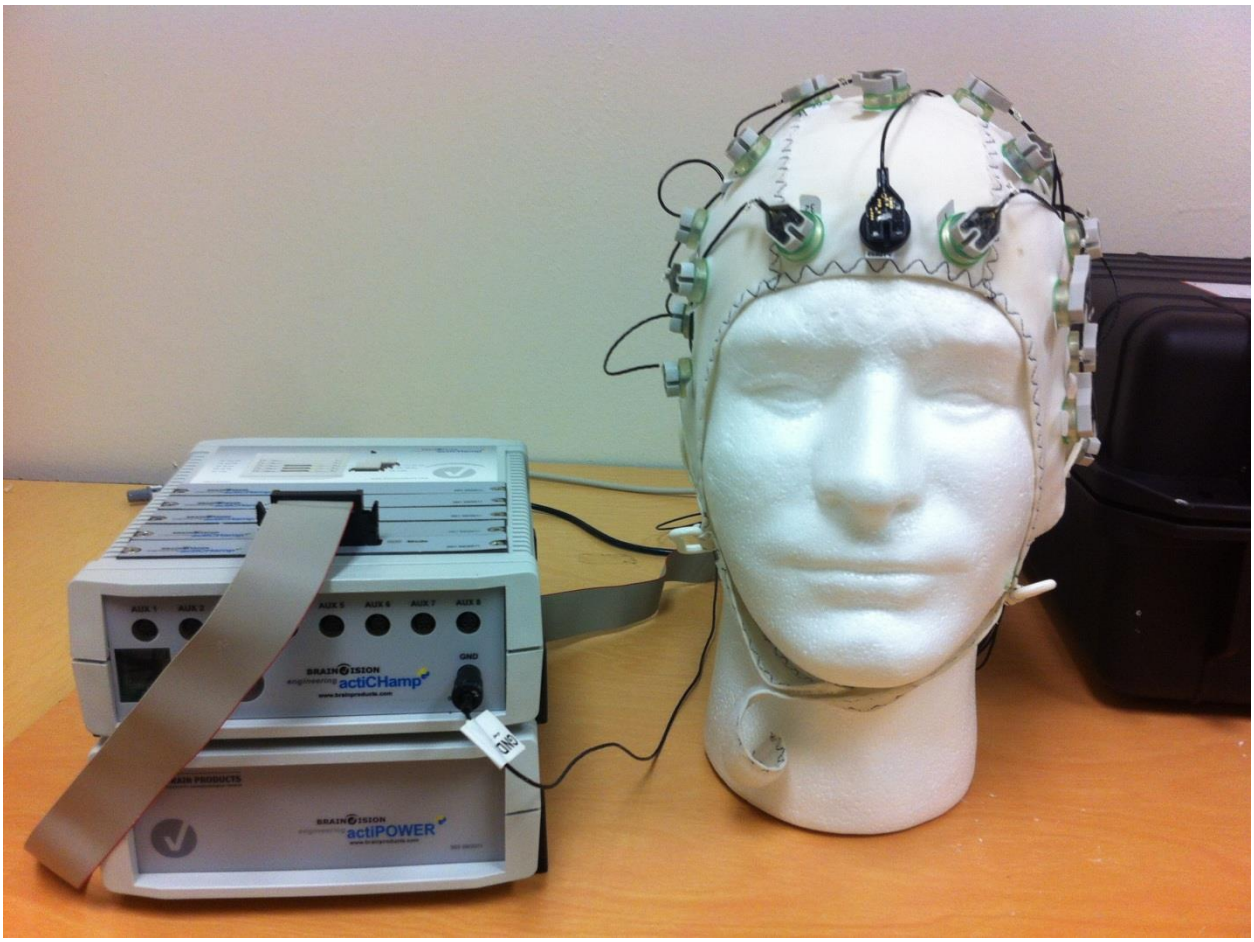


Figure A.1 Battery Powered EEG Setup.

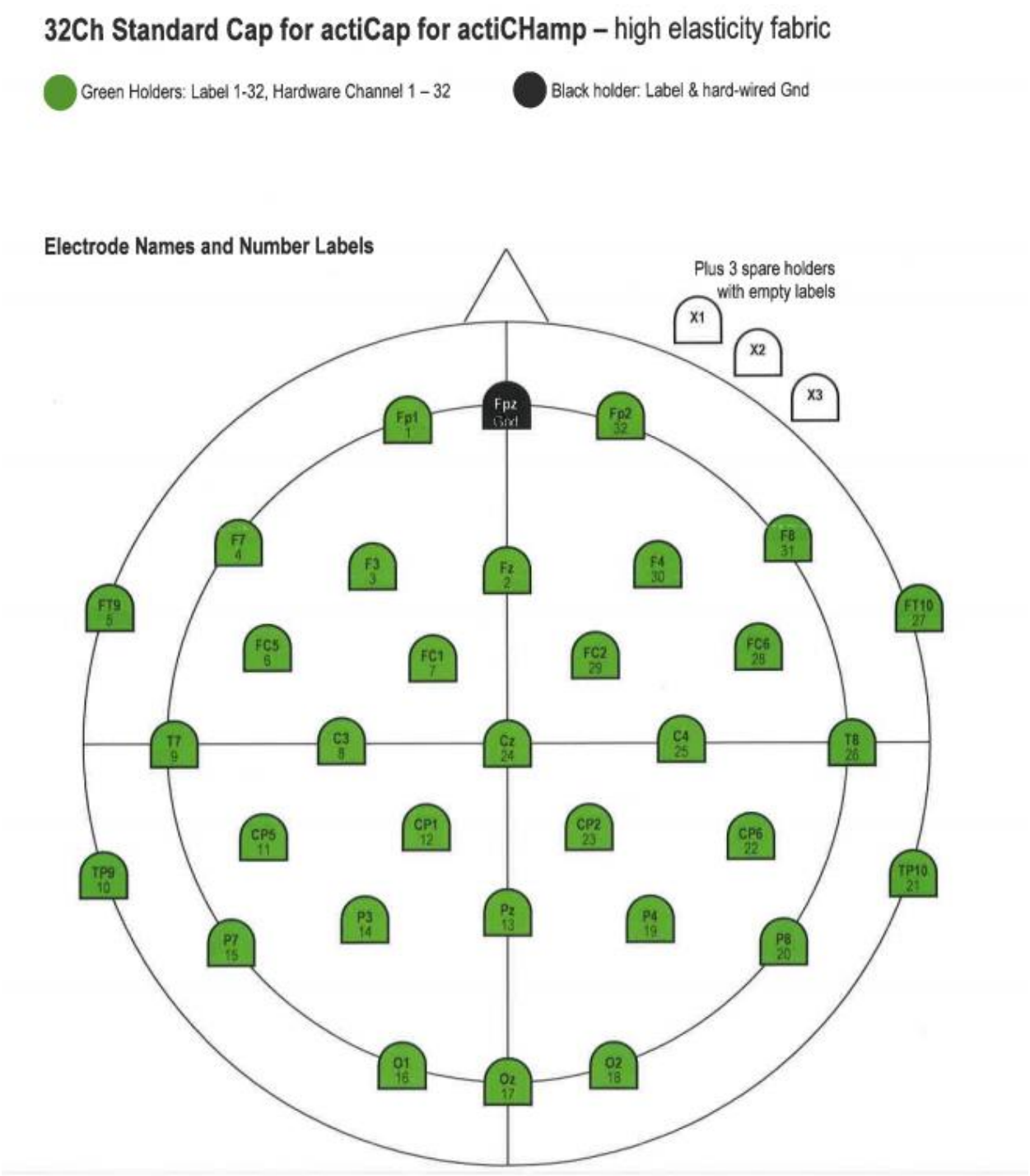


Figure A.2 EEG Cap Channel Set Up

Shallow Processing Study Task

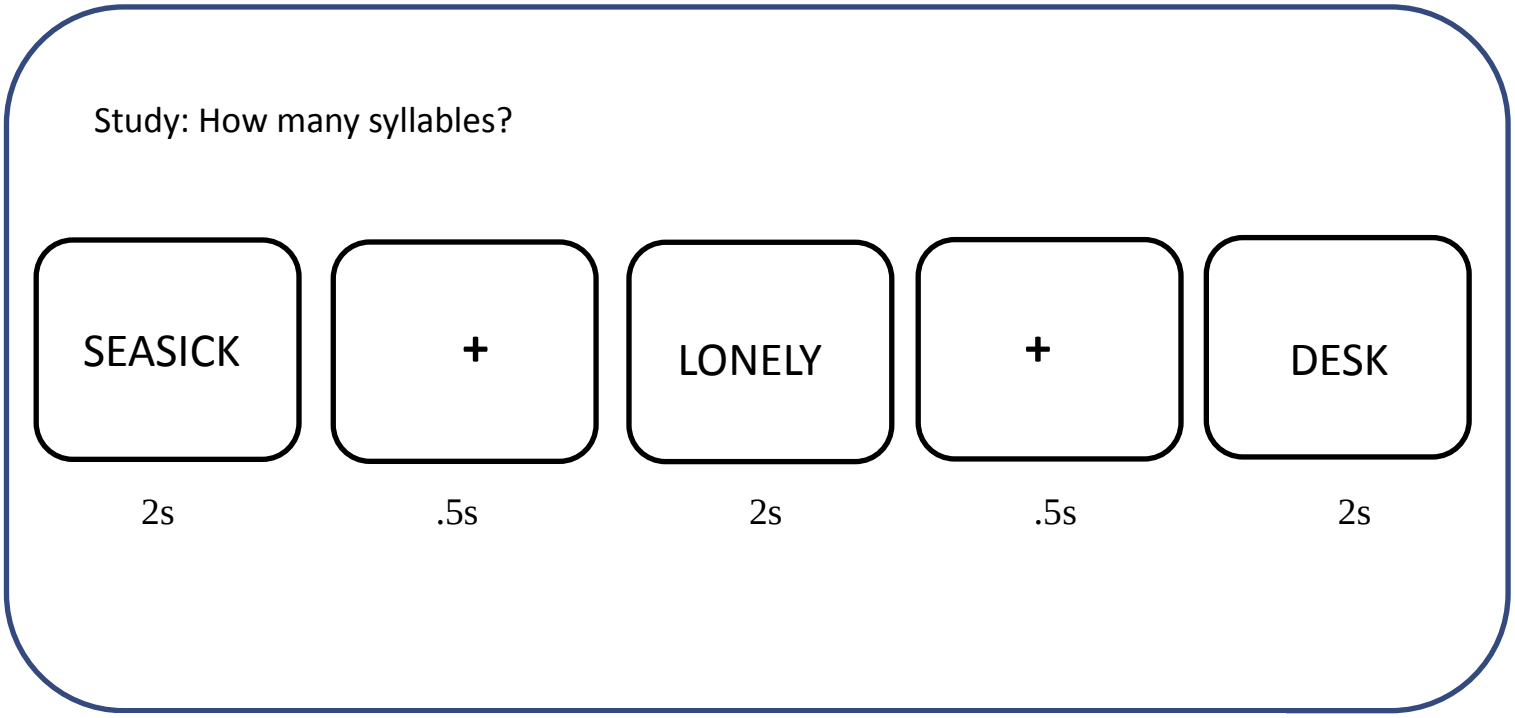


Figure A.3. Study session for shallow processing task. Participants are instructed to determine the syllable count of each word.

