January 2014

The Influence of Individual Differences on Emotional Processing and Emotional Memory

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The Influence of Individual Differences on Emotional Processing and Emotional Memory

by

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A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Arts
Department of Psychology
College of Arts and Sciences
University of South Florida

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Date of Approval:
June 18, 2014

Keywords: BIS/BAS, ERP, LPP, motivation, affect

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ABSTRACT

Emotional material is better remembered than neutral material and some suggest this is reflected in different Event Related potentials (ERPs) to affective stimuli by valence. Inconsistent results may be due to individual differences, specifically the behavioral inhibition/behavioral activation (BIS/BAS) motivational system. This study sought to examine the relationship between motivational systems, emotional memory, and psychophysiological response to emotional pictures. While using EEG recording, subjects were shown 150 affective pictures and given a recall and yes/no recognition task after a 20 and 30-minute delay, respectively. Overall, differences were found by valence, but not consistently based on individual trait. Controlling for arousal and mood, results did not support previous research that suggested high BIS was more responsive to negative pictures while higher BAS was more responsive to positive images. The role of ERP methodology and arousal are discussed, along with future directions.

INTRODUCTION

Researchers have suggested that humans have an adaptation to preferentially process emotional material compared to neutral material (De Kloet, Joëls, & Holsboer, 2005). Additionally, these events often benefit from *emotional memory enhancement*, which is an increased likelihood of remembering emotional memories, particularly those that produce arousal (Kensinger, 2009). While this enhancement in memory for emotional material has been reported across paradigms and across different types of stimuli, the exact mechanisms of preferential processing are not fully understood. Additionally, this effect is not always consistently found and some argue that the effect may be due to extraneous factors (e.g., stimulus characteristics, novelty, attention) and not the emotional content of the stimuli (e.g., Talmi & McGarry, 2011). One explanation for this disparity may be the effects of individual differences on emotional processing. Typically, both males and females are combined within one study, despite gender differences in emotional processing (Glaser et al., 2012). Additionally, individual traits have been found to evoke different responses to emotional material contributing to further variation. This study seeks to use behavioral and psychophysiological measures to examine differences in emotional processing and memory that may be caused by individual differences.

This paper will first provide a review of the mechanisms by which emotional enhancement may take place, particularly emphasizing the past research on attention and amygdala involvement. Next, Event Related Potential (ERP) methodology will be discussed, through examining differential responses of early and late components to response to emotional material. Lastly, individual differences in emotional material processing and memory will be discussed. Previous research in this last section is particularly scarce, but studies will be provided that indicate individual differences may predict certain responses to emotional material. The present study will seek to add to the literature by examining the effects of individual differences on the psychophysiological and behavioral aspects of emotional processing and memory.

Memory Enhancement of Emotional Material

Enhanced emotional memory has been demonstrated when presenting either emotional words (Kensinger & Corkin, 2003) or pictures (Palomba, Angrilli, & Mini, 1997; Weymar, Schwabe, Löw, & Hamm, 2012), relative to neutral words and pictures. Although there is a great deal of support for enhanced emotional memory, findings are not entirely consistent. One research group found that although participants report remembering emotional items better, they did not actually recall emotional items any better than neutral items (Sharot, Delgado, & Phelps, 2004). Additionally, stimulus characteristics, including organization, distinctiveness, and attention have been reported to primarily influence immediate emotional memory enhancement (Talmi & McGarry, 2011). Some investigators have suggested arousal, in general, produces enhanced memory, even if the material is not emotional (Abercrombie, Kalin, Thurow, Rosenkranz, & Davidson, 2003; Nielson, Yee, & Erickson, 2005), though memory enhancement has been found specifically for emotional material. A slower acting mechanism is hypothesized to occur in response to arousal: when an item is high in arousal, it is hypothesized that the amygdala and associated limbic regions are activated (Adolphs, Tranel, & Buchanan, 2005). Since the mechanism is slower acting, effects are more likely to be found after a delay. Using electrical shocks to elicit arousal, Schwarze, Bingel, and Sommer (2012) demonstrated that arousal associated with neutral picture presentations increased the ability to remember neutral pictures. However, this increased recall was only found after a delay period (24 hours) and not after the immediate recall (i.e., five minutes after presentation). Overall, there is evidence that arousing information benefits from enhancement during encoding, consolidation, and retrieval in a way unique to emotional material (see Kensinger 2009 for review).

Mechanisms for Emotional Memory Enhancement

While it is generally agreed upon that there is enhanced memory for emotional material, the mechanisms by which the enhancement takes place are not completely understood (Hamann, 2001; Humphreys, Underwood, & Chapman, 2010). The most common theories involve a combination of increased attention, through involvement of the prefrontal cortex, and increased amygdala activity. However, interactions with many other brain areas have been suggested to play a significant role.

Increased Attention and Emotional Memory

Emotional material is hypothesized to capture attention over non-emotional material (e.g., Alpers, 2008), specifically, negative material (e.g., Fiske (1980) and Hansen & Hansen (1988)). However, attention is difficult to measure. Talmi and McGarry (2011) suggest that organization, distinctiveness, and attention accounted for emotional memory enhancement. When all three were equated in a full attention condition, no difference in recall rates were found between negative and neutral pictures. However, different results were found in the divided attention condition. They found 1) within the divided attention condition fewer neutral pictures were remembered relative to negative pictures and 2) between the conditions (i.e., full vs. divided attention) fewer neutral pictures overall were recalled in the divided attention condition but not the negative pictures. These results suggest that recall of negative information remained stable, despite decreased attention, while neutral information evidenced a decrease in recall. The researchers concluded that these findings provide evidence that when organization and distinctiveness are equated, attention alone is responsible for any emotional enhancement.

Humphreys et al. (2010) examined attention by measuring amount of time a stimulus was viewed and how this related to later recall of the image. Participants looked at a pair of pictures (e.g., emotional-neutral or neutral-neutral) and were asked which images they preferred. Researchers measured latency to fixation, number of fixations, and total viewing time for each image, which they used to operationally define attention. They found that amount of time fixating on a neutral picture was correlated with recognition one week later, but the same effect was not found for emotional stimuli.

There was increased attention to positive pictures and decreased attention to negative pictures, however, participants recalled more negative than positive pictures. These results clearly indicate that emotional memory enhancement is not explained solely by increased overt attention, as measured through eye gaze.

Event related potentials (ERPs) have also been used to measure increased cognitive attentional resource allocation. Several studies have found that emotional material, in general, evoke an increased Late Positive Potential (LPP) relative to neutral material. This effect is proposed to be due to the motivational significance of the emotional material, with no clear differences between positive and negative stimuli reported (M.M. Bradley, Hamby, Löw, & Lang, 2007; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; De Cesarei & Codispoti, 2006; Hinojosa, Carretié, Valcárcel, Méndez-Bértolo, & Pozo, 2009; Schupp, Cuthbert, et al., 2004). Even when rapidly presenting emotional pictures in a mixed presentation, Schupp et al. (2000) still found that the LPP was greater for emotional pictures and concluded that LPP demonstrates increased amplitude in response to motivationally relevant material. LPP amplitude is hypothesized to predict increased cognitive attention and predict later recall, a phenomenon called ‘subsequent memory' (Friedman & Trott, 2000). In a study examining stress, emotional memory, and the LPP component, an increased LPP amplitude in response to emotional pictures was found in the stressed group and was related to subsequent negative picture recall, but not neutral recall (Weymar et al., 2012). The LPP component is thought to provide evidence that neural mechanisms offer additional resources when encoding emotional material that is not given to neutral material (Palomba et al., 1997; Weymar et al., 2012). However, these results are inconsistent when using recognition instead of recall to assess memory. Pérez-Mata, López-Martín, Albert, Carretié, and Tapia (2011) conducted a study investigating ERPs and emotional memory for pictures and found that while emotional stimuli evoked a larger LPP, there were no differences in recognition accuracy or reaction time between emotional and neutral images after a twenty-minute delay. The only difference that was found was between the extremes of positive relaxing stimuli and negatively arousing stimuli, again, possibly showing an arousal effect. However, these results may be confounded by a ceiling effect since participants correctly recognized 82-90% of the images across categories, possibly showing too little variation to demonstrate an effect.

Schupp, Cuthbert, et al. (2004) also examined attention in a different way. Researchers presented emotional images (positive and negative, varying in arousal) and neutral images. Periodically, noises sounded in headphones, which the participants were instructed to ignore. This noise, however, would elicit an ERP component each time it is heard (i.e., startle probe would elicit a P3 component). They found that the emotional material, regardless of valence, demonstrated decreased responses to the startle probes (i.e., smaller amplitude P3 components). This effect was most pronounced for motivationally relevant material; pictures high in arousal (threatening and erotic) evidence the largest decrease in startle response. Similarly, in their previous research they had found that while eye blink response tends to be augmented based on the valence of the stimuli, P3 amplitude varies based on the arousal of an image (Cuthbert, Schupp, Bradley, McManis, & Lang, 1998). The researchers postulate that this is evidence of decreased attentional resources available for other stimuli (i.e., startle probe) when motivationally relevant material is present.

These studies suggest that attention is not just increased through mechanisms such as an increase in time allotted to process emotional material or amount of time fixated on an image, but rather through the intensity of the response to the material. Increased attention is preferentially allocated to emotional stimuli, but attention is not able to fully account for preferentially emotional processing and memory. Additionally, this study will investigate if individual differences preferentially increase attention to one particular stimulus, explaining the strong support for the influence of attention.

Amygdala Involvement and Emotional Memory

While the attention and prefrontal cortex activity is thought to enhance emotional memory during encoding (Olofsson, Nordin, Sequeira, & Polich, 2008), the amygdala is thought to be involved throughout encoding, consolidation, and retrieval (Sharot et al.) 2004 also see (LaBar & Cabeza, 2006) for review), acting as a slower mechanism (Adolphs, Tranel, & Buchanan, 2005). There are competing views of the specific involvement or the precise nature of the involvement of the amygdala, but it is agreed that the amygdala is an essential part of emotional memory (Hamann, 2001). The core hypotheses about the amygdala's role are: 1) the amygdala plays a secondary role through facilitation of emotional memory with other brain regions, 2) the amygdala has a direct role in emotional memory enhancement, or 3) the amygdala works through a combination of both roles (Richter-Levin, 2004). Mickley Steinmetz and Kensinger (2009) found that amygdala activation on fMRI increased the probability of recall, though other interactions were involved as well. Increased activation in the left amygdala in response to negative pictures was related to later recall, but the same pattern was not found for neutral pictures (Ritchey, Dolcos, & Cabeza, 2008). When examining patients with amygdala damage, patients fail to show emotional memory enhancement, with left amygdala damaged patients showing more impairment (Adolphs, Cahill, Schul, & Babinsky, 1997; Buchanan, Denburg, Tranel, & Adolphs, 2001). Using a remember/know paradigm, the amygdala was found to show selective activation to emotional “remember” pictures during recognition, while the parahippocampal region showed more activation for neutral pictures identified as “remembered”.

The amygdala is also implicated in emotional memory because of its involvement in the autonomic system and stress responses. When encountering a stressor, the autonomic nervous system is the first to react. Immediately after the stressor is encountered, the vagus nerve is stimulated, which activates the nucleaus of the solitary tract (NST). Two norepinephrine (NE) pathways excite the baslolateral amygdala, one indirectly through the NST, and the other indirectly through the NST’s activation of the locus coeruleus. A slower acting system is the hypothalamic-pituitary-adrenal (HPA) Axis. The end product of the HPA axis is cortisol, commonly called the stress hormone. Cortisol then directly activates the basolateral amygdala and also activates the NST, enhancing the response to the amygdala (see Wolf (2008) and de Quervain, Aerni, Schelling, and Roozendaal (2009) for complete review of this system). The full effects of cortisol take approximately twenty minutes to manifest after a stressor (Droste et al., 2008). The interaction of the ANS and cortisol response is further described by Joëls, Fernandez, and Roozendaal (2011), who describe the enhancing effects to be very dependent on time of arousal and time of cortisol response. Since both systems activate the basolateral amygdala, its pivotal role is apparent and may be related to delayed emotional memory enhancement effects.

Other Connections in Enhancement of Emotional Memory

Amygdala activation and attention still may not be sufficient to explain enhanced emotional memory processing (Anderson, Yamaguchi, Grabski, & Lacka, 2006). Mickley Steinmetz and Kensinger (2009) suggest interactions with other structures play a significant role, including the interaction between the prefrontal cortex and amygdala. They report that for negative and all high arousal stimuli, fMRI activation was increased in temporo-occipital areas (with posterior temporal having the greatest activation). In contrast, when positive and low arousal stimuli were presented, there was more activation in frontal areas. Additionally, frontal activity was the strongest predictor of recognition memory. Steinmetz and Kensinger (2009) suggest that negative material involves more tempro-occipital processing (associated with visual processing) while positive material recruits more conceptual processing, evidenced by activation of the superior and middle frontal gyrus. They additionally emphasize the need to consider both the valence and arousal of a stimulus in relation to emotional memory, as there is an interaction between arousal and area of activation. Studies have also found evidence of increased connectivity with the insula and amygdala. Those carrying a “deletion variant” of the gene ADRA2B, which encodes for an adrenoreceptor, evidence enhanced connectivity between the amygdala and insula, increased activity in the amygdala, and better recall for negative emotional pictures (Rasch et al., 2010).

The temporal lobe may play a role in emotional memory enhancement as well. During retrieval of pictures, hippocampal activity was not significantly different between emotional and neutral pictures (Sharot et al., 2004). However, the medial temporal lobe may impact consolidation. In one study, patients with one medial temporal lobe removed and control patients viewed emotionally arousing (i.e., taboo) words (LaBar & Phelps, 1998). While both groups evidenced an appropriate skin conductance response to arousing words, after a one-hour delay, only control subjects evidenced emotional memory enhancement. The authors suggest this indicates that the medial temporal lobe is involved in consolidation of emotional memories. Similarly, Ritchey et al. (2008) examined recognition of negative and neutral pictures during fMRI in relation to both amygdala activation and amygdala connectivity. They found that while left amygdala activation equally predicted recall in the short (20-minutes) and long (one week) delay conditions, left amygdala functional connectivity with the bilateral medial temporal lobe (specifically, the parahippocampal gyrus) was a better predictor of long delay recall than short delay recall.

Emotional memory enhancement is not solely due to increased attention or arousal. Instead, the enhancement that emotional material receives most likely comes from a combination of the two systems and works through multiple brain regions, including the amygdala and other parts of the medial temporal lobe. While many of these studies are based on imaging, ERP research provides temporal resolution and may provide insight into the sequence of cortical activity that leads to enhanced memory for emotional material.

Affective Processing and ERP

One way to disentangle processing that may impact emotional memory is to examine cortical responses as emotional material is presented. Event Related Potentials (ERPs) offer the unique advantage of allowing researchers to measure cortical brain activation with temporal resolution, in the order of milliseconds, after a stimulus is presented. Most researchers use an oddball task, passive viewing, or active viewing (with categorization or stimulus ratings) to administer emotional material in the unique environment of an ERP study. All three methods have been found to be equally effective ways of administering material (Olofsson, Nordin, Sequeira, & Polich, 2008; Rozenkrants, Olofsson, & Polich, 2008). Different effects of emotional material are found throughout early/middle components (P1, N1, P2, N2) and a later component, the LPP.

Early/Middle ERP Components

Components occurring as early as 100ms after picture exposure can be impacted by the content of the stimulus (Taylor, 2002) rather than just a response to stimulus characteristics, such as location in space. For example, Taylor (2002) found that inverted faces produced different amplitude P1 components than upright faces. Schupp, Markus, Weike, and Hamm (2003) suggest that these early components demonstrate a reflexive attention to emotional stimuli that is distinct from volitional attention, aiding enhanced sensory processing when encoding. When participants are asked to exert control over their emotional response (e.g., using suppression or regulation techniques), effects are not seen until 300ms or later after stimulus onset, suggesting the earliest components occur before any top-down emotion regulation strategies can be used (Moser, Krompinger, Dietz, & Simons, 2009). Through a literature review of ERPs in response to emotional pictures, Rosenkrants et al. (2008) concluded that a majority of studies identified early components to be associated with valence, particularly P1 and N1. PCA analysis conducted by Foti, Hajcak, and Dien (2009) identified an early negativity (similar to the N1 component) that was unique in response to emotional compared to neutral pictures when passively viewing pictures for 1000ms each. In general, the effects of valence are less reliably found, and often overlapping with the effects of arousal (Olofsson et al., 2008).