Shallow Processing Memory Task

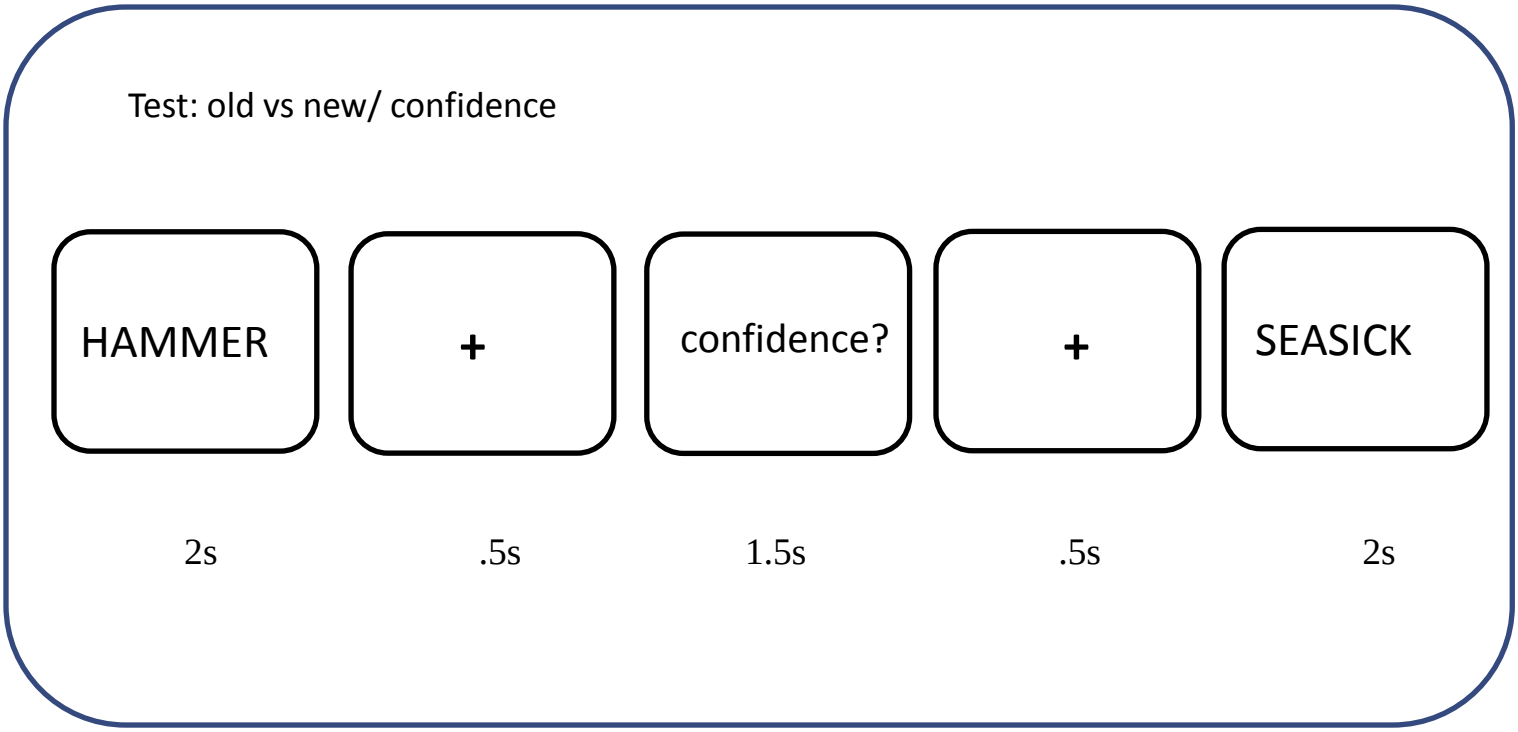


Figure A.4. Long-term memory paradigm for shallow processing task.

Deep Processing Memory Task

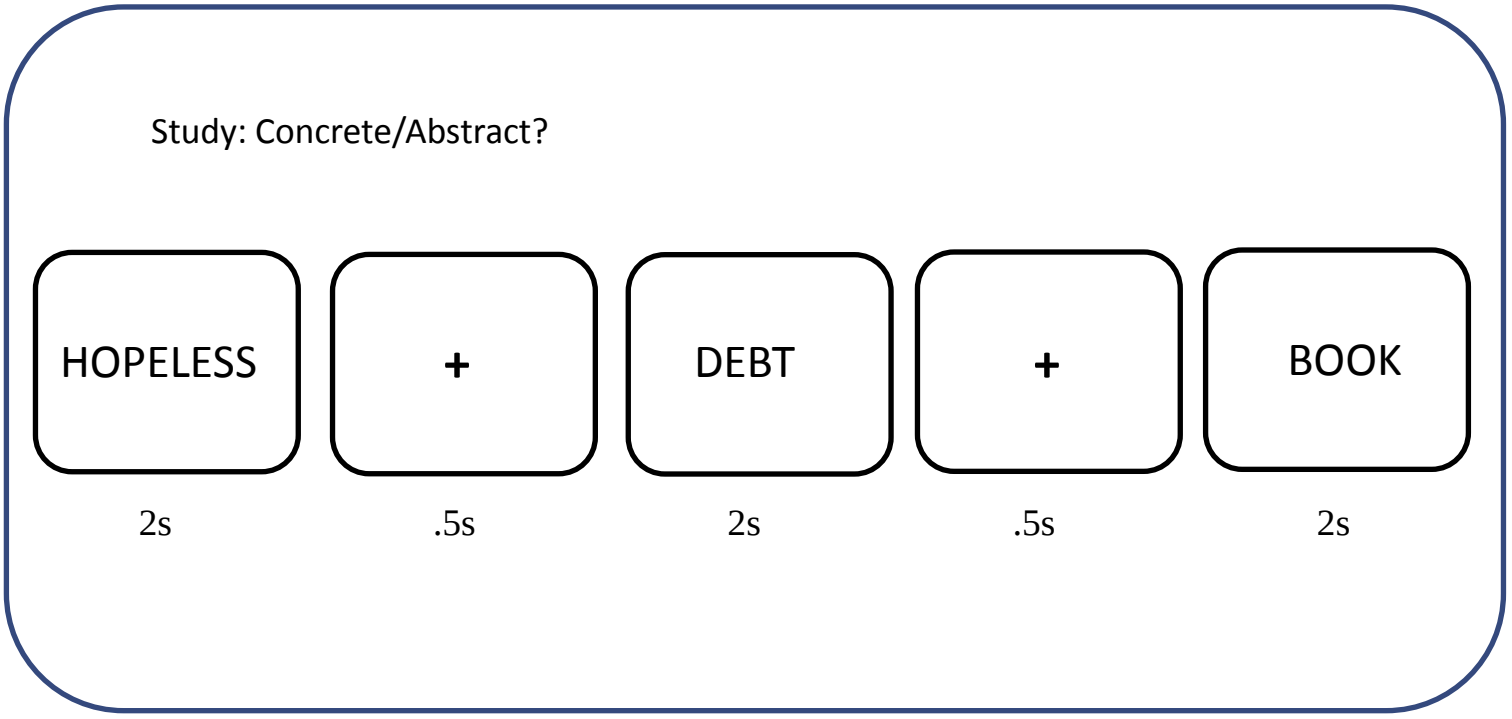


Figure A.5. Study session for the deep processing task. Participants are instructed to determine if each word is concrete or abstract.

Deep Processing Memory Task

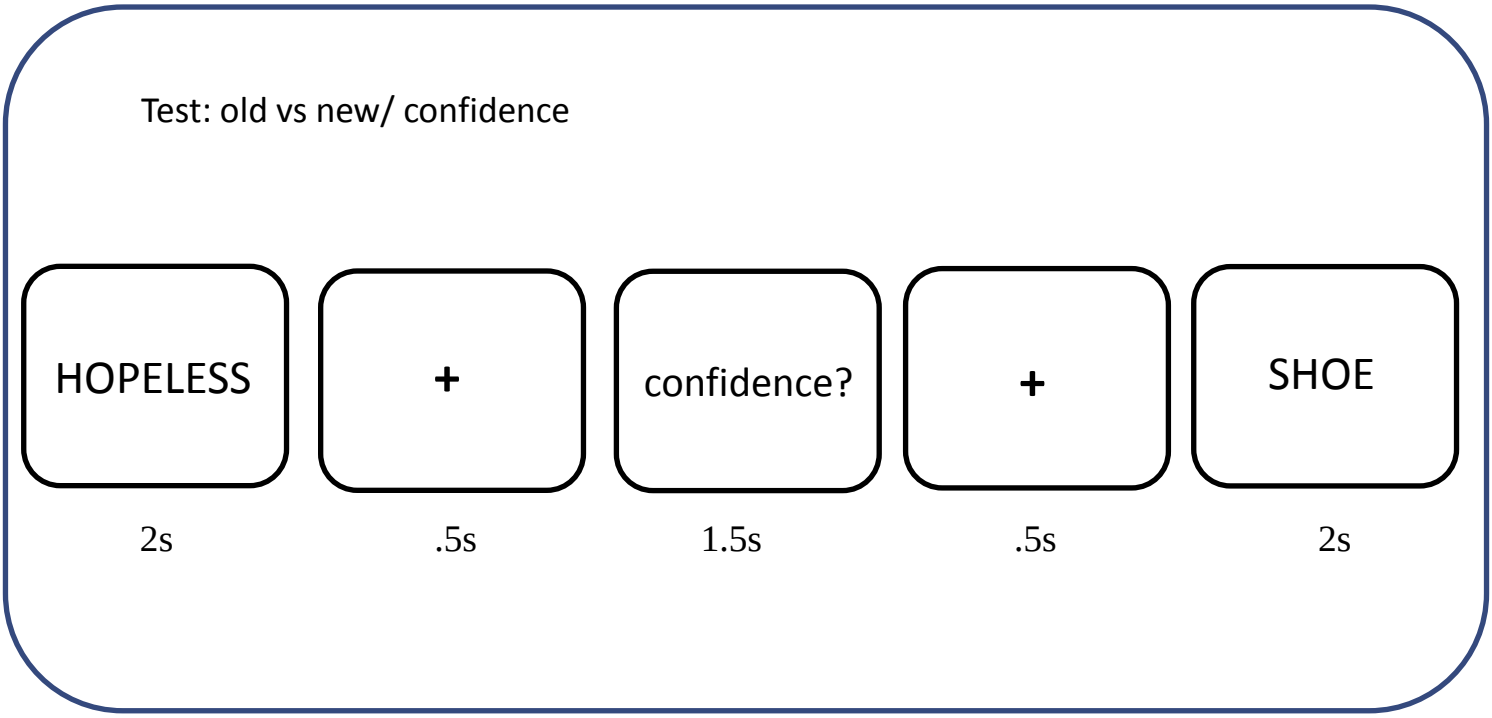


Figure A.6. Long-term memory paradigm for deep processing task.