Rapid presentation of pictures has been used in several studies to investigate early components. However, it is important to consider that rapid presentation itself is thought to induce a state of arousal and increased attention, impacting early components (Alexandra, Key, Dove, & Maguire, 2005). Junghofer et al (2001) found that when presenting only complex pictures at a rapid rate (333ms and 200ms per image with no interstimulus interval, ISI), difference in early components amplitudes were found for emotional compared to neutral pictures, with an effect seen for arousing images. They suggest that these results support the hypothesis that emotional discrimination occurs at the first presentation of a stimulus, rather than only being evidenced through later components. Schupp, Junghöfer, Weike, and Hamm (2004) presented pictures for 120ms each and found increased early negativity for emotional relative to neutral pictures. When stimuli are matched on arousal level and rapidly presented, the ERP response has been found to be stronger for negative pictures than positive pictures, with negative material producing larger amplitude P1s (Cacioppo, Gardner, & Berntson, 1999; Smith, Cacioppo, Larsen, & Chartrand, 2003). Versace, Bradley, and Lang (2010) presented pictures for 184ms presentation with no ISI and found an increased early negativity for emotional pictures. Additionally, those emotional pictures high in arousal were still found to result in increased recognition relative to low arousal and neutral images.

In one of the few studies systematically investigating the impact of valence and arousal on early components in response to IAPS emotional pictures, Feng et al. (2014) observed a valence effect with P1 (such that negative images had a higher amplitude P1) and an arousal effect with N1 (such that high arousing images demonstrated a larger N1 amplitude). While the N2 and P2 components demonstrated an arousal by valence interaction. Negative pictures produced more positive amplitudes when pictures were high in arousal, but positive pictures produced larger amplitudes when arousal was low.

Walker, O'Connor, and Schaefer (2011) presented negative images (ranging from moderate to high arousal) and neutral images (low in arousal). They found increased N2 and P2 amplitudes for moderate to high arousing negative pictures relative to neutral pictures. Though they only used negative pictures, another study reports early negativity (175 - 275ms) using PCA analysis for emotional relative to neutral pictures, with the amplitude in response to positive pictures being larger than negative pictures (Hinojosa et al., 2009). Schupp et al. (2003) further demonstrated early selective attention (though a posterior negativity between around 100 - 300ms) in the temporal-occipital regions in response to emotional pictures, but not neutral pictures. De Cesarei and Codispoti (2006) found that negative and neutral pictures elicited a larger positivity than positive pictures 150 - 300ms after stimulus onset. However, these pictures were not equated on arousal.

While these studies have found effects with the P1 and N1 components, these findings are inconsistent across studies (Olofsson et al., 2008), with some suggesting that P1 and N1 respond only to spatial location and color contrast. One limitation in studying early components is that they are very sensitive to stimulus characteristics, such as contrast, brightness and complexity (Fonaryova Key, Dove, & Maguire, 2005). Size of the image has been found to alter early components, increasing latencies and decreasing component amplitudes, however, the relationship among the categories of pictures remained the same (De Cesarei & Codispoti, 2006). In a study using positive, negative, and neutral IAPS pictures, Bradley et al. (2007) compared the impact of complex vs. simple figure ground relationships (e.g., a gun with a white background as opposed to a gun embedded in a complex scene). They found effects in early components posteriorly and frontally around 150ms after picture onset. Simple images showed less of a positivity over posterior sensors and less negativity over frontal sensors. These effects were found regardless of valence or arousal, suggesting that the nature of the pictures must be considered when comparing between valence categories.

The LPP Component

The LPP has been found to have larger amplitudes in response to both pleasant and unpleasant emotional pictures, an effect found more consistently than the effects on earlier components (Bradley et al., 2007; De Cesarei & Codispoti, 2006). Increased amplitude of the LPP is proposed to reflect increased automatic attentional allocation to one type of stimulus compared to another (Leite et al., 2012; Weymar, Schwabe, Löw, & Hamm, 2012), an indication of motivational significance (Schupp et al., 2003). Additionally, it may be related to individual appraisal and evaluation (Hajcak & Nieuwenhuis, 2006; Moser et al., 2006). Furthermore, it is hypothesized to be responsive to both automatic and controlled processes (Hajcak, Dunning, & Foti, 2009).

Dolcos and Cabeza (2002) suggest that parietal ERPs are more sensitive to arousal, while frontocentral ERPs are sensitive to both arousal and valence. Rosenkrants et al. (2008) further suggests that later ERP components are more associated with arousal than valence and studies have found increased LPP amplitude to arousing images relative to images low in arousal (Balconi, Falbo, & Conte, 2012; Cuthbert et al., 2000). De Houwer and Hermans (1994) found differences in the duration of the ERP wave after emotional stimulus onset. The LPP for unpleasant images lasted an average of 1000ms, while pleasant pictures lasted an average of 800ms. They suggest this provides evidence that unpleasant images hold attention longer than pleasant images, since LPPs after pleasant images return to baseline quicker. However, while pleasant and unpleasant images in this study were more arousing than neutral images, emotional images were not equated on arousal, which may have contributed to the effect. Schupp et al. (2000) examined rapid presentation of emotional images and found that the LPP amplitude was not influenced by rapid presentation rate when compared to a slower presentation rate. When emotional images were presented for 120ms, Schupp, Junghöfer, et al. (2004) found an increased LPP amplitude for emotional relative to neutral pictures. Additionally, Schupp et al. (2000) reported that while the LPP component was similar for both positive and negatively valenced pictures, arousal dictated the response, with pictures high in arousal ratings evidencing a larger LPP amplitude, indicating more motivational significance, than less arousing pictures.

Although earlier components are more susceptible to influence by stimulus characteristics, late components can be influenced as well. As previously discussed, early components were not found to be impacted by emotionality (i.e., valence and arousal) when controlling for figure-ground vs. scene relationships (M.M. Bradley et al., 2007). However, in the same study, they also found that the LPP amplitude was larger in response to simple figure ground images for both positive and negative valenced images. The authors suggest that the stark contrast augments the motivational significance and increases the ability to grab attention. When examining the impact of task difficulty on LPP amplitude, Davidson (2001) found that passive viewing and viewing while performing mathematics tasks (easy and hard tasks) did not impact the LPP component. They suggest that this indicates that emotional processing of stimuli is automatic, or bottom-up processing. While concurrent task difficulty may not impact the LPP, studies have found that the LPP amplitude can be modulated. Moser et al. (2006) demonstrated that when subjects are asked to suppress their response to an emotional image, decreased LPP amplitude was observed compared to the passive viewing condition. However, when subjects were instructed to enhance their response, no difference was found relative to the passive viewing condition. Using a longer presentation time and a trail-by-trail manipulation of instructions (as opposed to block manipulations), Moser et al. (2009) were able to demonstrate a significant effect on LPP amplitude for both suppression and enhancement manipulations.

Feng et al. (2014) examined the LPP in response to positive and negative IAPS pictures of high and low valence. They found that LPP amplitude was significantly larger for negative pictures at high arousal (relative to positive pictures), and vice versa at low arousal levels. They further speculate that since LPP amplitude during encoding is implicated in emotional memory, that arousal may therefore moderate the valence effects of emotional memory.

Early components are more impacted by stimulus characteristics than late components, but they also tend to be less impacted by cognitive control strategies. There is evidence that LPP amplitude can be modulated by participant regulation techniques and some stimulus features, but is not impacted by task difficulty. While increased LPP amplitude in response to emotional pictures is more reliably found than differential responses in some of the early components, the exact contribution of arousal and valence on these components has not yet been fully explained. Additionally, the impact of the participant's individual characteristics on the LPP amplitude in response to emotional compared to neutral material may provide insight into some of the discrepancy in the literature.

Individual Differences in Emotional Picture Processing and Memory

One reason for inconsistency in emotional memory findings may be due to individual difference in emotional material processing. Researchers have found individual differences in neural response to the same stimuli based on level of a trait endorsed. Joseph, Liu, Jiang, Lynam, and Kelly (2009) examined fMRI in response to arousing positive and negative pictures in those with high and low endorsement of the sensation seeking trait. They found that those with high sensation seeking were more responsive to arousal, demonstrating an overactive approach system. Those with low sensation seeking were more influenced by valence and tended to show more activation in areas associated with emotional regulation. Several other personality traits have been suggested to influence emotional material processing, including behavioral activation/behavioral inhibition (BIS/BAS) and introversion/extroversion (Canli, 2004; A. Gomez & Gomez, 2002; R. Gomez, Gomez, & Cooper, 2002; Hamann & Canli, 2004; Rafienia, Azadfallah, Fathi-Ashtiani, & Rasoulzadeh-Tabatabaiei, 2008), which can clearly influence memory for emotional material.

Eysenck's Extroversion and Neuroticism theory proposes that the reticulo-limbic and reticulo-cortical circuits in the brain differentially predict the response to physiological and cognitive arousal, respectively (Eysenck, 1967). Neuroticism relates to the physiological arousal while Extroversion relates to cognitive arousal (a continuum with the other extreme being called introversion); these traits are proposed to be orthogonal. Those high in neuroticism were found to have a greater autonomic response to positive and negative emotional stimuli, particularly to aversive pictures, relative to those lower in the trait (Norris, Larsen, & Cacioppo, 2007). When only examining positive stimuli, those high in neuroticism have also been found to have increased dorsolateral prefrontal activity in response to positive images (Britton, Ho, Taylor, & Liberzon, 2007). Greater neural responses to negative images have also been found for introverts and those with mood disturbances, while greater response to positive images has been found in extroverts and those without mood disturbances (Lim, Woo, Bahn, & Nam, 2012).

Gray’s theory, also now known as the reinforcement sensitivity model (Gray, 1987) proposes two motivational systems: behavioral inhibition system (BIS; trait anxiety) and behavioral activation system (BAS; trait impulsivity). Higher BIS endorsement is related to increased sensitivity to punishment (and non-reward), novelty, and the experience of anxiety while BAS is related to reward, appetitive stimuli, and escape from punishment. Gomez and Gomez (2002) examined the relationship between memory for emotional words and different personality traits, specifically behavioral inhibition/behavioral activation (BIS/BAS), impulsivity, and anxiety. BAS and impulsivity were consistently related to better recall and recognition for positive words, while anxiety and BIS sensitivity were correlated with better recall and recognition of negative words. Additionally, none of the constructs were related to recall of neutral words.

Overall, some differences in response to emotional memory have been found based on individual differences in the amount of the trait a person has. Specifically, BIS/BAS has been proposed to be related to primarily valence effects, while valence and arousal have been found to influence neuroticism and extroversion. Furthermore, it is possible that these traits impact the earliest processing of emotional information. ERP methodology may be a way to measure the earliest individual differences in emotional material processing and allow for examination of how this early processing relates to subsequent recall of information.

Early/Middle Components

Early ERPs are proposed to be impacted by trait characteristics, such as anxiety and fearfulness (Dien, 1998) and selective attention (Olofsson et al., 2008). However, as mentioned above, inconsistent results have been found in early components. Since differences exist across research stimuli and paradigms, one explanation may be found through an examination of individual differences in the involvement of early components in early emotional processing. When presented with negative stimuli compared to neutral stimuli, those high in the trait neuroticism demonstrated decreased latency to early components (P1, N1, P2, and N2) and increased amplitude of the P2 component compared with those scoring low in neuroticism (Kovalenko, 2010). Gable and Harmon-Jones (2012) conducted one of the only studies examining early components and the BIS/BAS scale. Using appetitive pictures, they found that, on average, all subjects demonstrated increased N1 amplitude of appetitive images. The magnitude of scores on the BAS scale predicted N1 amplitude, particularly the Reward Responsiveness subscale.

When individuals with a phobia are presented images of their feared stimuli, the early components are not different from those without the phobia (Miltner et al., 2005). In alexithymia, a characteristic that involves difficulty identifying and describing one’s own emotions, no differences were found for N1 and P1 amplitudes in response to negative arousing images relative to neutral images (Walker et al., 2011). However, when subjects were instructed to use techniques to regulate responses to the images (i.e., reappraisal, suppression), differences have been found in those scoring high and low on this trait. Those who were rated low in alexithymia demonstrated increased amplitude of the N2 component in response to negative pictures while using suppression techniques. In contrast, those with high alexithymia did not show the same effect in response to negative pictures while using suppression techniques. This demonstrates an earlier impact of cognitive manipulation on ERP components than was previously found by Moser et al. (2009). No other differences were found for reappraisal or for the control task of simply attending. These findings suggest that individual traits can impact emotional processing, however, this may not always be the case. At times, cognitive strategies inherent in certain traits may impact the response to emotional images.

The LPP Component

In contrast to earlier components, when individuals with a snake or spider phobia are presented with pictures of their feared object, those with the phobia evidence an increased LPP amplitude relative to other non-feared objects (Miltner et al., 2005). This suggests that motivational significance can vary based on individual characteristics.

Little research has been conducted to examine the impact of individual traits on the LPP in response to emotional pictures. One study found that those higher in attachment anxiety demonstrated larger amplitude LPP components in response to negative pictures (Zilber, Goldstein, & Mikulincer, 2007). In another study, Brown, Goodman, and Inzlicht (2013) examined the impact of mindfulness and neuroticism on the ERP response to emotional images. The researchers found that those high in mindfulness demonstrated a decreased LPP to negative high arousing images relative to neutral. Furthermore, both neuroticism and negative affect were correlated with increased LPP amplitude to negative high arousing images with negative affect also related to increased LPP amplitude for low arousing negative images. A third study examined individual differences in LPP amplitude used the BIS/BAS traits. Balconi et al. (2012) conducted a study examining the relationship between Carver and White's (1994) BIS/BAS scale and the relationship to ERP components during viewing emotional pictures. While all participants demonstrated larger amplitude LPPs for emotional pictures, differences emerged when BIS/BAS was considered. Higher BIS scores were correlated with larger LPP amplitudes in response to negative pictures, while higher BAS scores were correlated with larger amplitudes to positive pictures. Additionally, these effects were found regardless of arousal; effects were found for both high and low arousing pictures. However, the extents to which these effects influence memory still remain unknown.

Purpose of the Current Study

Emotional information is processed preferentially, which also allows emotional material to be better remembered. This enhancement is not due solely due to attention to emotional material in general and may vary based on individual differences, such as BIS/BAS. ERPs provide temporal resolution that allows cortical activity to be measured in the order of milliseconds after stimulus exposure. There is evidence that individual differences can impact ERP components and that increased LPP amplitude may be related to memory for emotional content. Findings suggest that those with certain traits may have a propensity for processing certain emotional stimuli, possibly explaining why some research results have been inconclusive. While some progress has been made in understanding the influence of individual differences on emotional processing, further research is needed to elucidate these relationships.

The purpose of this study was to examine the impact of one set of traits, BIS/BAS, have on ERP components and memory for actively viewed affective pictures. The BIS/BAS system has been hypothesized to be directly related to affect and emotional processing above and beyond the contribution of other commonly studies personality traits such that BAS has an affinity for positive material and BIS responds more to negative material (R. Gomez et al., 2002). However, the point in emotional processing at which those effects are influential and impact emotional memory require further research. Using a word completion task, A. Gomez and Gomez (2002) demonstrated that those who endorse higher levels of BIS or BAS remember emotional information differently. Through ERP, Balconi et al. (2012) found that higher levels of BIS or BAS correspond to enhanced LPPs for certain emotional stimuli. However, no study has examined emotional processing and emotional memory together based on BIS/BAS.

This study will examine differences in ERP components during encoding of emotional pictures and the influence of these components and individual traits on later recall and recognition of pictures (i.e., the subsequent memory effect). From the time of exposure, ERP allows an assessment of the earliest processing. Both early components (P1, N1, P2, N2) and the LPP will be evaluated. Due to the within subject design, stimulus characteristics will be less influential, allowing an examination of the effects specifically of valence. While P1 and N1 may vary based on trait, this would most likely reflect an overall reactivity to a stimuli and not vary by valence category. However, P2/N2 is proposed to vary by individual trait, as is LPP. Lastly, it was predicted that memory for pictures related to both LPP amplitude and BIS/BAS.

Hypotheses and Predictions

The hypothesis and predictions of the current study are as follows:

1) Expand previous findings demonstrating the influence of the BIS/BAS motivational systems on emotional memory (found by Gomez et al. 2007) to include recall and recognition of emotional pictures. Specifically, a) higher BIS scores will be related to higher recall/recognition of negative pictures, and b) higher BAS scores will be related to higher recall and recognition of positive pictures.
2) Examine the influence of BIS/BAS on early/middle psychophysiological responses (specifically, P1, N1, P2, and N2 components) to emotional pictures. Specifically, a) overall, emotional pictures will demonstrate larger amplitudes compared to neutral pictures, b) high BIS will demonstrate larger amplitudes for negative pictures, and c) high BAS will be related to larger amplitudes for positive pictures.
3) Examine the influence of BIS/BAS on LPP amplitude in relation to memory for emotional pictures, extending the findings of Balconi et al., 2012. Specifically, a) Higher BIS will be related to larger LPP amplitude at encoding for negative pictures, b) Higher BAS will be related to larger LPP amplitude at encoding for positive pictures, and c) LPP amplitude will be related to recall and recognition of pictures.

METHODS

Participants

A total of 69 undergraduate females were recruited from an undergraduate research participation system (SONA) at University of South Florida. Only females were used in this study as gender differences have been found in the way emotional material is processed (Glaser, Mendrek, Germain, Lakis, & Lavoie, 2012). Participants were offered course credit as compensation for participating in this study. Exclusion criteria were as follows: 1) Left handedness; 2) Under the age of 18 or over the age of 30 years old; 3) Currently receiving treatment for psychiatric disorder (e.g. major depressive episode, manic episode, panic disorder, or panic attacks); 4) Having ever experienced a psychotic episode or needing hospitalization for psychiatric reasons; 5) History of substance abuse (cocaine, amphetamines, barbiturates, benzodiazepines); 6) Current medications use that might affect physiological responses (e.g., benzodiazepines, beta blockers, neuroleptics, selective serotonin reuptake inhibitors, and tricyclic antidepressants); 7) Lifetime history of neurological injury (including head injury with loss of consciousness greater than 5 minutes), neurological disease, or neurological insult; 8) Vision problems not able to be corrected for by glasses or contact lenses; and 9) Participants must be able to physically complete the task and go through procedures, including having the EEG net applied to the head (some individuals may have been excluded due to hairstyle).

While participants were specifically screened through the recruitment system, some participants were subsequently excluded from the data analysis process based on information collected during the study. Seven were excluded; three due to high endorsement of current depressive symptoms, two for reporting a current psychological disorder (i.e., Post Traumatic Stress Disorder and anxiety disorder), one for hospitalization due to psychiatric reasons (i.e., panic attacks), and one due to loss of consciousness (she reported being involved in a roll over car accident with loss of consciousness, but denied hitting her head). The remaining 62 participants had an average age of 19.53 years (SD = 2.68), with an average grade level of sophomore and a median grade level of freshman. The racial makeup of the sample was 69.74% Caucasian, 8.06% Asian, 3.22% Black/African America, 16.12% as more than one race, and 6.45% as unknown (two did not wish to report), with 19.35% identifying as Hispanic. Since several analyses were used in this study, those of most importance were used to determine a priori sample size. A medium effect size for random effects regression model suggested a sample size of 38. However, to determine change in R^2, using a predicted effect size of $f^2 = 0.15$ (a medium effect size), revealed that 68 participants were needed for a power of 0.80.

Materials

The Positive and Negative Affect Scale (PANAS-X; Watson & Clark, 1999) is a self-report measure that consists of a list of 60 feeling and emotion words. Subjects are instructed to identify to what extent they are feeling each emotion and feeling and indicate this on a 5 point Likert scale (with 1 being very slightly or not at all, and 5 being extremely). The scale is composed of two higher order scales: Positive affect (PA) and Negative affect (NA). Additionally, there are lower order scales identifying Basic Negative Emotions (fear, hostility, guilt, sadness), Basic Positive Emotions (joviality, self-assuredness, attentiveness), and other affective states (shyness, fatigue, serenity, surprise). The scale can be given in reference to several time frames: current mood (how are you feeling right now?) or within a given time period (e.g., in the past week). For this study, subjects will be asked to give responses for how they feel at that moment. Internal consistency for current mood directions is $\alpha = 0.88$ for PA and $\alpha = 0.85$ for NA in a large sample of undergraduates. Additionally, convergent and divergent validity have been established. This scale has been shown to detect subtle changes in state affect when given repeatedly (Clark, Watson, & Leeka, 1989).

The Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1997) is a 20 question short self-report scale designed to measure depressive symptomatology in the general population. The items of the scale are symptoms associated with depression, which have been used in previously validated longer scales. Participants report their experience of these symptoms in the previous week on a 4 point Likert scale: Rarely or none of the time (less than 1 day); Some or a little of the time (1 - 2 days); Occasionally or a moderate amount of the time (3 - 4 days); Most or all of the time (5 - 7 days). Sample items include, “My sleep was restless” and “I had trouble keeping my mind on what I was doing”. Scores on this measure range from 0 to 60, with higher scores indicating presence of more depressive symptomology. A CES-D score of 16 or higher is indicative of “mild” depressive symptomatology. Those participants that were excluded due to depression had scores greater than two standard deviations above the entire sample mean (above 24). Average CES-D total score for all participants included in data analysis was 9.27 (SD = 5.70).

The Behavioral Inhibition/Behavioral Activation scale (BIS/BAS; Carver & White, 1994) is a 20 item self-report scale that assesses an individual’s sensitivities to appetitive and aversive stimuli, which indicate an affinity for a motivational system. Responses use a 4-point scale with 1 indicating agreement with the statement and 4 indicating strong disagreement with the statement. The BIS and BAS scale are independent, meaning high BAS does not necessarily indicate low BIS, though this finding is inconsistent (Leone, Perugini, Bagozzi, Pierro, & Mannetti, 2001). The BAS scale is composed of the subscales Drive, Fun Seeking, and Reward Responsiveness. These scales have been found to have convergent and divergent validity with several well established measures, good internal consistency ($\alpha = 0.66$ to 0.76 for BAS subscales, $\alpha = 0.81$ for BAS total; Smillie, Jackson, & Dalgleish, 2006), and test retest reliability over an 8 week period ranging from $r = 0.59$ to 0.69 (Carver & White, 1994). Strong psychometric properties have also been found by others and in a sample consisting of college students from the US, UK, and Italy (Leone et al., 2001). The BIS Scale ranges from 7 to 28, with high scores representing greater endorsement of the trait. The BAS scale ranges from 13 to 52 with higher score representing greater endorsement of the trait.

The Wechsler Test of Adult Reading (WTAR; Sen, Burmeister, & Ghosh, 2004) was used during the distractor portion of the study. The WTAR provides a measure of pre-morbid intelligence and has been normed with the Wechsler Adult Intelligence Scale (WAIS), a full battery to measure intelligence. Specifically, it measures the ability to correctly pronounce 50 phonetically irregular words. As the list progresses, the words get increasingly more difficult for the participant to correctly pronounce. The examiner determines accuracy of the pronunciation of the word as the participant reads the list. A standard score is derived using age and education for each participant.

The Stroop Color and Word Test (Golden & Freshwater, 1978) was used during the distractor portion of the study. Performance on the Stroop test is a measure of executive function, specifically requiring inhibition, selective attention, and cognitive flexibility. The Stroop test requires individuals to complete three tasks. First, words (names of colors) are presented on a sheet of paper and the participant is instructed to read as quickly as possible down a page. Next, the participant must say aloud the color of X's printed on a page as quickly as possible. Lastly, the participant is required to say the color of ink a word is printed in. The color of the ink and the color word printed are discrepant (e.g., the word red may be printed in green ink). The participant is required to inhibit the overlearned response of reading the word and instead must just say the color of the ink. The last part of the task requires a lot of effort and attention to prevent interference, and will ensure that the pictures cannot be rehearsed.

The Letter Number Sequencing (LNS; Wechsler, 2008) was also used during the distractor portion of the study. LNS measures working memory and attention by requiring mental manipulation of a series of numbers and letters. LNS is a subtest within the Wechsler Adult Intelligence Test Scale – Fourth Edition. Participants are read a series of numbers and letters (in alternating order) and are then asked to manipulate the information in their mind and repeat the information back. They are asked to first repeat back all the numbers, in numerical order, and then the letters, in alphabetical order.

The picture stimuli used in the study were taken from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1997) and administered using E-prime software (PST Inc., Pittsburgh). The IAPS scale is a standard set of affective pictures that have been normed on valence and arousal. Normative ratings are provided for males, females and the combined sample. Normative ratings of females were used in the study. From this collection of pictures, 50 positive (25 low arousal, 25 high arousal), 50 negative (25 low arousal, 25 high arousal), and 50 neural pictures were used as stimuli (25 neutral and 25 low arousal; See Appendix A for list of picture numbers used). All affective stimuli were significantly different between categories (e.g., high and low arousal; positive and negative) but were not significantly different within categories (see Table 1). Similarly, arousal ratings were equated within arousal categories (see Table 2). During the recognition trial, both target stimuli and 150 lures were presented. All lures were, on average, equated with the corresponding category (i.e., positive high arousal lure were not significantly different from positive high arousal targets).

Procedure

Piloting

The protocol was first piloted with several individuals who were naïve to the procedure and stimuli, including five subjects who received research participation credit and several research assistants and graduate students. Significant modifications based on piloting were as follows: 1) The amount of time to rate valence and arousal was increased, additionally making the interval between pictures standard across subjects (4 seconds each); 2) The directions were made more interactive (to maintain attention) and included one demonstration item and three sample items were presented; 3) The amount of time for free recall was extended to ten minutes. For more detailed piloting procedures and adjustments based on piloting, see Appendix B.

Study Procedure

The study was approved by USF Institutional Review Board (Appendix C). Prior to consent, a screening questionnaire issued through SONA was used to ensure that only participants who met study criteria were able to participate. Study procedures were explained to the participant and consent was obtained, however, participants were not told that a free recall or recognition trial would follow the image presentation. This deception was necessary as previous studies have found differences in recall when participants are told they will later be tested (Dodson & Schacter, 2002; also see Kensinger, 2006 for review). Instead, participants were told that the purpose of the study was to record how their brain responds to different pictures and participants were debriefed at the and of the study. Prior to applying the EEG, subjects were given the demographics questionnaire, BIS/BAS, CES-D, and PANAS. Beyond several questions typically assessed in a demographics questionnaire (age, education, socioeconomic status, etc.), participants additionally were ask directly about exclusion criteria including substance abuse, psychiatric history, and head injury with loss of consciousness. A

128-Channel EEG net was then applied using a saline solution.

Participants were then seated at a computer to perform the encoding task. Participants were read the directions (see Appendix D) and were given three practice trials to become familiar with the Semantic Affective Mannequin (SAM) that was used to indicate their valence and arousal responses (see Figure 1). Each image was presented for 4 seconds using E-prime software (Psychology Software Tools, Pittsburgh, PA). After picture presentation, subjects were given 4 seconds to rate each image on valence and then 4 seconds to rate the image on arousal. If the participant did not respond during the allotted time, a response was not recorded for that item.

After presentation of all pictures, completed several distractor tasks. First, they were asked to read words out loud, which provided an estimate of their verbal intelligence (the WRAT task). Next, they were asked to repeat lists of digits and letters by re-arranging the letters and numbers so that they were repeated sequentially (LNS). Lastly, participants completed the Stroop task, which requires inhibiting a more automatic, overlearned responses (i.e. reading the word) in order to name the color of ink in which the word is printed. Following these tasks, the participants completed the PANAS to ensure recall and recognition were not altered by their current mood and that the tasks did not alter their mood substantially. To ensure a standard 20-minute period between encoding and recall, participants were then asked to complete basic math tasks until 20 minutes had elapsed.

After the 20-minute delay, participants were asked to recall as many pictures as possible by writing down descriptions of each picture for ten minutes. A correct response was determined by two independent raters using criteria established in previous research requiring enough detail that an outsider could identify the picture and distinguish the picture from others presented (Dolcos & Cabeza, 2002; Weymar et al., 2012). After the free recall task, a recognition task that consisted of the 150 previously presented target pictures and 150 new pictures was administered. Each picture was presented on a computer screen and the participant was asked to press one key (labeled Y) if the image had been presented before and another key (labeled N) if the image had not been presented previously. Subjects were asked to respond as quickly and accurately as possible.

Scoring of Data

Scoring of free recall used similar methods to those used by (Bradley, Greenwald, Petry, & Lang, 1992). Two independent raters reviewed all participant responses and decided if credit should be given and for what item. Items were given credit to the extent that it could be identified which item was being recalled that had been presented. Credit was given more liberally if a questionable response could describe two images that belonged to the same valence category, for example, if the subject only responded with “graveyard”, two images matched this description, but they belonged to the same valence category and credit was given to the most common answer. If an item could fit a description that was across valence categories (e.g., old couple could refer to a negative hospital scene or a positive biking scene), credit was not given and the item was coded as unclear. Each rater scored every participant’s free recall responses, noting discrepancies in the coding with the other rater. After scoring, the two raters went through discrepancies together and came to an agreement about the type of discrepancy, which was either: 1) true disagreement or 2) an error made by one of the raters (errors included: checking the wrong box when scoring, missing an item, misunderstanding a response and marking it as “unclear”, and giving credit for a different item). In the case of true disagreements, a third rater was asked to make the decision. There were three disagreements in total in which the third rather was asked to advise on which item was given credit. All discrepancies were within the same valence/arousal categories. The most common error was not giving credit for a response. There were errors made by the raters on 4.7% of free recall responses. However, the two raters discussed any discrepancy and agreement was reached that the item was an error. The average proportion of false alarm responses (i.e., sample items recalled when participants were told specifically to not recall sample items) given by participants was 0.018 (SD=0.027) of all responses and 0.033 (SD = 0.050) for unclear responses (i.e., misperceptions, items not presented, vague descriptions).

Reaction times were used for recognition data due to the high rates of correctly recognized images (mean proportion of positive recognized: 0.88 (SD = 0.090), negative: 0.91 (SD = 0.075), neutral: 0.92 (SD = 0.059)). Reaction time was only included for correctly recognized items. All item reaction times falling outside of two standard deviations of this average were excluded from analysis. An average reaction time for each type of stimulus (i.e., positive, negative, and neutral) was calculated for each participant.

D prime (d’) was used as a measure of sensitivity analysis, which provides a measure of the difference between noise and signal in the data, given in standard deviation units (Stanislaw & Todorov, 1999). The larger the value, the more “signal” relative to noise, indicating better discrimination and recognition of the pictures. Sensitivity analysis provides a way to examine recognition (i.e., signal) while also considering how susceptible the individual was to false alarms (i.e., noise) of the same valence and arousal categories. Hits were the proportion of items correctly recognized. Endorsing a lure as having been in the original set was considered a false alarm. The z-scores of both hits and false alarms were calculated, and then false alarms were subtracted from hits. This yields a d' value in which higher scores indicate better sensitivity (more hits relative to false alarms) and low scores indicate poor detectability. Average d' values are as follows: neutral pictures (Mean = 3.51, SD = 0.59), negative pictures (Mean =3.01, SD = 0.094), and positive pictures (Mean = 3.28, SD = 0.65).

Lastly, EEG signals was recorded continuously from 128-channel net using an Electrical Geodesic system (EGI, Eugene, OR) through NETSTATION 4.0 acquisition software powered by a Macintosh G4 computer. Recordings were sampled at a rate of 250 Hz, using the vertex as recording reference, with 0.10 - 100 Hz. analog filtering, then digitally filtered offline at 20 Hz lowpass. Impedance for each electrode was kept below 50 kΩ. Epochs were established 160ms prior to stimulus onset until 800ms after stimulus onset. In data processing, digital artifact detection, ocular artifact detection, baseline correction, and average referencing were used. Any trials with unusable data were excluded from the analyses. In order to be included in the study, a minimum of 15 trials were needed per participant per valence category. Forty-nine participants had usable data that was sorted by category of valence and averaged to create the ERPs for each individual. Montages were used to create averages across electrodes (Figure 3), which corresponded to areas in which the components are typically found (Feng et al., 2014; Olofsson, Nordin, Sequeira, & Polich, 2008). Using known ERP time windows to IAPS affective pictures (Feng et al., 2014; Olofsson, Nordin, Sequeira, & Polich, 2008), and visual inspection of the data, time windows were established for each component: Parietal/occipital N1 (95-130), Parietal/occipital P1 (80-110), Frontal Central N2 (200-350), P2 (120-200), and parietal LPP (450-800). It should be noted that visual inspection of the data did not suggest a P2 component. Therefore, time windows for P2 using IAPS pictures from other studies (Feng et al., 2014; Olofsson, Nordin, Sequeira, & Polich, 2008) was used and expanded to include an earlier positivity rather than a specific time window seen in the current data.