APPENDIX B

EXPERIMENTAL RESULTS

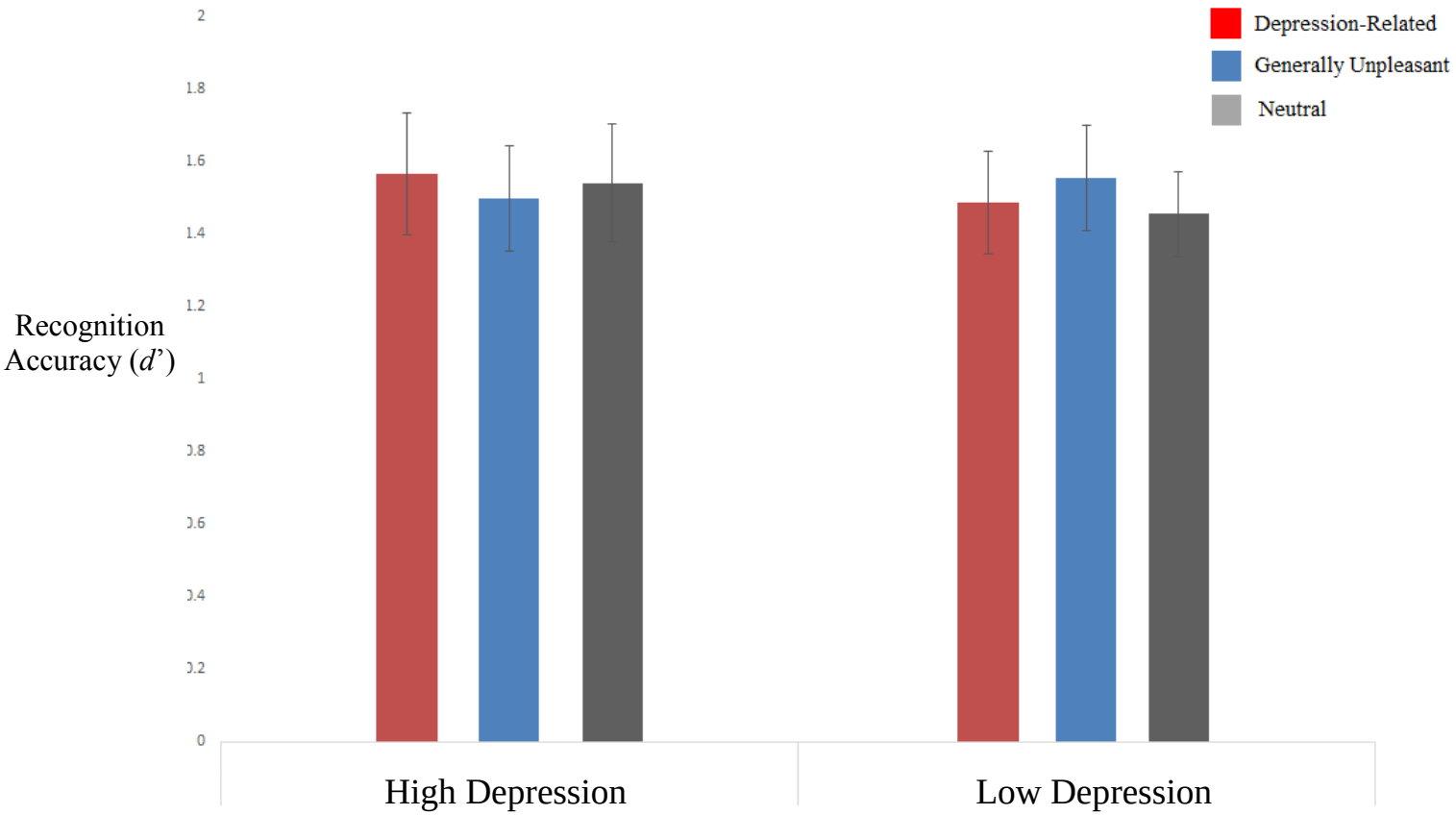


Figure B.1 – Long-term memory performance for shallow processing in individuals with high depressive symptomatology (n = 20) and low depressive symptomatology (n = 20).

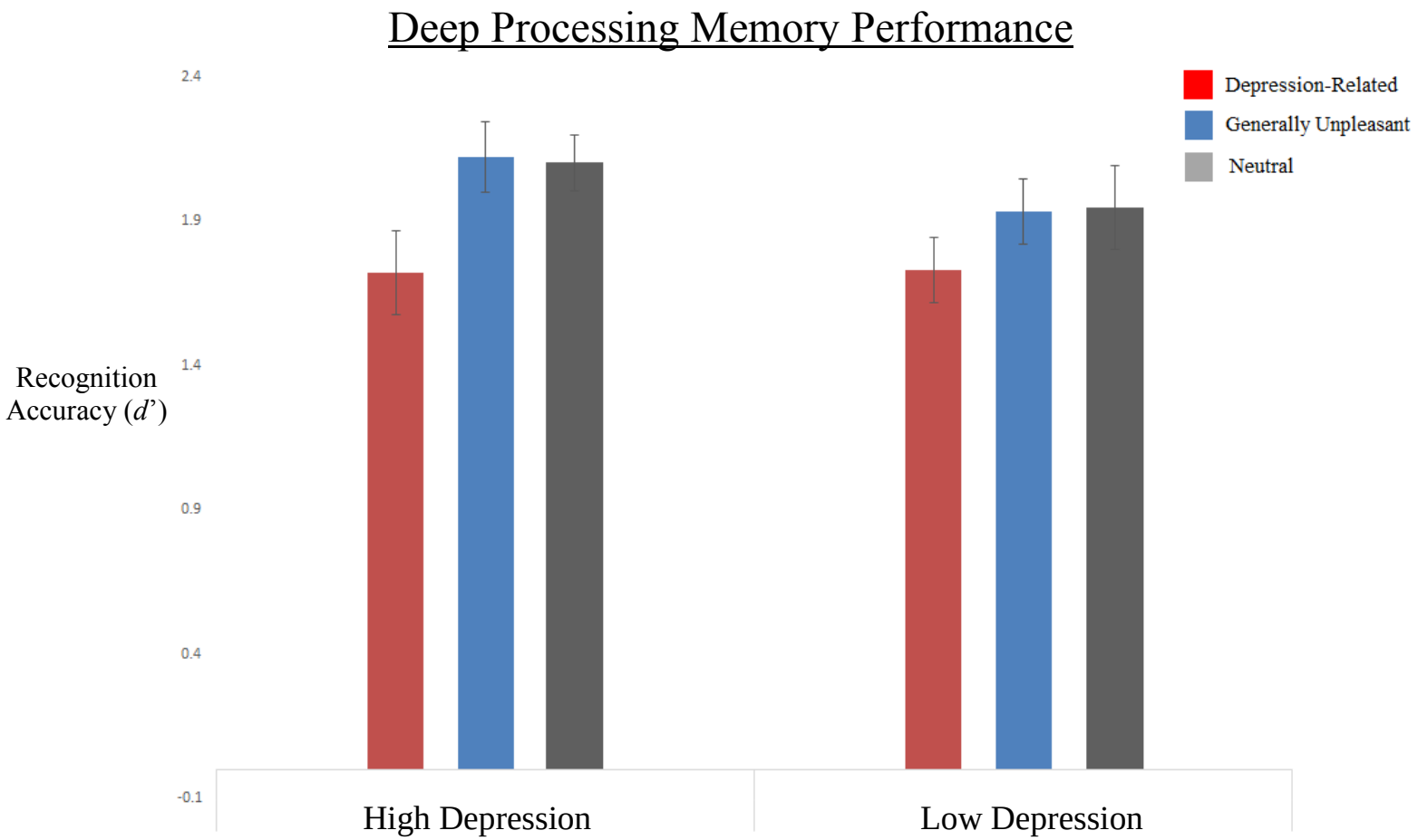


Figure B.2 - Long-term memory performance for deep processing in individuals with high depressive symptomatology (n = 20) and low depressive symptomatology (n = 20).

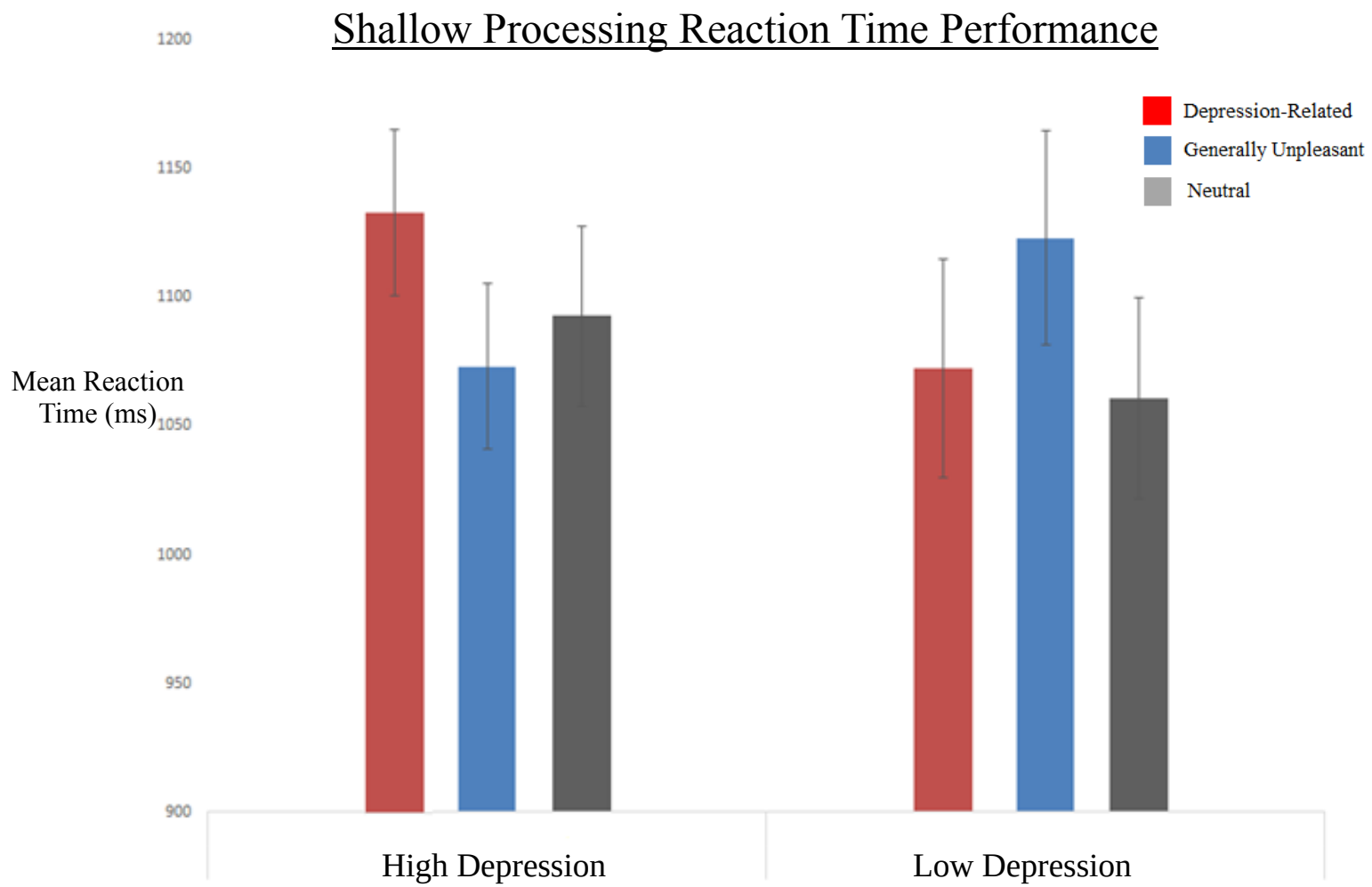


Figure B.3 – Mean reaction time performance for shallow processing in individuals with high depressive symptomatology (n = 20) and low depressive symptomatology (n = 20).