RESULTS

Data Diagnostics

Analysis was conducted using IBM SPSS Statistics 22 for Windows. Before beginning data analysis, data was examined for outliers. SPSS was used for examination of outliers for all data except individual reaction time. In this case, trials were excluded prior to the inclusion into the individuals average if that value was two standard deviations from the mean of the individual's performance. Individual averages were then analyzed using SPSS for statistical outliers. Outliers were detected visually using boxplots and then through the use of z-scores. Data points three standard deviations from the mean were considered statistical outliers. The BIS/BAS scale contained three outliers. Though these values were determined to be accurate based on the participant's responses, they were statistical outliers. Therefore the individual BIS values were removed for two participants and one BAS value was removed. These subjects were retained, however, as BIS and BAS are proposed to be independent constructs and their data was still able to be included for the other scales. Neutral recall proportion was identified as being positively skewed but was able to be made normal using square root transformed. With regards to reaction time, none of the participant's average reaction times fell outside of three standard deviations from the mean. However, two participants were consistently identified as extremes across the valence categories ($z > 2.5$), causing the data to be skewed. These two subjects were removed from the analysis of reaction time only. It is possible that these high reaction times indicate difficulty understanding the task or lack of effort. Additionally, Cook's distance, Mahalanobis, and leverage was examined to ensure any one data point was not influencing the regression analysis. Once these outliers were removed, the data was no longer skewed and little data was missing, but all missing variables were handled by excluding pairwise in each analysis.

Data was also examined for skewness, kurtosis, and normality using the Kolmogorov-Smirnov statistic in SPSS (Table 3-5). Skewness and kurtosis were both established by using the z score of each value produced by SPSS. A criterion of $z = 1.96$ was used to establish significant skew or kurtosis. BIS total was identified as negatively skewed and non-normal but was able to be square root transformed to become a normal variable (with appropriate skewness and kurtosis). Similarly, Recall for neutral pictures was positively skewed and was made normal by square root transformation. NA was highly positively skewed, with a majority of the participants endorsing little negative affect at Time 2. The variable was transformed to reduce the skewness using log transformation and square-root transformation, but NA still remained highly skewed ($p < 0.001$) and non-normal. Therefore, NA was not used in the analyses. Only PA-NA was used to control for mood given that this value represented current mood prior to recall and recognition and was normally distributed. At Time 1, PA-NA was also used for consistency, though PA-NA at Time 1 was only used for analysis of ERP variables since it was measured just prior to net application. PA-NA was not normally distributed, however, transformed results produced the same data as the raw variables. Therefore, when controlling for PA-NA at Time 1, raw values were used in analyses. Neutral proportion recalled was also significantly positively skewed and was corrected using a square root transformation. Additionally, the assumptions of regression were examined with each analysis. Cooks distance revealed no significant outliers, leverage was acceptable, and by examining the residual plot it was determined that the assumption of homoscedasticity was met.

In the ERP data (Table 5), several extreme points were identified using boxplots. However, further examination revealed these were true data that fell within three standard deviations of the mean. Given that this data was also considered to be true data, these values were all retained and with regression analysis, values were checked to ensure that they were not influencing the data through Cook's distance, Mahalanobis, and leverage. All data were made normal except for N2 ERP amplitude to neutral pictures. N2 neutral could only be made normal by removing the highest and lowest values. However, these values were not true outliers and were within three standard deviations of the mean. Because this variable could not be made normal and was not one of the primary outcome variables (i.e., used in the correlation and regression analyses as dependent variables), it was used in its raw form and transformation was not used.

Method Diagnostics

BIS and BAS are suggested to be independent constructs. As expected, BIS and BAS were not significantly correlated, *r*(58) = -0.026, p=0.85. BAS Drive subscales was not significantly correlated with the BIS scale (BAS-D, *r*(59) = -0.14, p = 0.29), though both Fun Seeking and Reward Responsiveness had relationships that were trending in significance (BAS-FS, *r*(56) = -0.23, p = 0.086; BAS-RR, *r*(56) = 0.22, p = 0.10). BIS was highly positively correlated with CES-D total, *r*(59) = 0.39, p<0.001. Interestingly, BAS-D had a trend level relationship with CES-D, *r*(61) = 0.21, p = 0.11. However, PA, NA, and the PA-NA difference at Time 2 did not correlate with BIS, BAS, or BAS subscales. Additionally, higher BIS was related to lower ratings of negative images at trend level significance (*r*(57) = -0.24, p = 0.07).

Paired samples t-tests were also used to compare mood at the beginning of the study (PA (Time 1): 26.42 (SD = 6.84), NA (Time 1): 11.68 (SD = 2.02)) to mood prior to recall and recognition (PA (Time 2): 23.84 (SD = 7.98), NA (Time 2): 12.19 (SD = 2.65)). Time between measurements was approximately an hour and a half and included net application, encoding procedures, and distraction procedures. Negative affect did not significantly change between the two measurements, *t*(54) = 1.39, p = 0.17, however, positive affect was significantly lower at the second measurement, *t*(54) = -2.43, p = 0.018. On average, positive affect decreased 2.11 (SD = 6.43) points. This suggests that participants experienced less positive affect as the study continued, but no change in negative affect.

Overall Free Recall Rates

Proportion recalled for each of the three valence conditions served as the data for analysis. Square root transformed variables were used to conduct a one-way Repeated Measures ANOVA with one within subject variable of picture valence (3 levels: positive, negative, neutral). All assumptions of the repeated-measures ANOVA were met, with spherecity found to be not significant. Proportion of pictures recalled differed significantly by valence, *F*(2,122) = 92.41, $p < 0.001$. Pairwise comparisons were then conducted using Bonferroni correction for multiple comparisons. These comparisons revealed that, compared to the neutral condition (Mean = 0.14, SD = 0.076), proportion recalled was significantly higher for positive pictures (Mean = 0.27, SD = 0.081, $p < 0.001$) and negative pictures (Mean = 0.27, SD = 0.094, $p < 0.001$). Recall of positive and negative pictures were not significantly different.

Overall Recognition Reaction Time Rates

Average reaction time for each of the three valence conditions served as the data for analysis. A one-way Repeated Measures ANOVA was conducted with one within subject variable of picture valence (3 levels: positive, negative, neutral). All assumptions of the repeated-measures ANOVA were met, with spherecity found to be not significant. Reaction times to pictures differed significantly by valence, *F*(2,118) = 5.60, $p < 0.01$. Bonferroni post hoc tests revealed that, compared to the negative condition (Mean = 840.85, SD = 100.21), reaction time in response to both positive pictures (Mean = 819.56, SD = 104.18, $p<0.05$) and neutral pictures (Mean = 817.35, SD = 99.45, $p < 0.01$) were significantly faster. Positive and neutral picture reaction times were not significantly different.

Overall Recognition Sensitivity Analysis

Log transformation was used to conduct a one-way Repeated Measures ANOVA with one within subject variable of sensitivity (3 levels: positive, negative, neutral). All assumptions of the repeated-measures ANOVA were met, with spherecity found to be non- significant. Proportion of pictures recognized differed significantly by valence, $F(2,122) = 6.03$, $p < 0.01$. Bonferroni corrected pairwise comparisons revealed that, compared to the neutral condition (Mean = 3.51, SD = 0.59), signal detection was significantly lower for negative pictures (Mean = 3.01, SD = 0.76, $p < 0.05$), but not positive pictures (Mean = 3.27, SD = 0.65). Additionally, positive and negative sensitivity were significantly different ($p < 0.01$), suggesting negative pictures have significantly more noise relative to signal.

Hypothesis 1: BIS/BAS and Recall/Recognition

The first hypothesis states that BIS and BAS will be related to the valence of the pictures recalled and recognized such that higher BIS is related to better recognition of negative pictures and BAS is related to better recall/recognition of positive pictures.

Free Recall was examined using two separate partial correlations, controlling for PA-NA, examined:

1) the correlation between BIS total and recall of negative pictures and

2) the correlation between BAS total and recall of positive pictures.

The distributions of the three BAS subscales could not be made normal; therefore only BIS and BAS totals were examined. BIS total was negatively correlated with recall of negative pictures at a trend level, $r(56) = -0.24$, $p = 0.065$, while BAS total was not significantly correlated with recall of positive pictures, $r(58) = -0.15$, $p = 0.57$ (Figure 2).

Two separate hierarchical regressions were conducted to determine if:

1) BIS total predicted recall of negative pictures and

2) BAS total predicted recall of positive pictures.

In the first model at Step 1, BAS and PA-NA at Time 2 were entered as predictors/control variables of recall of negative pictures (dependent variable). In Step 2, BIS was added to the model. Neither of the models was significant, though adding BIS explained more variance, though this was only at trend level ($\Delta R^2 = 0.044$, p= 0.11).

In the second hierarchical regression, BIS and PA-NA at Time 2 were entered in Step 1 as predictors/control variables of recall of positive pictures (dependent variable). In Step 2, BAS was added to the model. In the first step, the model was significant ($F(2,56) = 5.70$, $p < 0.01$), with 16.9% of the variance accounted for. The second step was also significant ($F(3,55) = 4.78$, $p < 0.01$), explaining 20.7% of the variance ($\Delta R^2 = 0.038$, p = 0.11). These findings (see Table 6) suggest that BAS accounted for a significant portion of variance in predicting decreased recall of positive pictures above and beyond that of BIS and PA.

Next, recognition (as measured by reaction time) was examined. Two separate partial correlations, controlling for PA-NA, examined:

1) the correlation between BIS total and recall of negative pictures and

2) the correlation between BAS total and recall of positive pictures.

The distributions of the three BAS subscales could not be made normal; therefore only BIS and BAS totals were examined. BIS was not significantly related to reaction time of negative pictures, $r(55) = -0.12$, p = 0.36 and BAS was not significantly related to reaction times to positive pictures, $r(56) = 0.20$, p = 0.14).

Two separate hierarchical regressions were conducted to determine if:

1) BIS total predicted reaction time to recognition of negative pictures and

2) BAS total predicted reaction time to recognition of positive pictures.

In the first model at Step 1, BAS and PA-NA at Time 2 were entered as predictors/control variables of reaction time to recognition of negative pictures (dependent variable). In Step 2, BIS was added to the model. The first model was at trend-level significance ($F(2,57) = 2.42$, $p = 0.098$), while the second model including BIS was not significant, ($F(3,56) = 1.66$, $p = 0.19$), with an insignificant change in variance accounted for ($\Delta R^2 = 0.004$, $p = 0.64$).

In the second hierarchical regression (Table 7), BIS and PA-NA at Time 2 were entered in Step 1 as predictors/control variables of reaction time to recognition of positive pictures (dependent variable). In Step 2, BAS was added to the model. In the first step, the model was significant at a trend level ($F(2,55) = 2.50$, $p = 0.092$), with 8.3% of the variance accounted for. The second step was also trending towards significant ($F(3,54) = 2.43$, $p = 0.076$), explaining 11.9% of the variance ($\Delta R^2 = 0.036$, $p = 0.15$). In the second model, PA-NA predicted decreased reaction time ($\beta = -0.28$, $p < 0.05$), while BAS Total was not a significant predictor ($\beta = 0.19$, $p = 0.15$). These findings suggest that higher mood contributes to faster reaction times to positive images.

Lastly, recognition sensitivity (measured using d') was examined to test the relationship between BIS/BAS and emotional memory. Two separate partial correlations, controlling for PA-NA, examined:

1) the correlation between BIS total and d' for negative pictures and

2) the correlation between BAS total and d’ for positive pictures.

The distributions of the three BAS subscales could not be made normal; therefore only BIS and BAS totals were examined. Variables were examined using log transformations of d’. BIS was not significantly related to d’ for negative pictures ($r(57) = 0.088$, $p = 0.51$), nor was BAS related to d’ for positive pictures, $r(58) = 0.15$, $p = 0.24$).

Two separate hierarchical regressions were conducted to determine if:

1) BIS total predicted d’ for negative pictures and

2) BAS total predicted d’ for positive pictures.

In the first model at Step 1, BAS and PA-NA at Time 2 were entered as predictors/control variables of d’ for negative pictures (dependent variable; log transformed values used). In Step 2, BIS was added to the model. Neither the first ($F(2,56) = 0.16$, $p = 0.85$) or second ($F(3,55) = 0.25$, $p = 0.86$) models were significant, with an insignificant change in variance accounted for ($\Delta R^2 = 0.008$, $p = 0.52$).

In the second hierarchical regression, BIS and PA-NA were entered in Step 1 as predictors/control variables of reaction time to recognition of positive pictures (dependent variable, log transformed values used). In Step 2, BAS was added to the model. Neither the first step ($F(2,56) = 1.97$, $p = 0.15$) or second step were significant ($F(3,55) = 1.77$, $p = 0.16$), explaining 8.8% of the variance, though not accounting for a significant change in variance ($\Delta R^2 = 0.022$, $p = 0.25$).

Hypothesis 2: BIS/BAS and Early ERP Components

The second hypothesis sought to examine if overall amplitude was increased for all emotional pictures (relative to neutral). Additionally, it was expected that higher BIS would relate to higher amplitude of early components in response to negative pictures, while BAS would relate to higher amplitude in response to positive pictures. PA-NA at Time 1 was used to control for mood, as this questionnaire was answered prior to encoding.

P1/N1 Components

A repeated measures ANOVA was performed to examine the interaction of valence and N1 and P1 components. A 3 (positive, negative, neutral) x 2 (P1, N1) repeated measures ANOVA was run using square root transformed variables. All assumptions of the repeated-measures ANOVA were met, with spherecity found to be not significant. There was a significant main effect for valence, $F(2,94) = 28.06$, $p < 0.001$. Post-hoc analyses revealed that neutral amplitude was significantly larger than amplitude for both positive and negative pictures ($p < 0.001$), though positive and negative pictures were not different. There was also a main effect for component, $F(1,47) = 15.34$, $p < 0.001$, though this was expected given the positive and negative inflections of the waves, with N1 much more negative than P1. Additionally, there was an interaction between component and valence, $F(1.78,83.60) = 124.47$, $p < 0.001$. A graph of the interaction revealed that while negative and neutral pictures showed the same patter across the two components, positive pictures decreased less in amplitude from the P1 to N1 component (see Figure 4 for P1 and Figure 5 for N1 amplitudes).

Next, four separate partial correlations, controlling for PA-NA at Time 1, examined:

1) the correlation between BIS total and P1 amplitude to negative pictures,

2) the correlation between BIS total and N1 amplitude to negative pictures,

3) the correlation between BAS total and P1 amplitude to positive pictures, and

4) the correlation between BAS total and N1 amplitude to positive pictures.

The distributions of the three BAS subscales could not be made normal; therefore only BIS and BAS totals were examined. BIS was not correlated to P1 amplitude ($r(44) = 0.22$, $p = 0.15$) or N1 ($r(44) = 0.12$, $p = 0.43$) amplitude to negative images. BAS was not correlated to P1 amplitude ($r(45) = 0.17$, $p = 0.27$) or N1 ($r(45) = 0.18$, $p = 0.23$) amplitude to positive images.

Four separate hierarchical regressions were conducted to determine if:

1) BIS predicts P1 amplitude for negative pictures during encoding,

2) BIS predicts N1 amplitude for negative pictures during encoding,

3) BAS predicts P1 amplitude for positive pictures during encoding and

4) BAS predicts N1 amplitudes for positive pictures during encoding.

In the first regression, BAS total and PA-NA at Time 1 were added into the model. In Step 2, BIS was added to the model. The first model was not significant ($F(2,43) = 0.79$, $p = 0.46$) accounting for only 3.5% of the variance. The second model was also not significant ($F(3,42) = 1.08$, $p = 0.37$), and the change in variance of P1 amplitude was not significant ($\Delta R^2 = 0.036$, $p = 0.21$).

In the second regression, BAS total and PA-NA at Time 1 were added into the model. In Step 2, BIS was added to the model. The first model was not significant ($F(2,43) = 0.74$, $p = 0.48$) accounting for only 3.3% of the variance. The second model was also not significant ($F(3,42) = 0.70$, $p = 0.56$), and the change in variance of P1 amplitude was not significant ($\Delta R^2 = 0.014$, $p = 0.43$).

In the third regression, BIS total and PA-NA at Time 1 were added into the model as predictors/control variables. In Step 2, BAS was added to the model to predict amplitude of P1 to positive pictures. The first model was not significant ($F(2,43) = 0.57$, $p = 0.57$), nor was the second model ($F(3,42) = 0.79$, $p = 0.51$) and did not account for a significant change in variance of P1 amplitude ($\Delta R^2 = 0.027$, $p = 0.28$).

In the fourth regression, BIS total and PA-NA at Time 1 were added into the model as predictors/control variables. In Step 2, BAS was added to the model to predict amplitude of N1 to positive pictures. The first model was not significant ($F(2,43) = 0.25$, $p = 0.78$), nor was the second model ($F(3,42) = 0.64$, $p = 0.60$) and did not account for a significant change in variance of N1 amplitude ($\Delta R^2 = 0.032$, $p = 0.24$).

P2/N2 Components

A repeated measure 3 (positive, negative, neutral) x 2 (P2, N2) ANOVA was performed to examine the interaction of valence and P2 and N2 components (see Figure 6). All assumptions of the repeated-measures ANOVA were met, with spherecity found to be not significant. There was a significant main effect for valence, $F(2,96) = 5.21$, $p < 0.01$. Post-hoc analyses revealed that positive picture amplitude was smaller (i.e., less negative) than amplitude for negative pictures ($p < 0.01$) and there was a trend for negative picture amplitude to be more negative than neutral picture amplitude ($p = 0.08$). There was also a main effect for component, $F(1,48) = 29.15$, $p < 0.001$, though this was expected given the positive and negative inflections of the waves, with

N2 much more negative than P2. Additionally, there was an interaction between component and valence, *F*(2,96) = 9.33, $p < 0.001$. The graph indicated that while positive and neutral picture amplitudes follow a similar patter across electrodes, negative pictures are more negative in amplitude in the N2 component.

Because P2 was not visible when examining the components, analyses were used only to examine N2. Two separate partial correlations, controlling for PA-NA at Time 1, examined:

1) the correlation between BIS total and N2 amplitude to negative pictures and

2) the correlation between BAS total and N2 amplitude to positive pictures.

The distributions of the three BAS subscales could not be made normal; therefore only BIS and BAS totals were examined. BIS was not significantly correlated with amplitude of N2 to negative pictures (*r*(42) = -0.13, p = 0.42), nor was BAS significantly correlated with amplitude of N2 to positive pictures (r(42) = -0.08, p = 0.62).

Two separate hierarchical regressions were conducted to determine if:

1) BIS predicts N2 amplitude for negative pictures during encoding and

2) BAS predicts N2 amplitudes for positive pictures during encoding.

In the first regression, BAS total and PA-NA at Time 1 were added into the model as predictors/control variables. In Step 2, BIS was added to the model as a predictor of N2 amplitude to negative pictures. The first model was not significant (*F*(2,43) = 1.49, p = 0.24), nor was the second model (*F*(3,42) = 1.52, p = 0.22), with no significant change in variance accounted for ($\Delta R^2 = 0.033$, p = 0.22). In the second regression, BIS total and PA-NA at Time 1 were added into the model as predictors/control variables. In Step 2, BAS was added to the model as a predictor of N2 amplitude to positive pictures. In the second hierarchical regression, the first model was not significant ($F(2,43) = 0.42$, $p = 0.66$), nor was the second model ($F(3,42) = 0.30$, $p = 0.83$), with no significant change in variance accounted for ($\Delta R^2 = 0.002$, $p = 0.80$).

Hypothesis 3: BIS/BAS, LPP, and Recall/Recognition

The third hypothesis sought to examine the influence of BIS/BAS on the LPP and the relation to memory for emotional pictures (Figure 7). A one-way Repeated Measures ANOVA for LPP amplitude with one within subject variable of picture valence (3 levels: positive, negative, neutral) was conducted. All assumptions of the repeated-measures ANOVA were met except that spherecity was significant; therefore, the Greenhouse-Geisser corrected values were used. Amplitude to pictures were trending towards being significantly different by valence, $F(1.77, 84.97) = 2.80$, $p = 0.07$, with negative being significantly higher in amplitude than neutral pictures ($p < 0.05$), a trending relationship of negative being higher than positive pictures ($p = 0.12$), and negative and positive not significantly different.

Two separate partial correlations were conducted, controlling for PA-NA (Time 1) examined:

1) the correlation between BIS total and LPP amplitude to negative pictures and

2) the correlation between BAS total and LPP amplitude to positive pictures.

LPP amplitude to negative pictures was not correlated with BIS ($r(44) = 0.003$, $p = 0.99$), nor was LPP amplitude to positive pictures correlated with BAS ($r(45) = 0.061$, $p = 0.68$.

To investigate the relationship between LPP and emotional memory, six separate partial correlations, controlling for PA-NA at Time 2, examined:

1) the correlation between LPP amplitude to positive pictures during encoding and free recall of positive pictures
2) the correlation between LPP amplitude to positive pictures during encoding and reaction time of recognition of positive pictures
3) the correlation between LPP amplitude to positive pictures during encoding and d' of positive pictures
4) the correlation between LPP amplitude to negative pictures during encoding and free recall of negative pictures
5) the correlation between LPP amplitude to negative pictures during encoding and reaction time of recognition of negative pictures and
6) the correlation between LPP amplitude to negative pictures during encoding and d' of negative pictures

In regards to positive picture recall and recognition, LPP amplitude to positive pictures was significantly correlated with recall ($r(46) = 0.38$, $p < 0.01$) and reaction time during recognition ($r(46) = -0.33$, $p < 0.05$), but was not related to d' ($r(46) = 0.17$, $p = 0.25$). In regards to negative picture recall and recognition, only d' showed a trend level relationship with LPP amplitude to negative pictures ($r(46) = 0.23$, $p = 0.11$), while neither reaction time ($r(46) = -0.14$, $p = 0.36$) nor free recall ($r(46) = 0.04$, $p = 0.81$) demonstrated a significant relationship.

Based on the previous results, 3 separate hierarchical regressions were conducted to determine if:

1) BAS adds a significant amount of variance above and beyond affect and LPP amplitude in predicting free recall of positive pictures,
2) BAS adds a significant amount of variance above and beyond affect and LPP amplitude in predicting reaction time to positive pictures, and
3) BAS adds a significant amount of variance above and beyond affect and LPP amplitude in predicting.

In the first regression, BIS total, PA-NA at Time 2, and LPP amplitude to positive pictures were added as predictors/control variables to predict free recall of positive picture (dependent variable). In Step 2, BAS was added to the model. The first model was significant ($F(3,42) = 5.71$, $p = 0.002$), accounting for 29.0% of the variance. The second model was also significant, ($F(4,41) = 5.76$, $p = 0.001$), with a significant increase in variance ($\Delta R^2 = 0.070$, $p = 0.04$). In the second model, PA-NA and LPP amplitude were significant positive predictors of positive free recall and BAS was a significant negative predictor of positive free recall (Table 8).

In the second hierarchical regression, BIS total, PA-NA at Time 2, and LPP amplitude to positive pictures were added as predictors/control variables to predict reaction time (dependent variable). In Step 2, BAS was added to the model. The first model was significant ($F(3,42) = 3.15$, $p < 0.05$), accounting for 18.4% of the variance. The second model was also significant, however, BAS was not a significant predictor ($\beta = 0.17$, $p = 0.24$) and did not account for a significant increase in variance ($\Delta R^2 = 0.028$, $p = 0.24$).

In the third hierarchical regression, BIS total, PA-NA at Time 2, and LPP amplitude to positive pictures were added as predictors/control variables to predict d’ of positive pictures (dependent variable). In Step 2, BAS was added to the model. The first model was not significant ($F(3,42) = 1.18$, $p = 0.33$), accounting for 7.8% of the variance. The second model was also not significant ($F(4,41) = 0.87$, $p = 0.49$), and BAS did not account for a significant increase in variance ($\Delta R^2 < 0.000$, $p = 0.998$).

DISCUSSION

This study sought to examine the relationship between motivational systems, emotional memory, and psychophysiological response to emotional pictures. Motivational systems were measured using Carver and White's (1994) Behavioral Inhibition/Behavioral Activation (BIS/BAS) scale so that each individual had both a BIS and BAS score. Emotional memory was measured using free recall, yes/no recognition, and reaction time to recognize 150 emotional pictures taken from the IAPS (equated on valence and arousal) after a delay. Due to the nature of emotional memory, mood was controlled for since affect has been suggested to influence emotional memory (Rusting, 1998). Specifically, the difference between positive and negative affect was used in this study. It was predicted that BIS/BAS would be related to recognition and recall of affective pictures. BAS was predicted to have a stronger relationship to increased recall and recognition of positive pictures and BIS was expected to relate similarly with negative picture recall and recognition. Little evidence was found to support the hypothesis that self-endorsed BIS or BAS ratings were related to enhanced memory for emotional pictures of a specific valence. Additionally, ERP components were used as an objective measure of psychophysiological response to emotional images. Early ERP components (P1, N1, P2, N2) and late components (LPP) were also examined to determine if ERP amplitude varied by valence as a function of BIS and BAS endorsements. Time windows for components were established using windows reported in other studies and visualizing the grand average referenced data. It was expected that ERPs would also demonstrate differences in response to stimuli as predicted by BIS/BAS. This study found little evidence that ERP component amplitude was related to BIS or BAS endorsement.

BIS/BAS and Memory for Emotional Pictures

Free recall data demonstrated an emotionality effect, such that emotional pictures (positive and negative) were recalled more often than neutral pictures, which is consistent with the results of other studies involving free recall of pictures (Palomba, Angrilli, & Mini, 1997; Bradley, 1992; Dolcos & Cabeza, 2002; Weymar et al., 2012). Interestingly, there was a trend for higher BIS predicting decreased recall of negative pictures and higher BAS predicting decreased positive recall. Additionally, positive affect predicted increased positive picture recall. This is somewhat discrepant, as previous research has found BAS positively related to positive affect (Erdle & Rushton, 2010) and related to enhanced memory for positive material (Gomez & Gomez, 2002), with BIS related to increased negative affect and increased memory for negative material (Erdle & Rushton, 2010; Gomez & Gomez, 2002). Possible reasons for these results may be due to differences in methodological approach, which will be discussed below.

In general, participants were slower to respond to negative pictures than positive and neutral pictures. This may evidence a negativity bias, where processing negative information generally takes a longer time and more cognitive effort (Huang & Luo, 2006). Regression analysis showed affect was a significant predictor of decreased positive picture recognition reaction time (RT), suggesting those with better mood were more likely to have decreased reaction times for positive images that were correctly recognized. However, no significant relationship was found between RT and BIS/BAS.

The use of d’ takes into account correctly identified targets and lures incorrectly identified as being seen before. Past research has shown that recognition of emotional pictures may not evidence an emotionality effect, with most participants performing very well with little variability across subjects (Perez-Mata et al., 2011). Overall, participants demonstrated better discrimination for positive and neutral images compared to negative images. Additionally, discriminability was found to be lower for negative images despite seemingly equal recognition rates (Table 2), however, d’ did not relate to BIS/BAS. Previous studies found that while recognition is stronger for negative pictures relative to neutral, there is a decrease in source memory for these pictures (Mitchell et al., 2006). This may contribute to why more lures were endorsed as being previously seen even if both positive and negative lures were equated.

Taken together, the behavioral results do not suggest that memory for positive material is enhanced for BAS nor that memory for negative material is enhanced for BIS. Instead, decreased memory performance was found with the respective valence. However, the overall valence results support that the stimuli produced replicable and expected results: emotional pictures were recalled more than neutral, reaction time was slower to negative pictures, and d’ was lower for negative pictures. However, that these valence effects were not strongly influenced by BIS/BAS.

BIS/BAS and ERP Components

Early/Middle ERP Components

While previous studies have suggested ERP amplitude may vary based on individual differences (Dien, 1998), differences related to BIS and BAS total was not found. Early components (i.e., N1, P1, N2, P2) are proposed to be modulated primarily by low-level visual characteristics, though some propose they are impacted by valence, with later components more impacted by arousal (e.g., LPP; Olofsson et al., 2008). There was evidence of an overall valence effect across components. In P1/N1 components, positive pictures showed a different response across components, with N1 having larger amplitudes for positive pictures. This is consistent with the overall effect observed in Cuthbert et al. (1998) and Gable and Harmon-Jones (2008), however, Gabel and Harmon-James additionally found that BAS scores predicted increased N1 amplitude to appetitive stimuli. In this study, BIS/BAS did not relate to N1 or P1 amplitude, indicating specialized processing as indicated by BIS and BAS may not exist in the earliest components. A similar overall pattern was found for P2 and N2; negative pictures had higher amplitude, specifically with the N2 component. Again, differences in amplitude were not related to BIS/BAS, despite N2 being suggested to be the earlier component most sensitive to individual differences (Kovalenko & Pavlenko, 2009; Olofsson et al., 2008). The P2 component was not included in all analyses since it was not present when visualizing the data at the frontal sites (Figure 7). The P2 component is elicited by visual stimuli, particularly when classifying or categorizing that stimuli; it increases in amplitude with increasing stimuli's perceptual complexity, and does not vary much in terms of individual differences (Kovalenko & Pavlenko, 2009). Therefore, this component was expected to be produced and be visible in central frontal sites at around 160-190ms post stimulus (Feng et al., 2014). Olofsson et al. (2008) further suggests that middle components (i.e., N2 and P2) are most suseptible to differences across referencing methdods, with a larger effect demonstrated when using linked mastoid and earlobe referenced waveforms. The average reference used in the current study may have contributed to differing morphology of the waves. Of note, Olofsson et al. (2008) suggest little attention has been paid to differences in amplitude due to verying methods of referencing despite the significant impact on results, with some studies finding significant differences depending on type of reference used (Joyce & Rossion, 2005; Dien, 1998). Furthermore, sometimes studies fail to even report what reference was used (e.g., Brown, Goodman, & Inzlicht, 2013; Zilber, Goldstein, & Mikulincer, 2007). This also makes comparisons across studies difficult, for example, Balconi et al. (2012) used earlobe reference while and Feng et al. (2014) uses average mastoid reference, while the current study uses average reference.

Late Parietal Positivity (LPP)

LPP has previously been found by Balconi et al. (2012) to demonstrate strong relationship with BIS/BAS endorsement. In the current study, higher BAS was related to increased amplitude to positive images and higher BIS was related to increased amplitude in response to negative images. This was not found in the current study. One explanation for the differences may be in the nature of the participants. Balconi et al. (2012) used only 25 participants, consisting of both males and females. Additionally, they employed different methodology; they did not control for affect, used passive viewing, and administered the BIS/BAS questionnaire three days after the study, which may have affected the results. While the current study attempted to use the same pictures as those in Balconi et al. (2012), this was not possible as many were similar (e.g., several skydiving pictures for positive high arousing) and would not work with the free recall portion of this study. The images used in Balconi et al. (2012) were too visually similar for participants to be able to describe the picture and have it be distinguished from other pictures presented. Other studies have also failed to find this relationship. Gable and Harmon-Jones (2008) did not find differences in late positivity amplitude in appetitive stimuli. Additionally, LPP amplitude may be influenced by elaboration upon presentation of stimuli, which may have been altered by asking participants to rate the pictures on valence and arousal upon presentation. Lastly, Matthews and Gilliland (1999) propose that those high in neuroticism (comparable to BIS) may take longer to habituate. Due to the nature of the study, 30 minutes to 45 minutes into the study (when encoding occurred) or viewing 150 pictures may have allowed adequate time to habituate that was not available in other studies.

BIS/BAS, ERP, and Memory for Emotional Pictures

LPP amplitude to positive pictures was related to increased free recall and decreased reaction time in response to positive pictures. Additionally, there was a trend relationship for LPP amplitude in response to negative pictures to be related to increased d’ to negative pictures, indicating better detection of negative pictures. These findings are consistent with other studies that have found increased amplitude in late positive components that relate to better memory for those items (Dolcos & Cabeza, 2002; Weymar et al., 2012). However, BIS and BAS were not found to have the expected relationship with LPP amplitude to positive or negative pictures, with BAS being a negative predictor of positive recall.