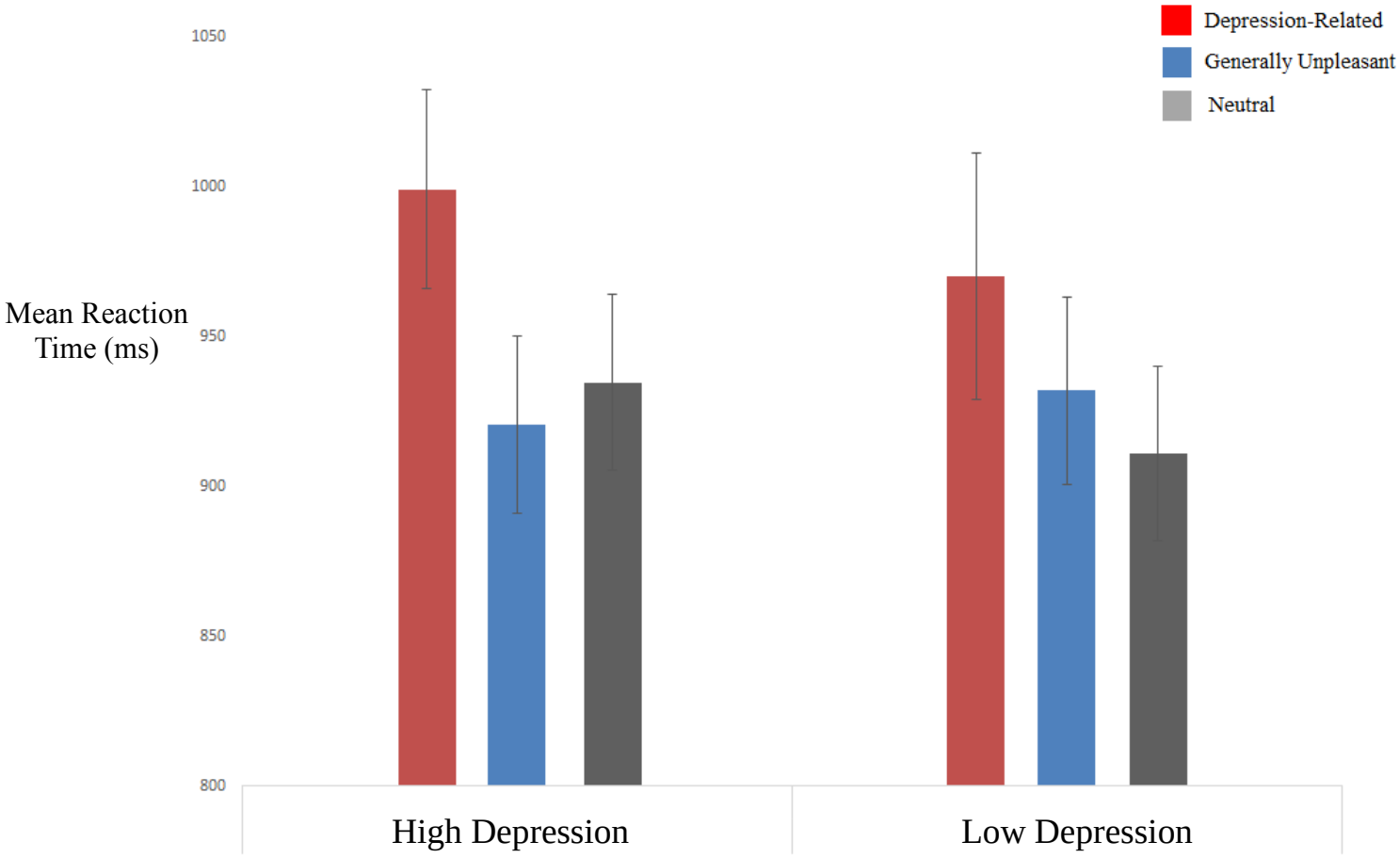


Figure B.4 – Mean reaction time performance for deep processing in individuals with high depressive symptomatology (n = 20) and low depressive symptomatology (n = 20).

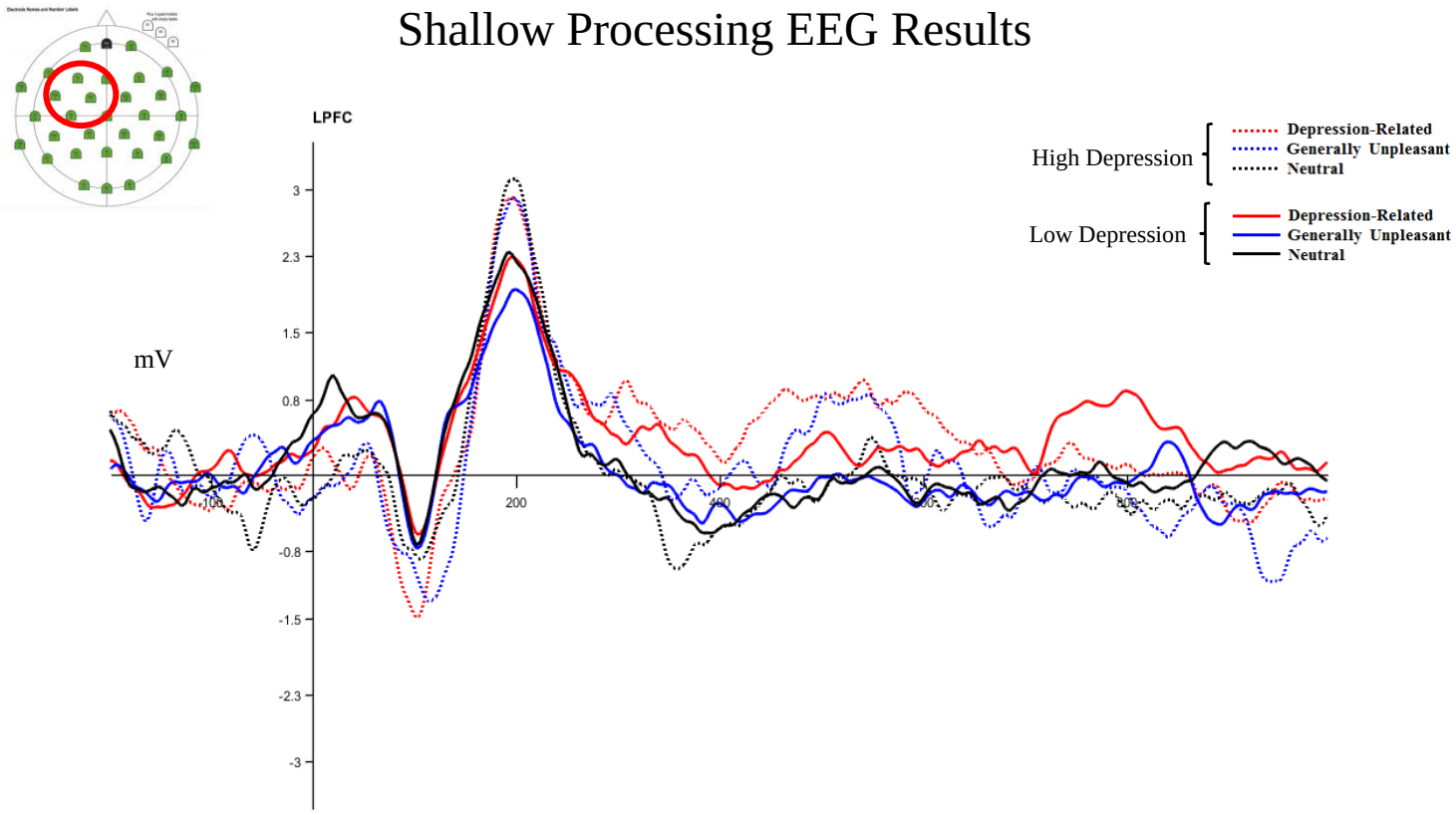


Figure B.5 – ERP of shallow processing during the encoding of DR, U-NDR, and neutral content on the left prefrontal regions (averaged electrodes f3, f7, fz, fc1) for individuals with high depressive symptomatology (n = 20) and low depressive symptomatology (n = 20).