Limitations and Future Directions

There were several participant and methodological factors that may have impacted results. One major factor may have been sample size. While ERP sample size typically tests between 15 to 25 people to examine the relationship between BIS/BAS and ERPs (Balconi et al., 2012; Gable & Harmon-Jones, 2008), the current sample size may not have been large enough to detect an effect in emotional memory. Most importantly, the range of the BIS and BAS variables was very limited. While BIS could range from 7 to 28, the observed range was 15 to 28 in the current study, with the lowest scores needing to be removed because they were statistical outliers and having an undue influence on the data. Likewise, BAS could range from 13 to 58, but the observed range was 30 to 49, with the highest scores removed as outliers. Furthermore, due to the highly abnormal distribution of the BAS subscale scores; these could not be included in analysis due to violation of statistical assumptions. The subscales have been reported to have different relationships. For example BAS-Drive (D) and BAS-Fun Seeking (FS) have not been found to relate to early ERP components while BAS-Reward Responsiveness (RR) and overall BAS total have (Gable & Harmon-Jones, 2008). Additionally, Carver and White (1994) report a positive correlation between RR and BIS. In the current study, RR was positively related to BIS and FS was negatively related to BIS at a trend level. Though BAS as a whole was not related to BIS, this may suggest that individual subscales could influence the results in unintended directions depending on the distribution. Depending on the influence of RR on the data, this may have influenced decreased (rather than increased) positive recall and recognition predicted by BAS due to its relationship to BIS. However, due to the abnormalities of the BAS subscales, influence of each individual subscale could not be evaluated.

These relationships may suggest that the interaction of BIS and BAS can influence the results. While BIS/BAS was originally proposed as orthogonal constructs, some have argued that the systems are better conceptualized as interacting constructs (Corr, 2001, 2002). The Joint Systems Hypothesis proposes that someone highest in one domain and lowest domain in the other (e.g., High BIS and High BAS) will not respond the same as someone with a different pattern (e.g., High BIS and Low BAS). Furthermore, the theory proposes that the strength of the affective material influences whether BIS and BAS act as inhibitory or facilitative, with BIS typically acting to inhibit BAS. For example, when a weak negative stimulus is encountered, anxiety will inhibit BAS while impulsivity will inhibit BAS. In response to a strong negative affective stimulus, Corr suggests that anxiety facilitates BIS while impulsivity facilitates BAS. This produces differential responses in an individual depending on the interrelationship of BIS and BAS. This interaction is not adequately measured by Carver and White’s (1994) BIS/BAS scale, as it treats BIS and BAS as independent traits. Further support for this theory is found in a study by Kuppens (2008). His study, he sought to identify if valence and arousal were always independent within individuals or if this is only seen when looking at group or average data. Overall, he found that valence and arousal were independent, replicating previous results. However, when examining individuals, he found significant variation, such that one person may be highly aroused by a positive situation while another may be calmed by it. Similarly, he described negative situations can be accompanied by low arousal for some (e.g., depression, hopelessness) or high arousal (e.g., anxiety, stress). These relationships were found to vary from negatively correlated, zero correlation, to strongly positively correlated. BAS-RR demonstrated a positive relationship between arousal and positive valence. Given that both high and low arousing pictures were used in this study, the interaction of valence and arousal may have been enhanced and altered results, possibly through the differential responses to arousal. While this study did attempt to account for the possible relationship of BIS and BAS by using regression analysis with both scales included, this does not fully address the proposed relationship of the scales. A better measure of the interaction is needed beyond Carver and White's BIS/BAS and a scale that is consistent with the Joint Systems Hypothesis.

An additional methodological confound is that EEG was measured during encoding, while subjects evaluated the valence and arousal of each picture. Active view was primarily used in order to ensure attention was given to the pictures, which has been done through other categorization techniques in other studies (e.g., categorizing by valence or content; see Olofsson et al., 2008 for review). Tasks that take attention away from the emotional content of the stimulus, such as categorizing by whether or not people are present, will also decrease the responses to emotional stimuli (Schupp, Schmalzle, & Flaisch, 2013). However, Olofsson et al. (2008) reviewed the literature of ERP in response to emotional stimuli and found that most agree that active viewing (e.g., rating the image for emotional content, alive or dead, is a person present), did not impact the ERP data. When specifically examining the LPP, Hajcak, Dunning, and Foti (2007) found that difficulty of a concurrent task does not impact ERP amplitude to emotional pictures, though Davidson (2001) suggests the LPP is not impacted. However, Taylor, Phan, Decker, and Liberzon (2003) contend that rating IAPS pictures for emotional content can alter activation. In a PET study, they specifically found decreased insula activity, which was more caudal and dorsal in passive compared to active viewing. Furthermore, active viewing demonstrated increased medial frontal activity. They further suggest that it may be that generating ratings cause these differences or that different processes are allowed to occur when the subject is not thinking about a rating and is better able to elaborate and process the picture. This may have required some regulation to suppress or control emotional response in order to complete the given task. If the task did require suppression, all components may be impacted, specifically later components (after 400ms; Moser et al., 2009). However, other studies have found that individuals can modulate their response as early as the P1 component (Rutman et al., 2010). Beyond simple suppression of emotional experience, this also may have prevented elaborative processes that may have occurred in a passive viewing task (Taylor et al., 2003). Future research could provide further information on this process and determine if ability to regulate emotion interacts with BIS/BAS to influence ERP amplitude and emotional memory.

Other theories of personality should also be considered, as others may make different predictions within this paradigm beyond Gray’s reinforcement sensitivity model. Eysenck’s dimensions of Extroversion and Neuroticism are also related to positive and negative stimuli processing. Few studies have compared Gray and Eysenck’s theories specifically related to emotional memory. One such study that compared the two used emotional word stems, recognition, and recall (Gomez & Gomez, 2002). While they did not statistically compare the two, the conclusions drawn from measurements of Eysenck's traits (Extroversion and Neuroticism on the Eysenck personality Inventory) did not differ from those using Carver and White's BIS/BAS scale. These additional traits may provide more information on the relationship between personality and emotional processing. To date, no studies are known to compare emotional processing in BIS/BAS and Extroversion/Neuroticism.

Theoretical Implications

One consistent battle in understanding emotion processing is to disentangle valence and arousal effects, which may also be at play with BIS and BAS. A trend relationship was found between BIS total and decreased valence ratings of negative images, meaning those with high BIS rated negative images as more negative relative to those with lower BIS total scores. This is consistent with Balconi et al. (2012), though they additionally found that BAS was related to ratings of increased valence (i.e., more positive) for positive pictures. Additionally, effects have also been found related to arousal, such that those higher in BIS rate images as more arousing (Balconi et a., 2012). In BAS, for example, attention to positive stimuli is differentially affected by level of arousal (Gable & Harmon-Jones, 2008).

ERP components are also impacted by arousal. LPP amplitude is found to vary according to level of arousal, regardless of valence (Leite et al., 2012). Furthermore, Feng et al. (2014) demonstrated that arousal could affect components as early as P1, with later components demonstrating an interaction of valence and arousal effects. Therefore, while efforts were made in the current study to control for arousal, individual differences may create an arousal effect. A subject's own rating of arousal is a better predictor of medial frontal and the sublenticular extended amygdala activity in an fMRI study than using large group averages (i.e., normative arousal ratings) of what subjects typically rate the picture (Phan et al., 2003). A measure of arousal is also important because Eysenck and Gray's dimensions respond differently to arousal. Brenner, Beauchaine et al. (2005) found physiological measures of arousal (i.e., heart activity through sinus arrhythmia and pre-ejection period and skin conductance) were relatively unrelated to endorsement of the BIS/BAS, while Eysenck's traits were found to be related to this physiological autonomic response (Canli et al., 2001; Norris et al., 2007). Furthermore, response to arousal differs such that extroverts may be more reactive overall, but introverts reach maximum arousal at a lower threshold (i.e., lower arousal level) than extroverts (Matthews & Gilliland, 1999).

These results may imply that BIS/BAS relates more to arousal ratings at a lower arousal threshold. Gray and McNaughton (2003) propose that the behavioral inhibition system is primarily driven by the septo-hippocampal system, with the amygdala being a downstream projection playing a secondary role. However, the amygdala involvement may contribute to arousal effects. If, indeed, BIS/BAS does relate to valence and this was modulated by the procedure (i.e., rating the stimuli), this provides evidence for this predisposition to be overcome by labeling and describing the emotion. These are techniques that are used in cognitive behavior therapy (Beck, 2011). As such, these may provide a means to moderate the emotional response to an affective picture prior to presentation, regardless of ones predisposition to valence sensitivity.

In relation to Gray's theory, the extension of motivational systems to emotional processing was not supported. It is possible that the model applies more to reward sensitivity and punishment than to processing and memory for emotional pictures. Additionally, valence (i.e., how pleasant or unpleasant a stimuli is) and action motivation (i.e., approach or avoidance in response to a stimuli) have been described as different constructs (Berkman & Lieberman, 2010). While some paradigms may recruit action motivation, this study may not have, possibly explaining why the results have been inconsistent from other studies.

Conclusion

The relationship between BIS/BAS, ERP response to emotional pictures, and memory for emotional pictures was investigated. While an overall valence pattern of results was found when examining memory and ERP morphology, these factors were not related to BIS/BAS. The inability to replicate the relationship between BIS/BAS and emotional memory and BIS/BAS and LPP amplitude suggest the relationship may not be as strong as other studies suggest. It is also possible that it is better accounted for by elaborative processing and arousal, rather that a valence effect. Further research is needed to determine the role that emotional regulation and arousal play in the relationship between BIS/BAS and emotional processing.

TABLES AND FIGURES

Table 1: Mean valence ratings of target IAPS pictures

	Low Arousal	**High Arousal**	**Neutral**	**Overall Average**
Positive	7.63 (0.60)	7.52 (0.57)	-	7.78 (0.58)
Negative	2.98 (0.73)	2.66 (0.61)	-	2.82 (0.69)
Neutral	5.22 (0.51)	-	4.99 (0.59)	5.11 (0.55)
Total	5.28 (2.01)	5.09 (2.52)		

Note: Image valence rating taken from IAPS normative data, using only female average ratings. All images are significantly different across categories (e.g., positive vs. negative valence) and not significantly different within categories (e.g., positive low arousing and positive high arousing valence). Each category contained 50 pictures. Neutral/Neutral was chosen in lieu of Neutral/High arousal due to the nature of IAPS images where very few items meet the criteria of neutral high arousing images.

Table 2: Mean arousal ratings of target IAPS pictures

	Low Arousal	**High Arousal**	**Neutral**	**Overall Average**
Positive	4.08 (0.34)	6.32 (0.49)	-	5.20 (1.21)
Negative	4.22 (0.51)	6.47 (0.53)	-	5.34 (1.25)
Neutral	4.13 (0.16)	-	4.97 (0.32)	4.55 (0.49)
Overall Average	4.12 (0.37)	6.40 (0.51)	-	-

Note: Mean (SD) given for each. Image arousal rating taken from IAPS normative data, using only female average ratings. All images are significantly different across categories (e.g., high vs. low arousing) and not significantly different within categories (e.g., positive low arousing and negative low arousing). Each category contained 50 pictures. Neutral/Neutral was chosen in lieu of Neutral/High arousal due to the nature of IAPS images where very few items meet the criteria of neutral high arousing images.

Table 3: Diagnostics of predictor variables

Variable (n = 62)	**Mean (SD)**	**Skew**	**Kurtosis**	**Normality**
BIS Total*	21.15 (3.15)	-0.30	-0.18	n.s.
BAS Total*	40.83 (3.96)	-0.28	-0.04	n.s.
BAS-D	10.79 (2.09)	0.13	-0.45	0.14, p = 0.003
BAS- FS	11.76 (1.56)	0.24	-0.04	0.15, p = 0.003
BAS-RR	18.62 (1.25)	-0.84	0.31	0.20, p < 0.001
PANAS-NA T2	12.08 (2.52)	1.25	0.61	0.24, p < 0.001
NA Sqrt trans.	-	1.12	0.22	0.23, p < 0.001
NA Log trans.	-	0.99	-0.12	0.23, p < 0.001
PANAS-PA T2	23.81 (7.98)	0.54	0.064	n.s.
PA-NA T2	11.50 (8.74)	0.32	-0.40	n.s.
PA-NA T1	13.94 (7.15)	0.39	-0.31	0.14, p = 0.02
PA-NA T1 Sqrt trans	-	*-0.43*	*1.10*	*n.s.*

Note: n.s. = not significant; *Sqrt trans* = square root transformation applied to variable to attempt to make distribution normal. *Log trans* = log transformation applied to variable to attempt to make distribution normal. PA-NA = Positive affect minus negative affect score at Time 2, used as a control variable as measure of mood; T2 = Time 2, before free recall and recognition; T1 = Time 1, prior to net application and encoding. *N = 60 for BIS and BAS total.

Table 4: Diagnostics of behavioral dependent variables

Variable (n=62)	**Mean (SD)**	**Skew**	**Kurtosis**	**Normality**
Recall				
Overall Recall	0.23 (0.067)	0.20	-0.45	n.s.
Positive proportion	0.27 (0.081)	0.22	-0.44	n.s.
Negative proportion	0.27 (0.094)	-0.012	-0.53	n.s.
Neutral proportion	0.14 (0.076)	0.88	0.62	0.15, p= 0.001
Neutral Sqrt Transformed	-	*0.23*	*-0.25*	*n.s.*
Recognition				
Overall Recognition	0.90 (0.075)	-	-	-
Positive Rate	0.88 (0.090)	-	-	-
Negative Rate	0.91 (0.075)	-	-	-
Neutral Rate	0.92 (0.059)	-	-	-
Sensitivity Analysis				
Positive d’	3.27 (0.65)	-0.68	-0.14	0.14, p = 0.005
Positive d’ log trans	-	*-0.004*	*-0.28*	*n.s.*
Negative d’	3.01 (0.76)	-0.30	-0.39	n.s.
Neutral d’	3.51 (0.59)	-0.61	-0.23	0.12, p = 0.031
Neutral d’ log trans	-	*-0.018*	*-0.21*	*n.s.*
Recognition Reaction Time				
Overall RT	825.92 (95.18)	-0.17	-0.53	n.s.
Positive RT	819.56 (104.18)	-0.06	-0.09	n.s.
Negative RT	840.85 (100.21)	-0.30	-0.62	n.s.
Neutral RT	817.35 (99.45)	0.56	0.29	n.s.
Image valence ratings				
Positive valence rating	7.0 (0.82)	0.01	-0.65	n.s.
Negative valence rating	2.55 (0.88)	0.88	-0.14	n.s.
Neutral valence rating	4.74 (0.53)	0.45	3.24	0.15, p = 0.001

Note: n.s. = not significant; *Sqrt trans* = Variable was transformed using the square root of ((highest variable +1) – X); *log trans* = Variable was transformed using Lg10(highest variable +1) – X). This means that all relationships with these variables are reversed (i.e., a positive relationship is truly a negative relationship); true relationships are reported.

Table 5: Diagnostics of mean amplitude by ERP component

Variable (n = 49)	Mean (SD)	Skew	Kurtosis	Normality
P1				
Positive	4.55 (3.66)	0.83	0.37	0.14, p = 0.02
Positive Sqrt Transformed	**-**	*0.12*	*-0.097*	*n.s.*
Negative	5.75 (3.70)	0.55	-0.020	n.s.
Neutral	4.83 (3.04)	0.56	-0.46	n.s.
N1				
Positive	3.80 (3.64)	0.65	0.09	0.16 p = 0.004
Pos Sqrt Transformed	-	-0.05	0.034	n.s.
Negative	4.50 (3.59)	0.55	0.17	n.s.
Neg Sqrt Transformed	-	0.22	0.13	n.s.
Neutral	3.81 (3.49)	0.49	0.63	n.s.
P2		-	-	-
Positive	-3.52 (2.49)	-0.18	0.20	n.s.
Negative	-3.90 (2.37)	-0.25	1.07	n.s.
Neutral	-3.62 (2.60)	-0.65	0.35	n.s.
N2				
Positive	-4.32 (2.70)	-0.12	1.15	n.s.
Negative	-5.23 (2.72)	0.47	0.77	n.s.
Neutral*	-4.60 (3.00)	-0.45	0.54	0.13, p = 0.04
LPP				
Positive	2.57 (3.09)	-0.38	0.94	n.s.
Negative	3.25 (3.25)	-0.16	0.15	n.s
Neutral	2.43 (2.68)	-0.25	0.28	n.s

Note: Sqrt trans = square root transformation. Because same values are negative, variable is transformed by adding the smallest value +1 and taking the square root. N2 neutral could only be made normal by removing the highest and lowest values. However, these values were not true outliers and were within three standard deviations of the mean. Therefore, the raw values were used for analysis.

Table 6: Hierarchical linear regression of prediction of positive picture recall

	B	*SE* B	β
Step 1			
Constant	0.26	0.072	
BIS	-0.001	0.003	-0.055
PA-NA	0.004	0.001	0.41*
Step 2			
Constant	0.34	0.11	
BIS	-0.002	0.003	-0.060
PA-NA	0.004	0.001	0.40*
BAS	-0.004	0.002	-0.20§

Note: R^2 = 0.169 for Step 1; ΔR^2 = 0.038 for Step 2 (p = 0.038); *p < 0.01, §p = 0.11

Table 7: Hierarchical linear regression of prediction of positive recognition RT

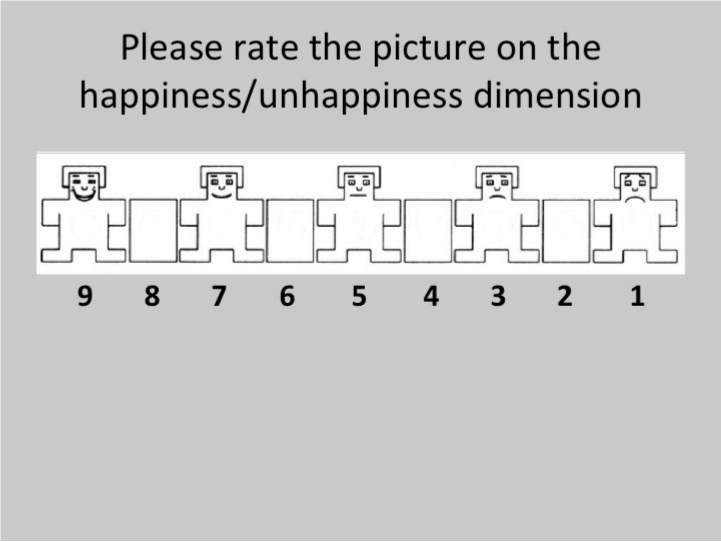
	B	*SE* B	β
Step 1			
Constant	901.22	98.13	
BIS	-1.92	4.28	-0.058
PA-NA	-3.40	1.54	-0.29*
Step 2			
Constant	693.93	170.73	
BIS	-1.75	4.23	-0.053
PA-NA	-3.34	1.53	-0.28*
BAS	4.97	3.36	0.19

Note: $R^2 = 0.083$ for Step 1; $\Delta R^2 = 0.036$ for Step 2 ($p = 0.15$); *$p < 0.05$

Table 8: Hierarchical linear regression of prediction of positive free recall

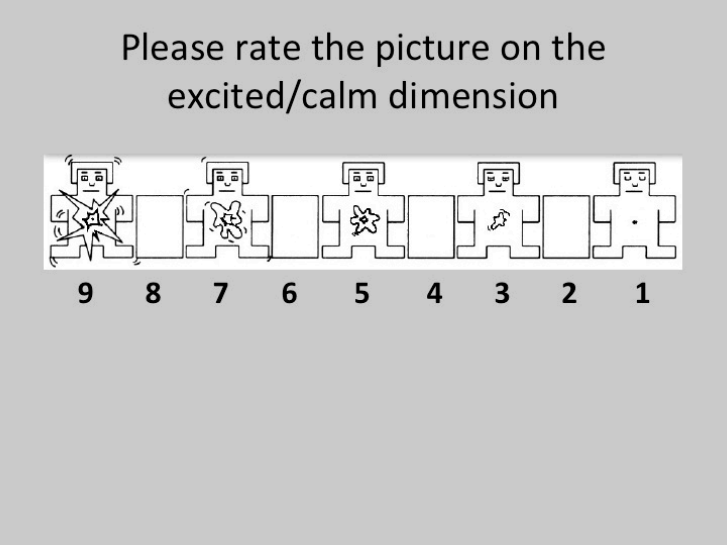
	B	*SE* B	β
Step 1			
Constant	0.27	0.076	
PA-NA	0.003	0.001	0.34*
BIS	-0.003	0.003	-0.19
LPP amplitude	0.009	0.003	0.36*
Step 2			
Constant	0.50	0.133	
PA-NA	0.003	0.001	2.87**
BIS	-0.003	0.003	-0.99
LPP amplitude	0.010	0.003	0.38**
BAS	-0.006	0.003	-0.27*

Note: $R^2 = 0.29$ for Step 1; $\Delta R^2 = 0.070$ for Step 2 ($p = 0.04$); *$p< 0.05$, **$p < 0.01$



Please rate the picture on the happiness/unhappiness dimension

A.



Please rate the picture on the excited/calm dimension

B.

Figure 1. Semantic Affective Mannequins (SAMs) presented when rating valence (A) and arousal (B).

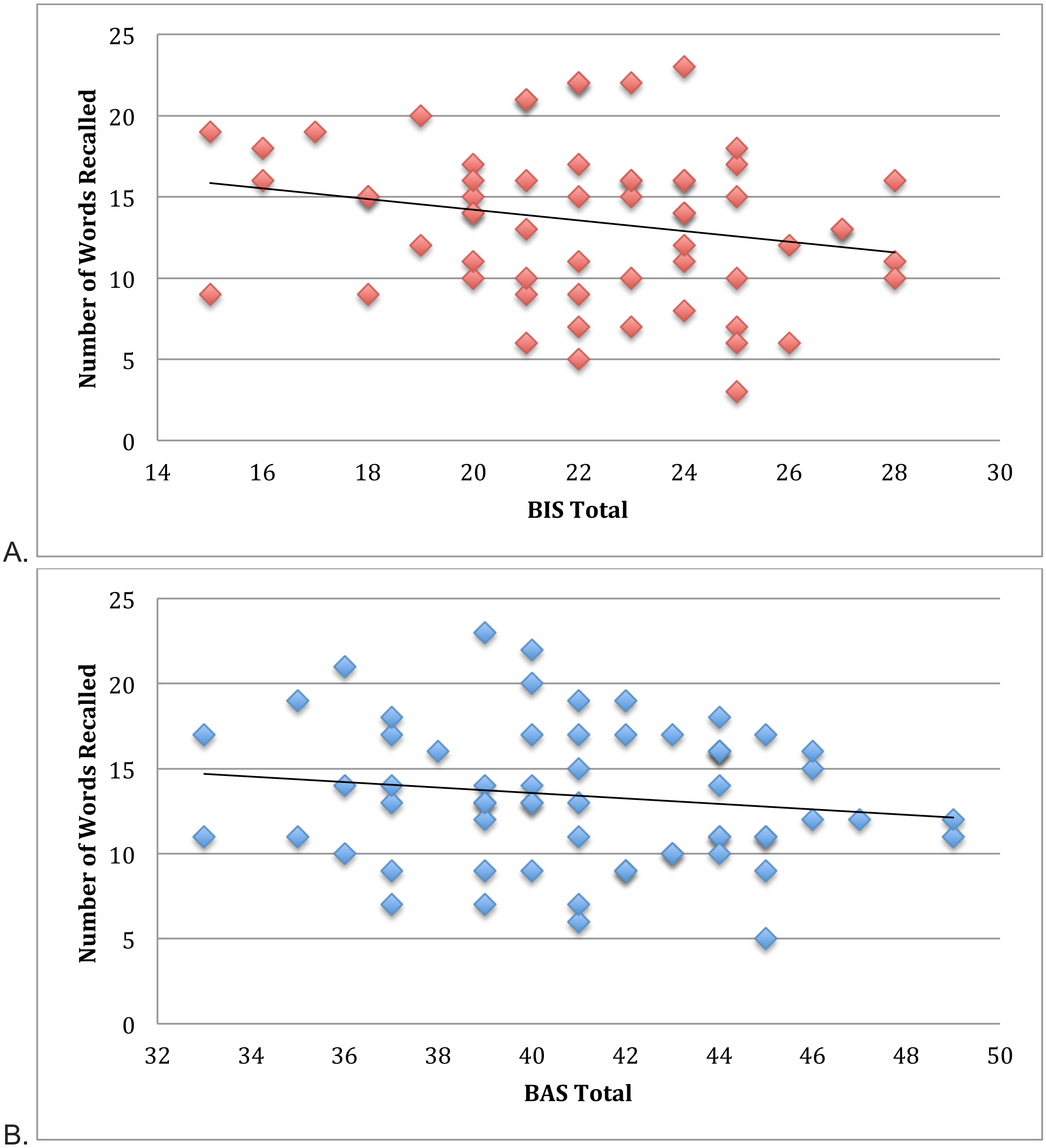


Figure 2. Relationship between BIS/BAS and free recall. (A) Free recall of negative pictures and self endorsed BIS Total (*r*(56) = -0.24, p = 0.065); (B) Free recall of positive pictures and self-endorsed BAS total (*r*(58) = -0.15, p = 0.57).

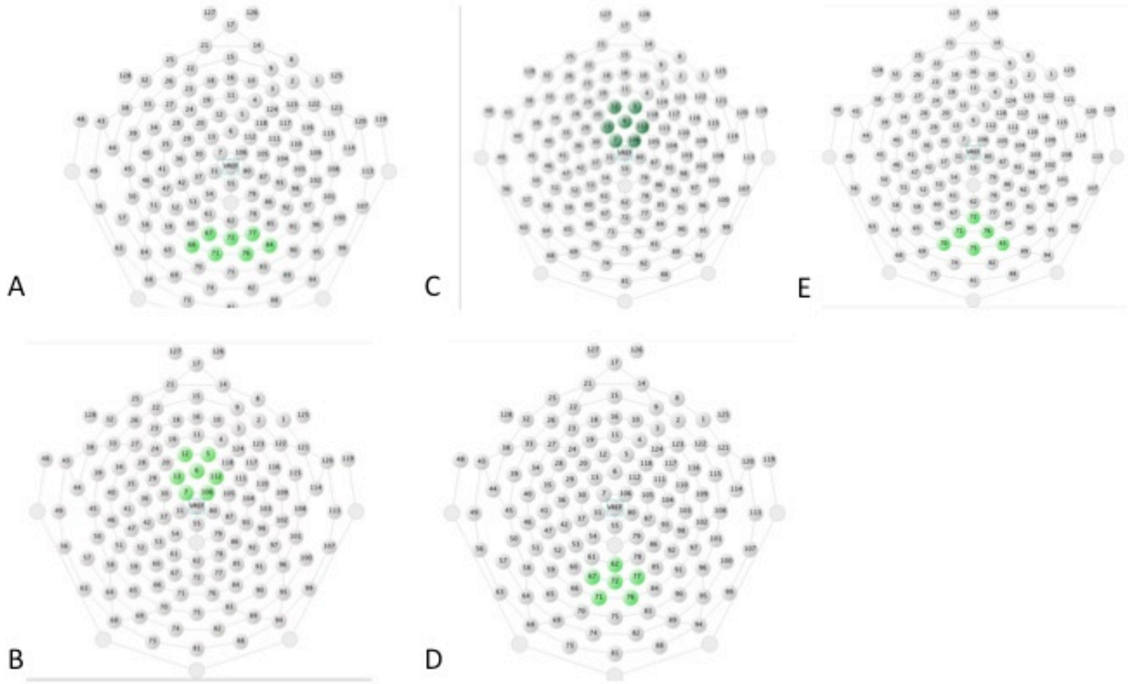


Figure 3. Montages used by component. Electrode montages used for statistical extraction. Amplitude was averaged over all electrodes in montage. A = LPP montage (electrodes: 72, 77, 67, 71, 76, 84, 66); B = N2 Montage (electrodes: 12, 13, 5, 6, 7, 112, 106); C = P2 montage (electrodes: 6, 12, 7, 13, 106, 112, 5); D = N1 montage (electrodes: 67, 73, 78, 66, 72, 77, 85, 76); E = P1 montage (electrodes: 73, 72, 77, 76, 71, 84).

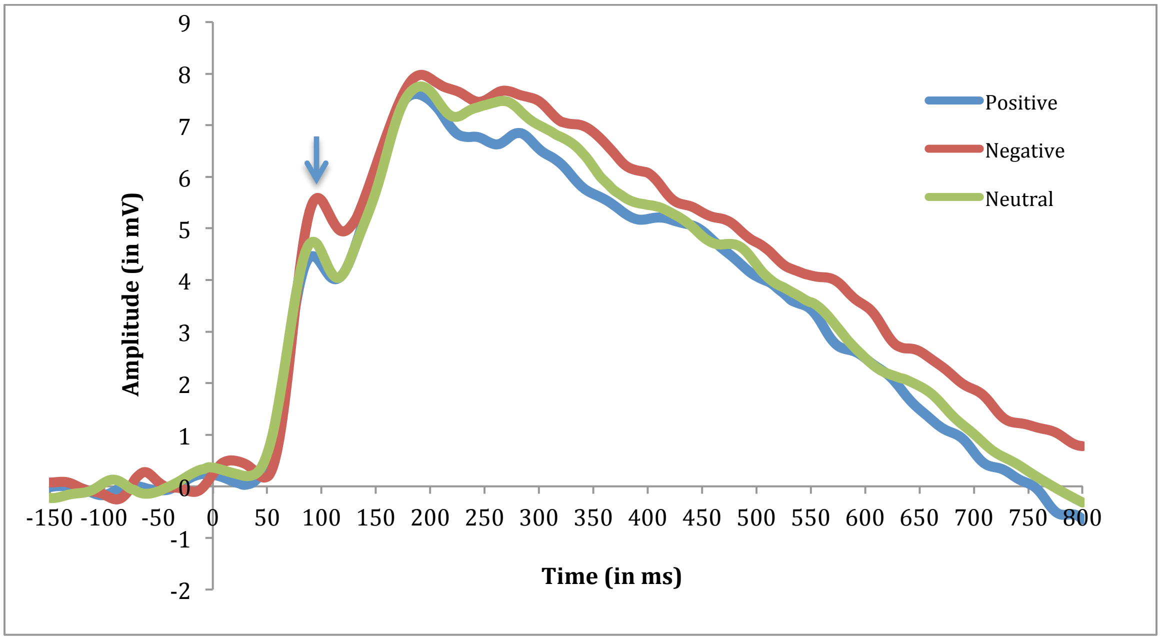


Figure 4. Grand average ERP by valence (P1 montage). P1 component was measured between 80 - 110ms.

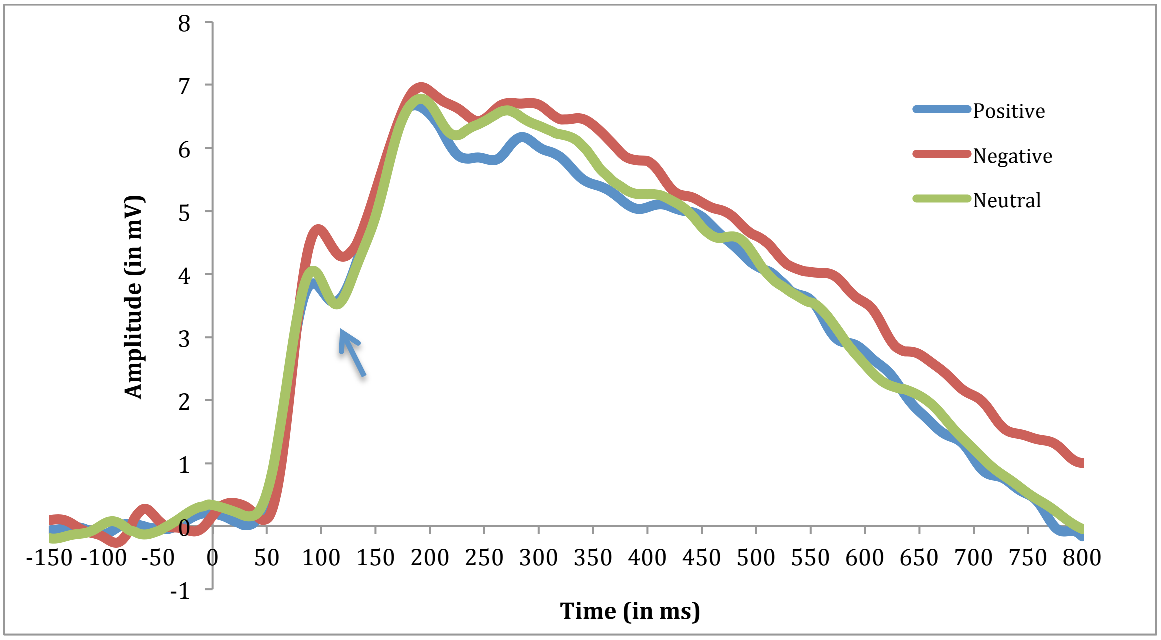


Figure 5. Grand average ERP by valence (N1 montage). N1 component was measured between 95 - 130ms.