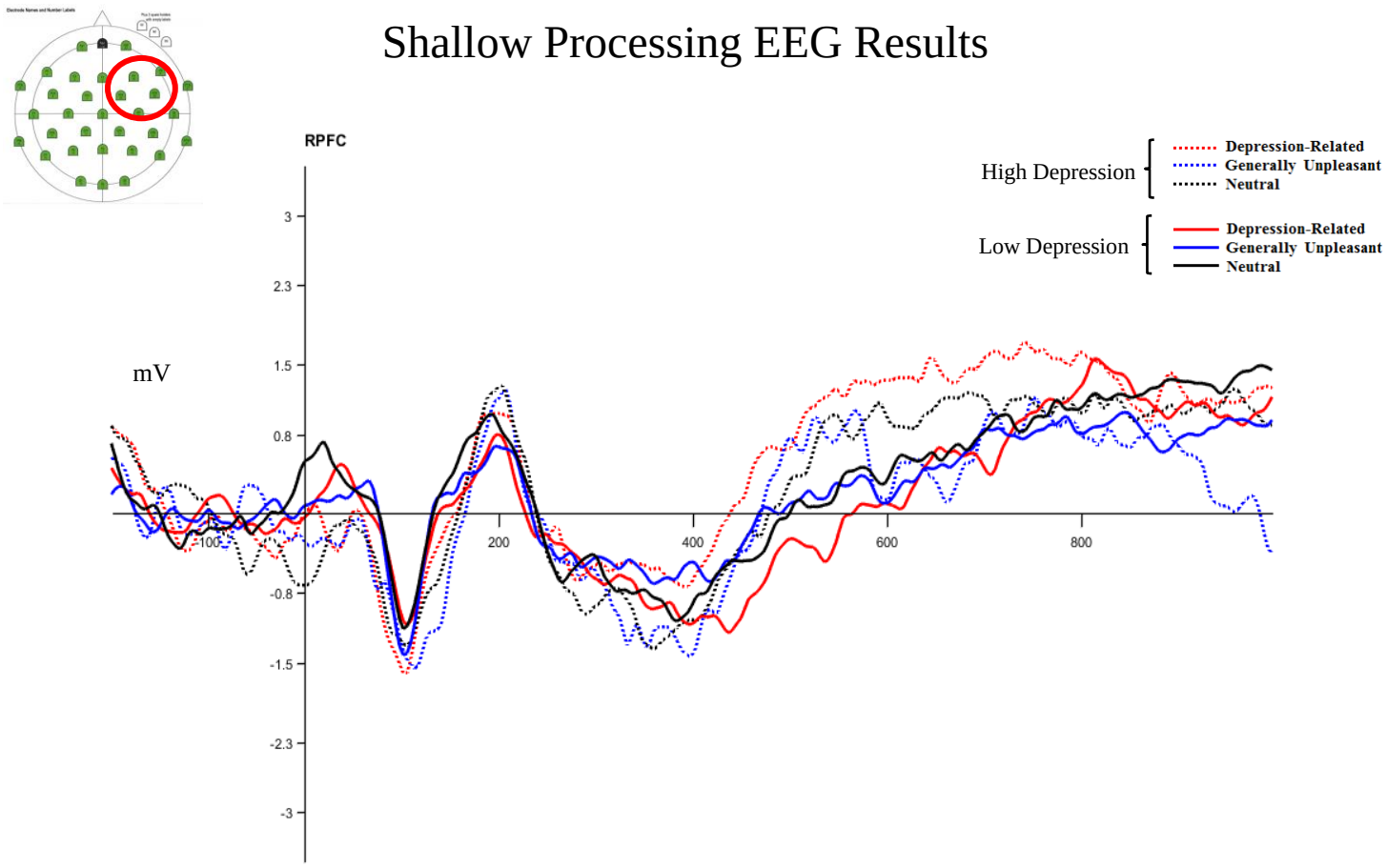


Figure B.6 – ERP of shallow processing during the encoding of DR, U-NDR, and neutral content on the right prefrontal regions (averaged electrodes f4, f8, fc2, fc6) for individuals with high depressive symptomatology (n = 20) and low depressive symptomatology (n = 20).

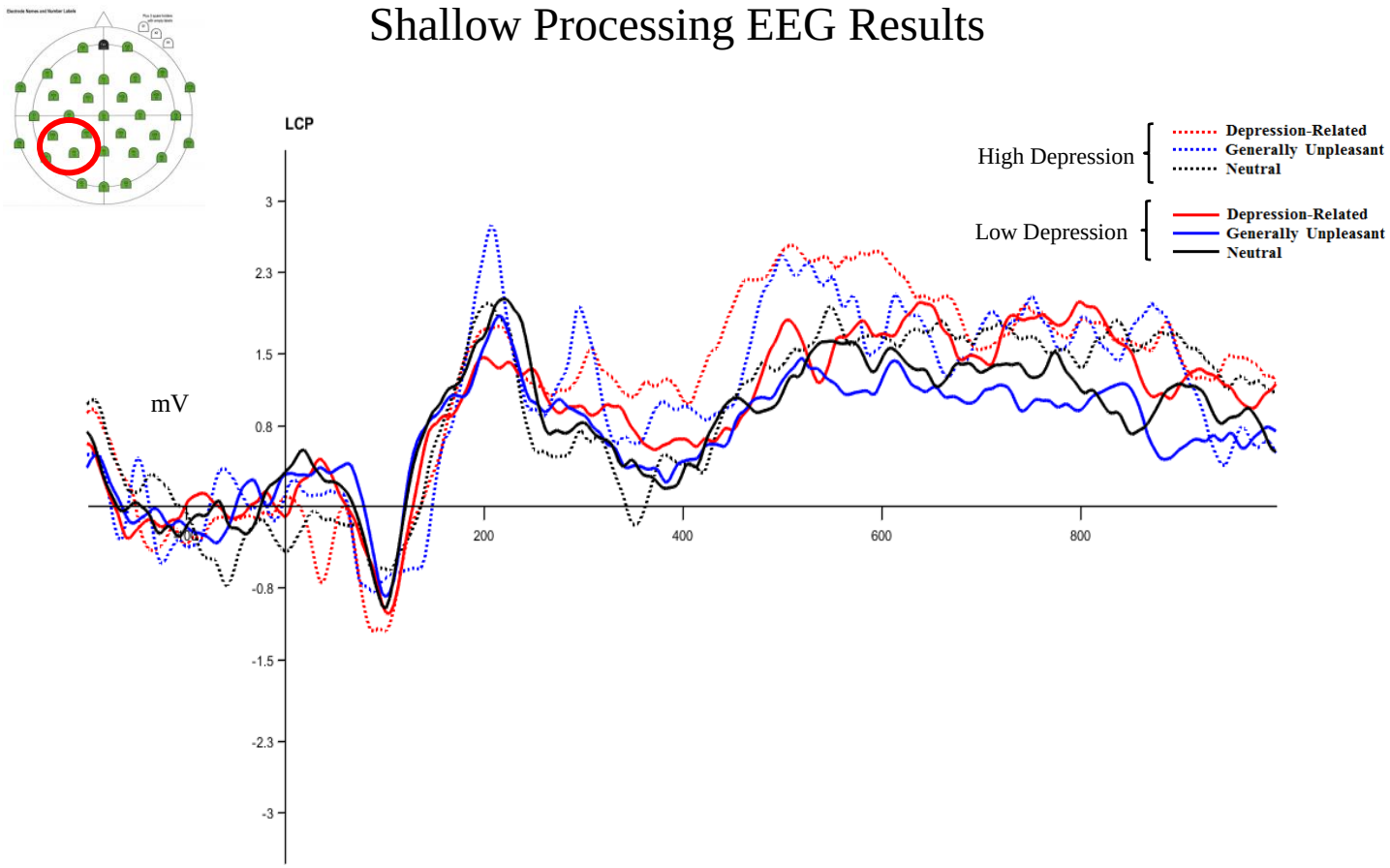


Figure B.7 – ERP of shallow processing during the encoding of DR, U-NDR, and neutral content on the left centro-parietal regions (averaged electrodes c3, cz, cp1, cp5) for individuals with high depressive symptomatology (n = 20) and low depressive symptomatology (n = 20).

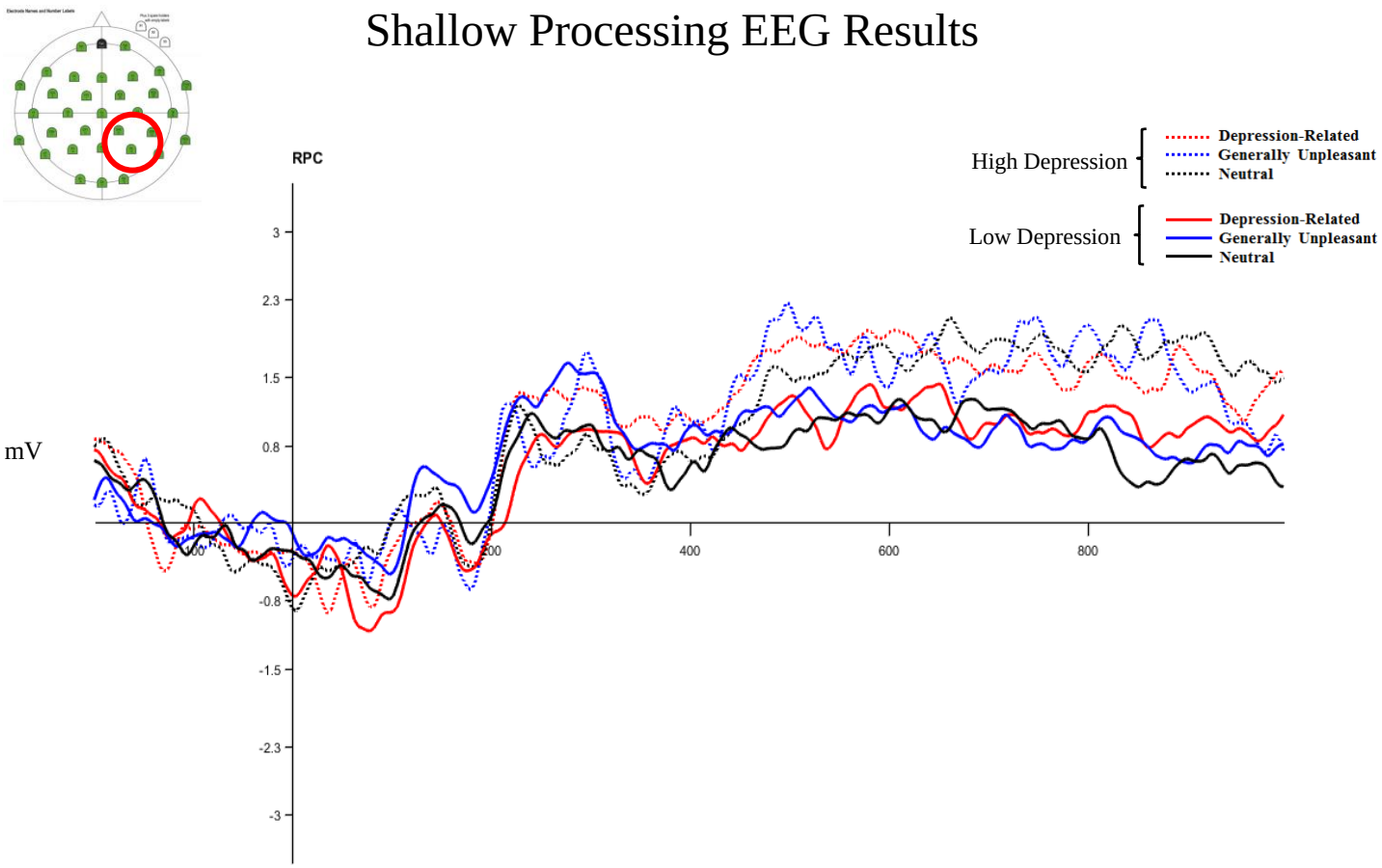


Figure B.8 – ERP of shallow processing during the encoding of DR, U-NDR, and neutral content on the right centro-parietal regions (averaged electrodes p4, p8, cp2, cp6) for individuals with high depressive symptomatology (*n* = 20) and low depressive symptomatology (*n* = 20).