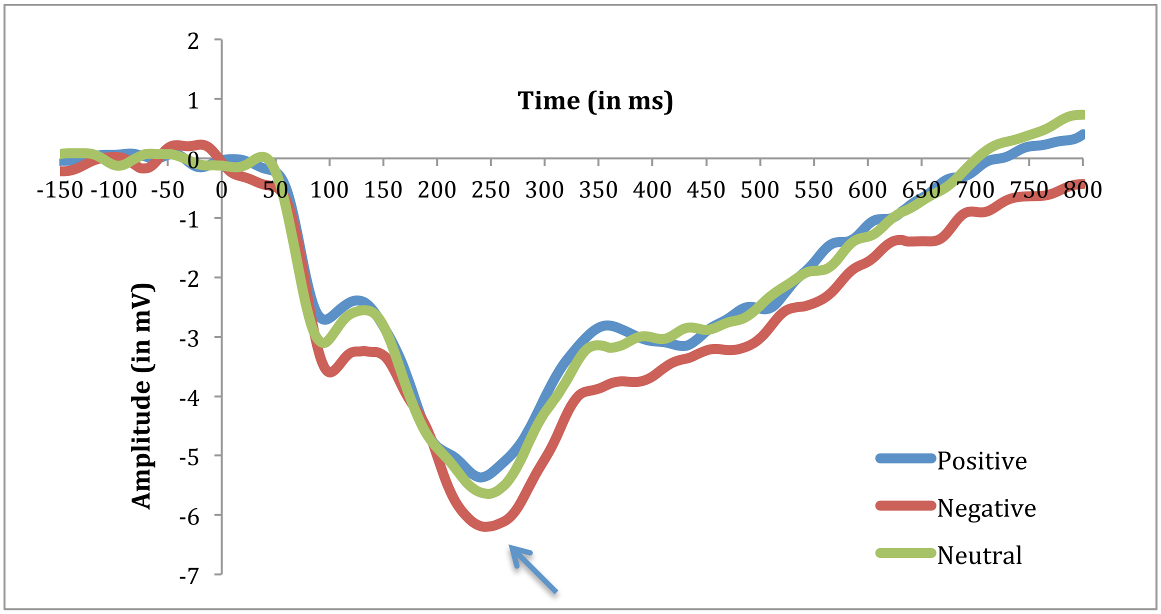


Figure 6. Grand average ERP by valence (N2 montage). N2 was measured between 200 - 350ms. P2 is hypothesized to occur around 160 - 190ms (Feng et al., 2014), though a positive component is not apparent at that time window.

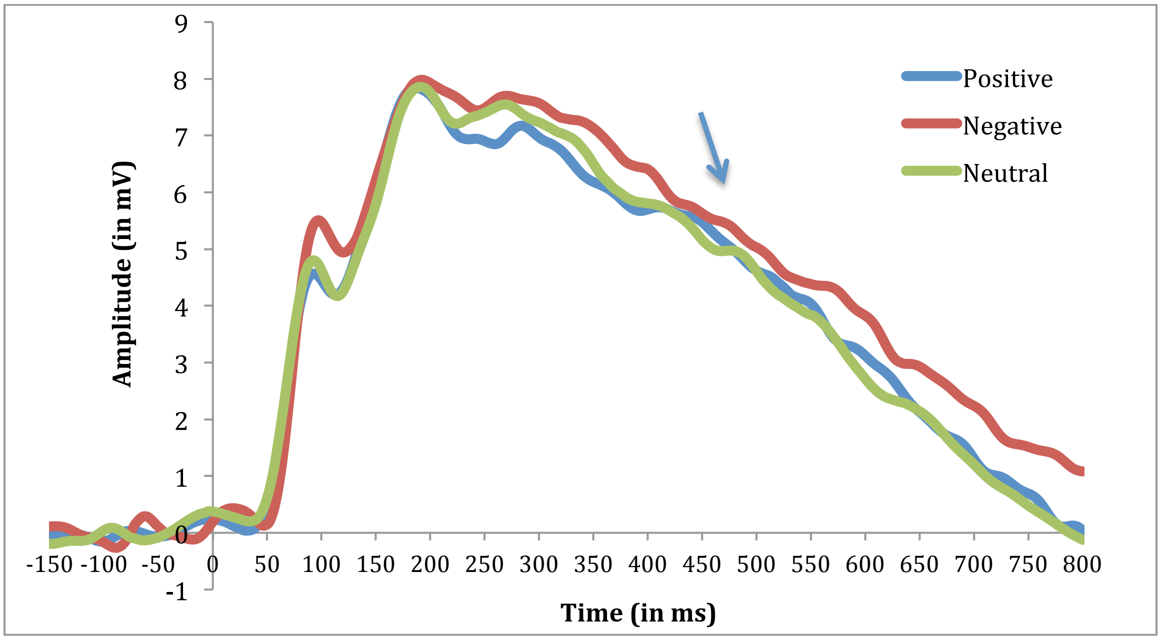


Figure 7. Grand average ERP by valence (LPP montage). LPP component abstracted between 450 - 800ms.

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APPENDICES

Appendix A: IAPS Pictures Used for Each Condition

Table A1. IAPS pictures used for emotional memory paradigm by valence and arousal categories

Valence	**Arousal**	**N**	**IAPS Pictures Used**
Positive	Low	25	1460, 1600, 1441, 1630, 1750, 1812,1900, 2299, 2302, 2222, 2151, 2360, 2388, 2530, 4616, 5001, 5600, 5760, 2217, 5781, 5890, 7280, 7325, 7350, 7580
	High	25	1710, 2045, 2216, 7405, 4542, 4626, 4640, 5621, 5626, 8001, 8030, 7650, 8080, 7502, 8178, 8158, 8186, 8200, 8370, 8116, 8470, 8490, 8496, 5480, 8501
Negative	Low	25	2206, 2312, 2399, 2490, 4233, 9001, 9435, 2722, 2752, 9440, 7046, 7700, 9000, 9101, 2750, 9342, 2205, 9471, 2900.1, 9220, 9280, 6311, 9290, 9390, 7078
	High	25	1019, 1120, 1201, 1270, 1300, 1321, 1930, 3019, 3022, 3160, 3400, 5971, 9160, 6230, 6550, 6570.1, 6821, 6831, 8480, 9810, 9300, 9326, 6020, 9622, 9909
Neutral	Low	25	1560, 1645, 1122, 1390, 7560, 2122, 2309, 3550.2, 8466, 7077, 7477, 6930, 8211, 8065, 9150, 9468, 8117, 8250, 5455, 7211, 8620, 9582, 7497, 8060, 2616
	Neutral	25	1675, 1947, 2034, 2272, 2489, 4325, 2521, 2308, 2635, 2575, 7285, 7365, 7018, 5661, 8121, 2359, 5535, 2690, 7504, 7595, 7506, 9401, 7081, 1616, 5040

Note: International Affective Picture System = IAPS; IAPS picture numbers refer to the original item numbers given by Lang, Bradley, and Cuthbert (1997).

Appendix B: Piloting Procedures and Adjustments to Methods

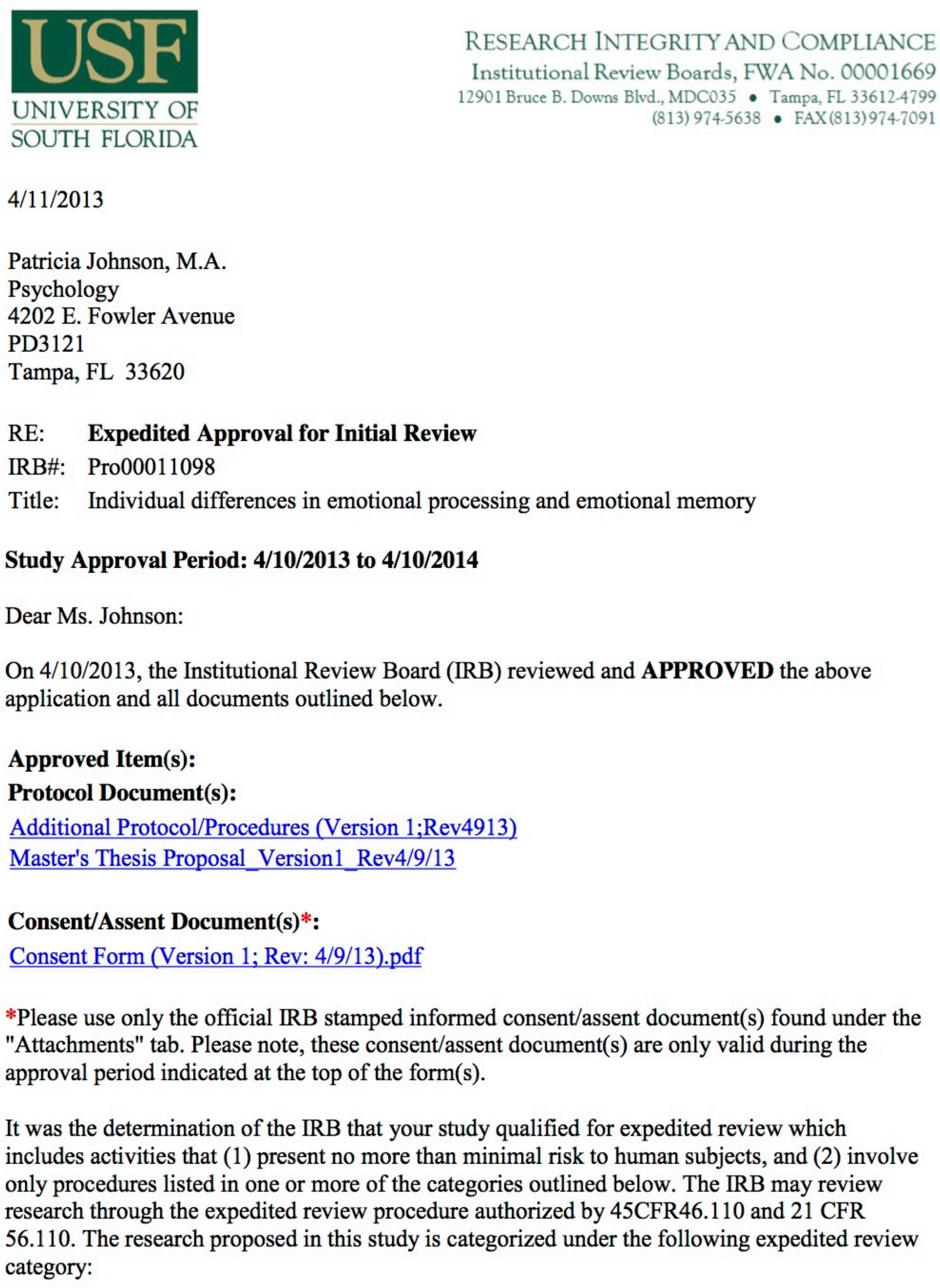
Initial piloting was conducted using just behavioral data on 5 undergraduates. After consent, participants completed all procedures except for the application of the EEG net and initiation of EEG software. Subjects were informally told that this was the initial phase of the study and were asked about the burden of the tasks. None expressed concern, with some even indicating the tasks were easy and fun. Changes based on the piloting are outlined below:

- It was discovered that participants were still writing answers after 5 minutes for the free recall. After two occurrences, the examiner extended the time to 10 minutes and asked the subjects if they were given too much time. Subjects indicated that they were just running out of answers and believed the time limit was sufficient.
- Subjects were initially given unlimited time to rate valence and arousal. However, it was discovered that this lead to variable exposure time for images. After piloting was conducted, this was changed so that images were displayed for 4 seconds, then subjects were given 3 seconds to rate valence, then 3 seconds to rate arousal.
- The study duration was found to be around one and a half hours.

After producing a semi-final product, research assistants and graduate students were asked to complete the task and provide feedback on challenges and improvements.

- It was suggested that a more interactive instruction set would be helpful. As such, button presses and verbal responses were added to keep subjects focused during the initial instructions about rating valence and arousal.
- It was suggested that demonstration items be used. An initial item in which subjects were given as much time as needed to rate valence and arousal was added, followed by three items (one from each valence category), which were presented with a set allowed response time were added.
- Duration of response time during encoding was extended from 3 to 4 seconds as the students felt this was too quick, especially for the initial items.

Appendix C: Institutional Review Board Approval for Study



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4/11/2013

Patricia Johnson, M.A.
Psychology
4202 E. Fowler Avenue
PD3121
Tampa, FL 33620

RE: **Expedited Approval for Initial Review**
IRB#: Pro00011098
Title: Individual differences in emotional processing and emotional memory

Study Approval Period: 4/10/2013 to 4/10/2014

Dear Ms. Johnson:

On 4/10/2013, the Institutional Review Board (IRB) reviewed and **APPROVED** the above application and all documents outlined below.

Approved Item(s):
Protocol Document(s):
Additional Protocol/Procedures (Version 1;Rev4913)
Master's Thesis Proposal_Version1_Rev4/9/13

Consent/Assent Document(s)*:
Consent Form (Version 1; Rev: 4/9/13).pdf

*Please use only the official IRB stamped informed consent/assent document(s) found under the "Attachments" tab. Please note, these consent/assent document(s) are only valid during the approval period indicated at the top of the form(s).

It was the determination of the IRB that your study qualified for expedited review which includes activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45CFR46.110 and 21 CFR 56.110. The research proposed in this study is categorized under the following expedited review category:

(4) Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing.

(6) Collection of data from voice, video, digital, or image recordings made for research purposes.

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval by an amendment.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

Kristen Salomon, Ph.D., Vice Chairperson
USF Institutional Review Board

Appendix D: **Instructions Given Prior to Encoding Presentation**

(Adapted from original IAPS instructions during normative trials)

In this study, we are interested in how people respond to pictures that represent a lot of different events that occur in life. You will be looking at different pictures projected on the screen in front of you, and you will be rating each picture in terms of how it made you feel while viewing it. There are no right or wrong answers, so simply respond as honestly as you can.

If you'll look at the demonstration sheet in front of you, you will see 2 sets of 5 figures, each arranged along a continuum. We call this set of figures SAM, and you will be using these figures to rate how you felt while viewing each picture. You will make both ratings for *each* picture that you observe. SAM shows two different kinds of feelings: Happy vs. Unhappy and Excited vs. Calm.

You can see that each SAM figure varies along each scale. In this illustration, the first SAM scale is the happy- unhappy scale, which ranges from a smile to a frown. At one extreme of the happy vs. unhappy scale, you felt happy, pleased, satisfied, contented, or hopeful. If you felt completely *happy* while viewing the picture, you can indicate this by selecting the number 9 (point to 9 on SAM). Please press the number nine key on the keypad. The other end of the scale is used if you feel completely unhappy, annoyed, unsatisfied, gloomy, despaired, or bored. You can indicate feeling completely *unhappy* by selecting the figure to the right, which is number 1. Please press the number one on the keypad. The figures also allow you to describe intermediate feelings of pleasure, by selecting any of the other numbers. If you feel completely neutral, neither happy nor unhappy, select the number 5, which corresponds to the figure in the middle. Please press the number five on the keypad. If, in your judgment, your feeling of pleasure or displeasure falls *between* two of the pictures, then select the number that represents the space between two figures, such as the number 6. This permits you to make more finely graded ratings of how you feel in reaction to the pictures.

The excited vs. calm dimension is the second type of feeling displayed here. One extreme of the scale indicates feeling stimulated, excited, frenzied, jittery, wide-awake, or aroused. If you felt completely *aroused* while viewing the picture, which would you select? That's right, you would select 9. At the other end of the scale, if you feel completely relaxed, calm, sluggish, dull, sleepy, or unaroused, which would you select? That's right, you would select 1. As with the happy- unhappy scale, you can represent intermediate levels selecting any number in between 9 and 1. If you were not at all excited nor at all calm, which would you select? That's right, you would select five. Again, if you wish to make a more finely tuned rating, you may choose a number such as the number 6.

Some of the pictures may prompt emotional experiences; others may seem relatively neutral. Your rating of each picture should reflect your immediate personal experience, rate each one *AS YOU ACTUALLY FELT WHILE YOU VIEWED THE PICTURE*.

In this experiment, you will see a picture displayed for several seconds. After you see this image, you will be asked to make a rating on both scales. Please watch the screen for a demonstration item. (Show demonstration item, hit "s"). If needed, prompt: 'Please rate the picture on the happiness/unhappiness dimension', then 'Please rate the picture on the excited/calm dimension' *Read remaining directions on screen, instruct the participant to keep her hands over the key pad so she can respond quickly.*

REMIND THE PARTICIPANT TO KEEP HER HAND OVER THE KEYPAD