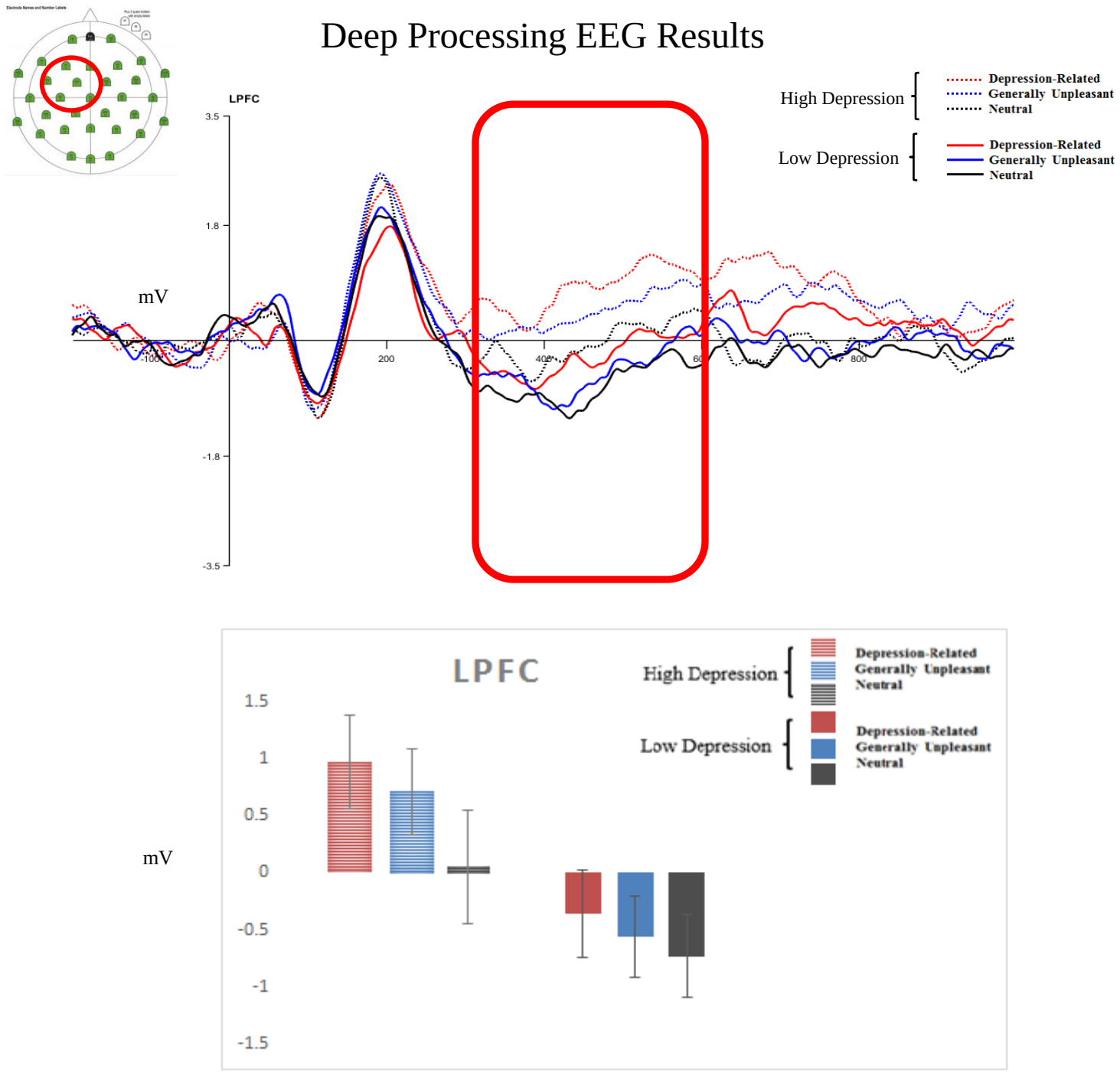


Figure B.9 – ERP and significant mean amplitude bar graph (350 – 600 ms) of deep processing during the encoding of DR, U-NDR, and neutral content on the left prefrontal regions (averaged electrodes f3, f7, fz, fc1) for individuals with high depressive symptomatology (n = 20) and low depressive symptomatology (n = 20).

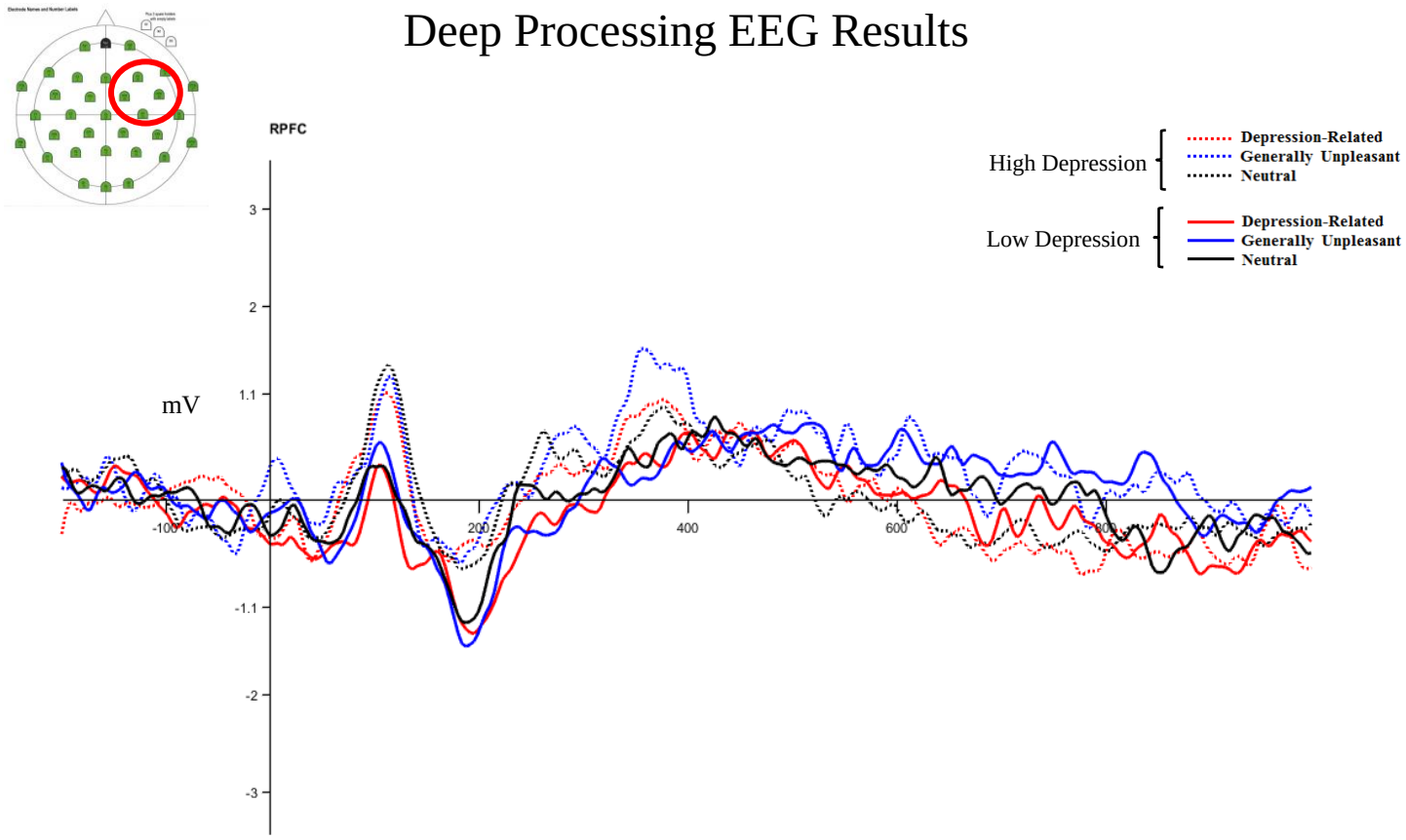


Figure B.10 – ERP of deep processing during the encoding of DR, U-NDR, and neutral content on the right prefrontal regions (averaged electrodes f4, f8, fc2, fc6) for individuals with high depressive symptomatology (n = 20) and low depressive symptomatology (n = 20).

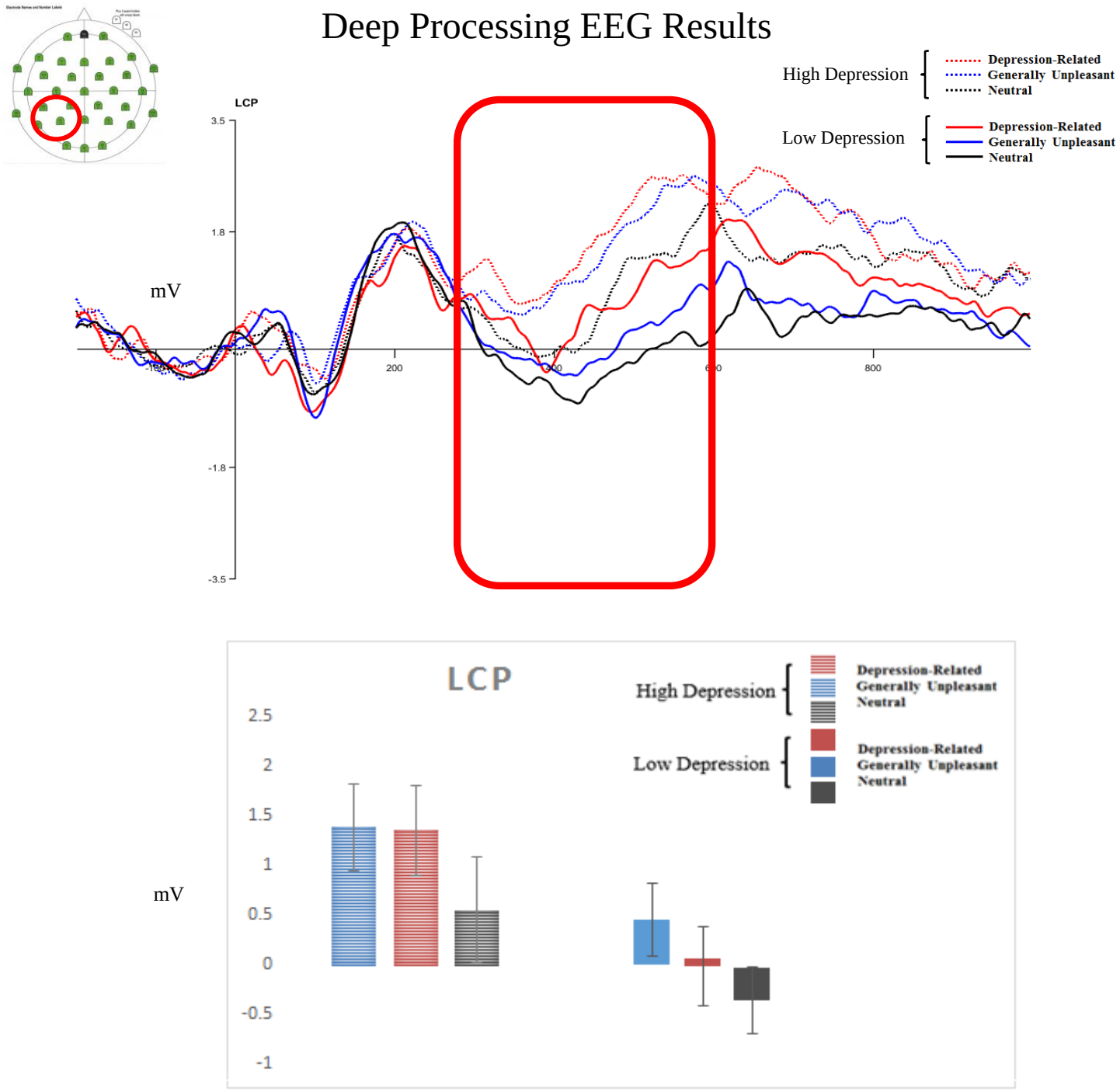


Figure B.11 – ERP and significant mean amplitude bar graph (350 – 600 ms) of deep processing during the encoding of DR, U-NDR, and neutral content on the left centro-parietal regions (averaged electrodes c3, cz, cp1, cp5) for individuals with high depressive symptomatology (*n* = 20) and low depressive symptomatology (*n* = 20).

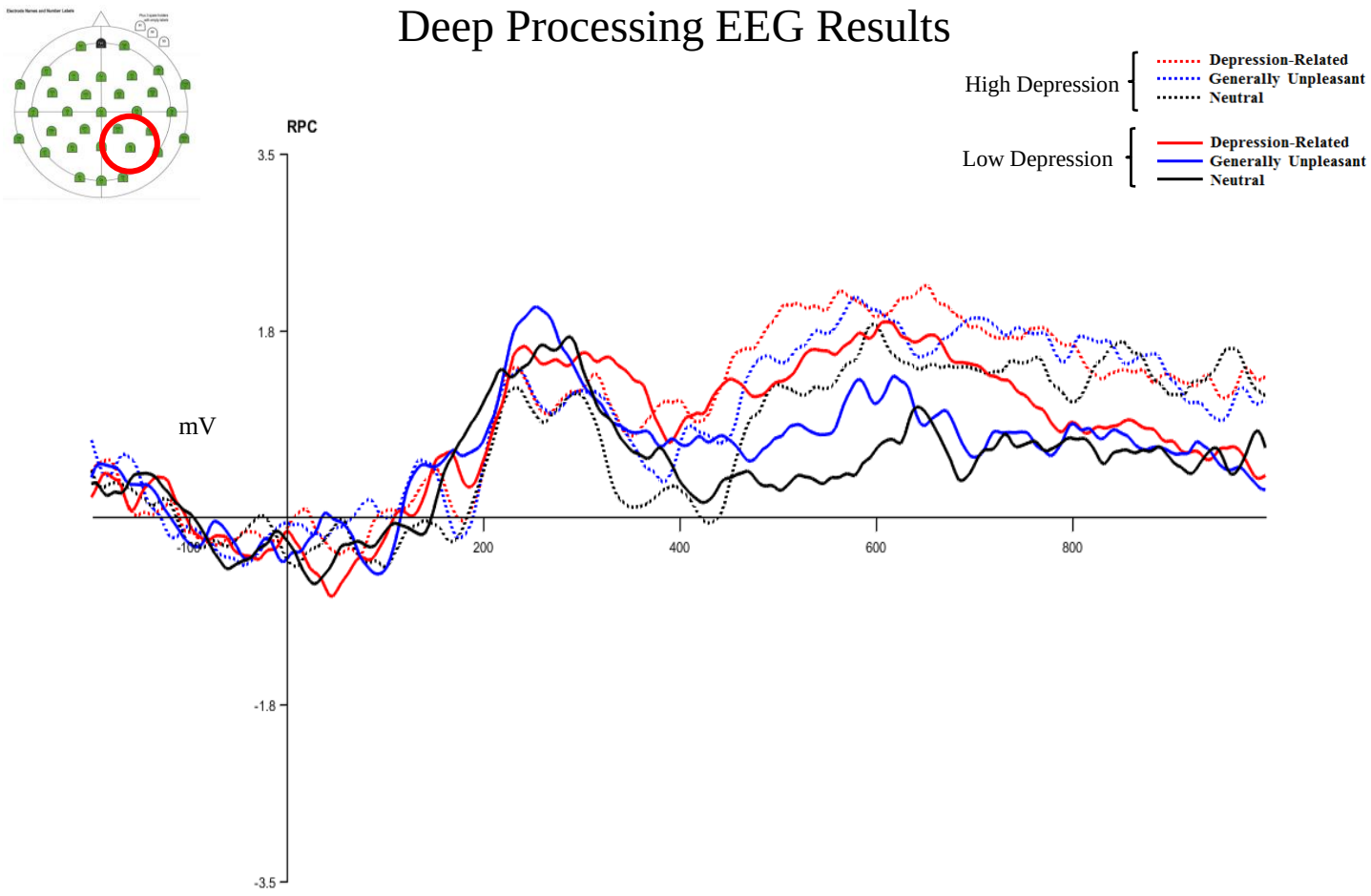
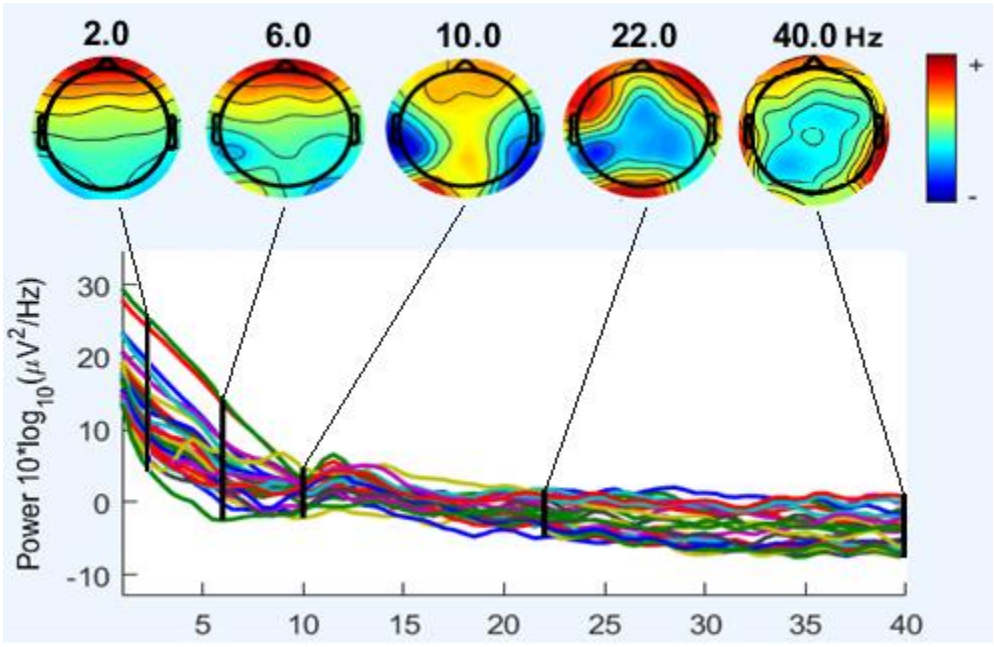


Figure B.12 – ERP of deep processing during the encoding of DR, U-NDR, and neutral content on the right centro-parietal regions (averaged electrodes p4, p8, cp2, cp6) for individuals with high depressive symptomatology (n = 20) and low depressive symptomatology (n = 20).

Shallow Processing Power Spectrum Analysis

A)



B)

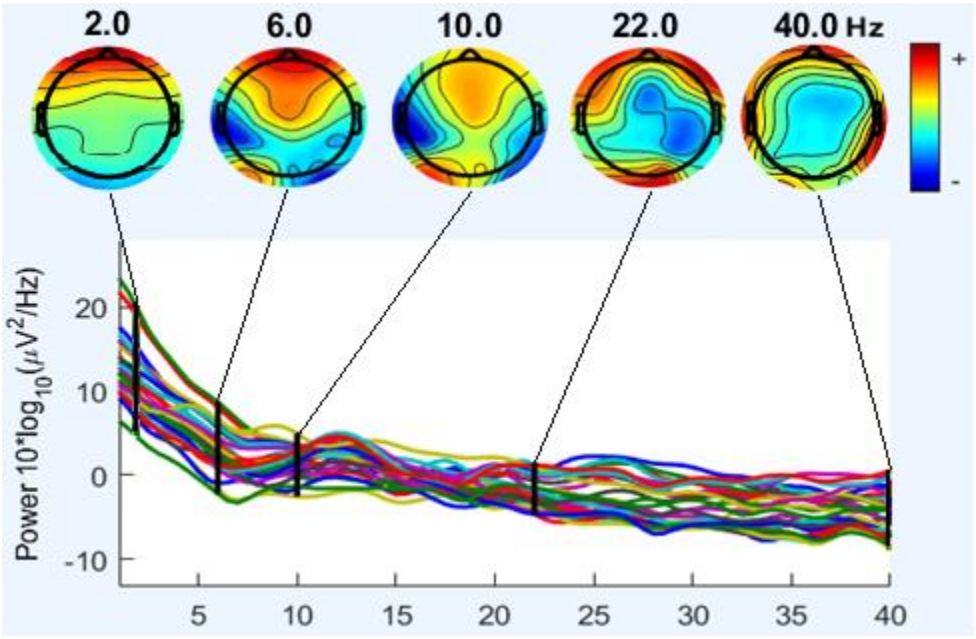
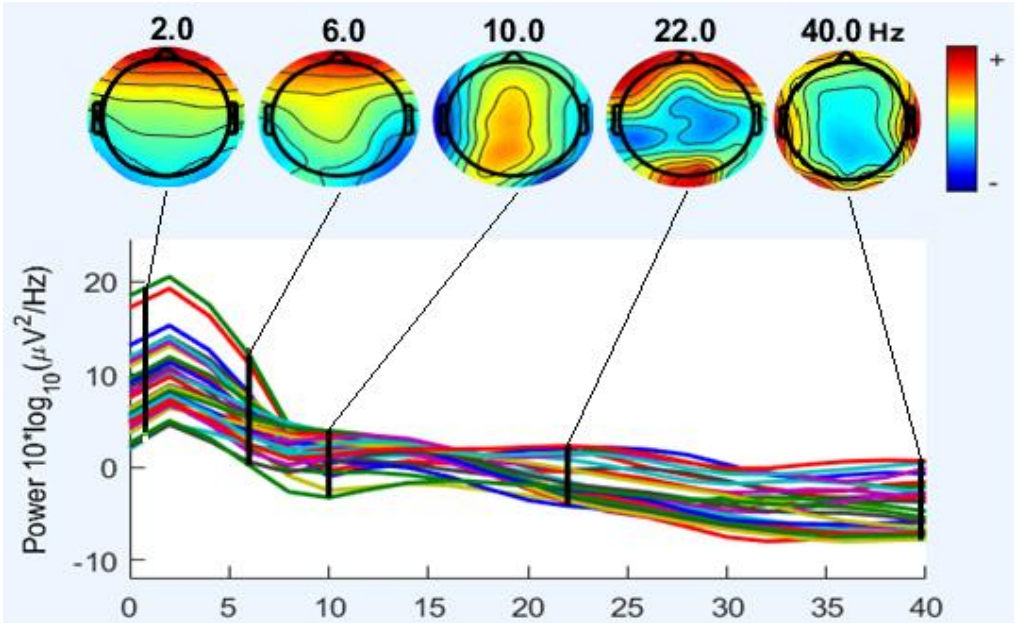


Figure B.13 – A) delta, theta, alpha, beta and gamma bands corresponding to overall hits for low depressive symptomatology compared to B) delta theta, alpha, beta and gamma bands corresponding to overall hits for high depressive symptomatology during the shallow processing task. No significant effects.

Deep Processing Power Spectrum Analysis

A)



B)

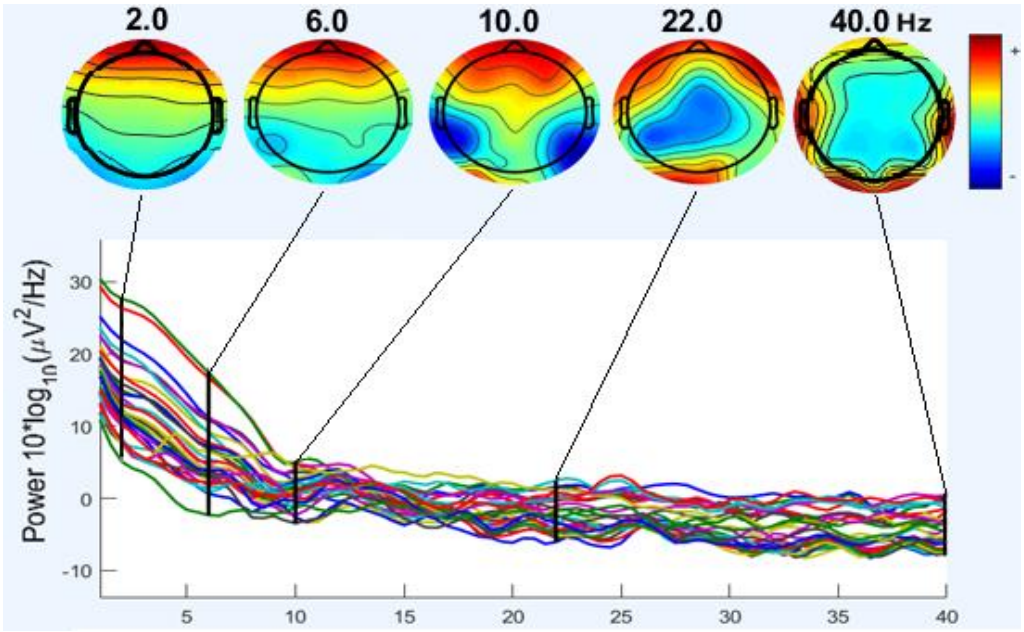


Figure B.14 – A) delta, theta, alpha, beta and gamma bands corresponding to overall hits for low depressive symptomatology compared to B) delta, theta, alpha, beta and gamma bands corresponding to overall hits for high depressive symptomatology during the deep processing task.

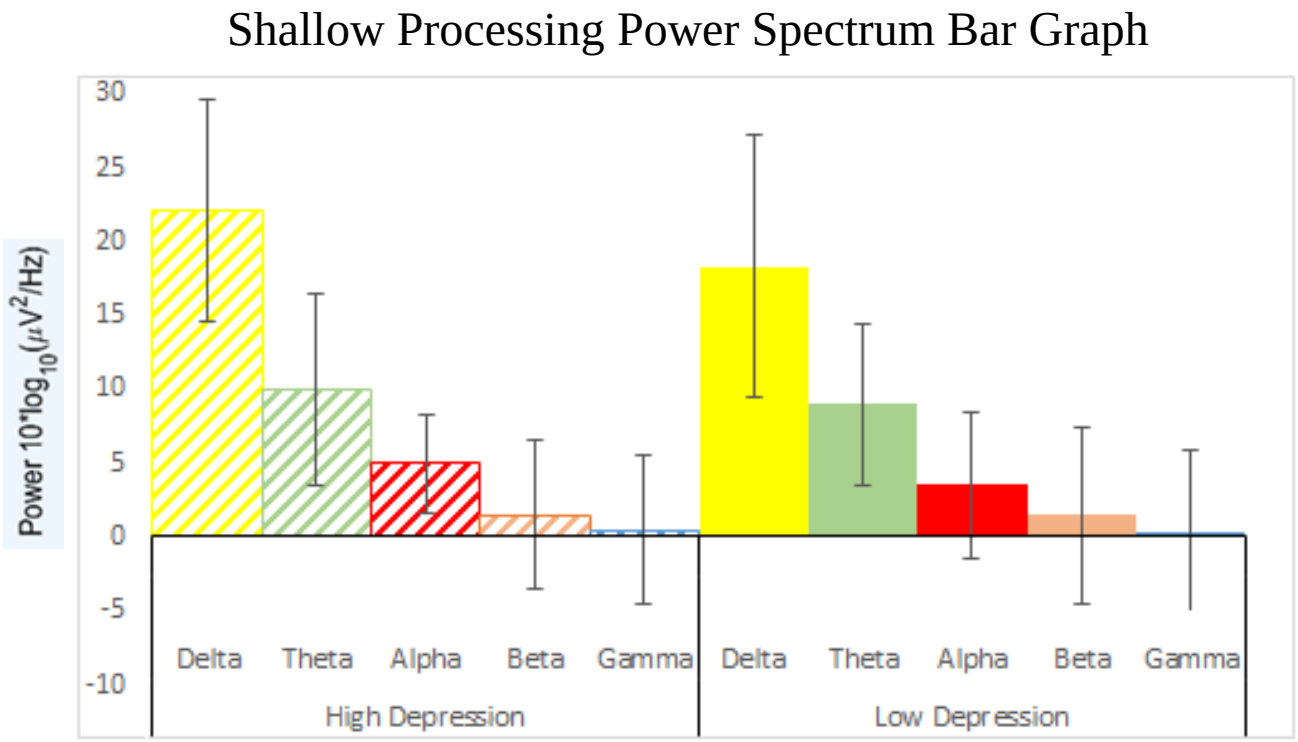


Figure B.15 – Power spectrum bar graphs of volts-squared per hertz for prefrontal cortex (f3, fz, f4, fp1, fp2). A) delta, theta, alpha, beta and gamma bands corresponding to overall hits for low depressive symptomatology compared to B) delta theta, alpha, beta and gamma bands corresponding to overall hits for high depressive symptomatology during the shallow processing task. No significant effects.

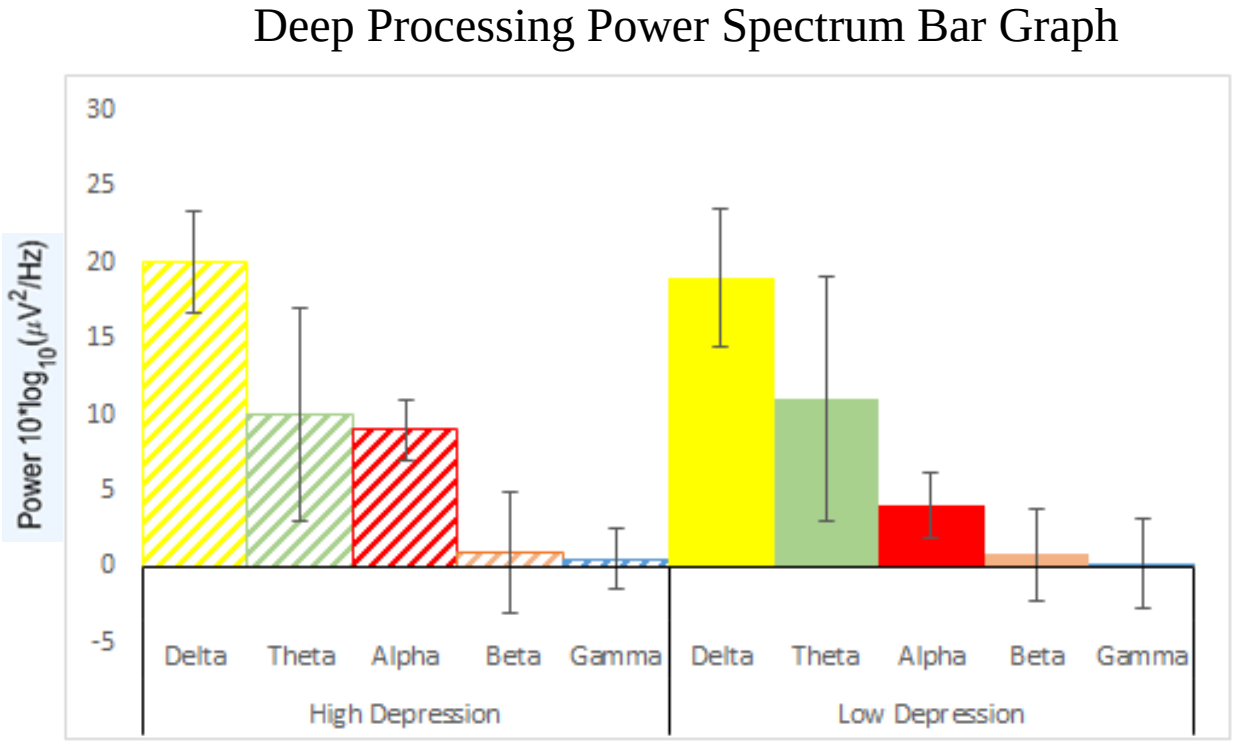


Figure B.16 – Power spectrum bar graphs of volts-squared per hertz for prefrontal cortex (f3, fz, f4, fp1, fp2). A) delta, theta, alpha, beta and gamma bands corresponding to overall hits for low depressive symptomatology compared to B) delta, theta, alpha, beta and gamma bands corresponding to overall hits for high depressive symptomatology during the deep processing task.

BIOGRAPHICAL INFORMATION

Kellen Gandy is a fourth-year graduate student and teaching assistant in the Psychology department at the University of Texas at Arlington. He is a former member of Dr. Heekyeong Park's Cognitive Neuroscience of Memory Lab and has published in neuroscience journals. He is a current member of Dr. William Ickes' lab who has been a wonderful mentor. His research focuses on understanding the underlying mechanisms involved in the encoding and retrieval of source, item-specific memory, associative memory and cognitive impairments in depression using a wide variety of imaging techniques including electroencephalography (EEG), functional magnetic resonance imaging (fMRI), and functional near-infrared spectroscopy (fNIRS). Kellen received his Master of Science in Experimental Psychology from the University of Texas at Arlington in 2015. Previously, Kellen received a Bachelor of Science in Psychology with a minor in Neuroscience from Texas A&M University in 2012.