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Emotional Memory: Examining Differences in Retrieval Methods

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Emotional Memory: Examining Differences in Retrieval Methods

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Each person whose signature appears below certifies that this dissertation in his/her opinion is adequate, in scope and quality, as a dissertation for the degree Doctor of Philosophy.

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ABSTRACT OF THE DISSERTATION

Emotional Memory: Examining Differences in Retrieval Methods

by

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Emotional information is generally remembered better than non-emotional information, especially when the emotional information is highly arousing. Priority Binding Theory has grown out of several years worth of research on memory and emotion. The theory proposes that in mixed lists comprised of negative and arousing words and neutral words, negative and arousing words will take priority during mental processing resulting in stronger encoding for the emotional words relative to neutral words with no such effect predicted for pure lists. Our lab made several attempts to extend the theory to picture stimuli, but were unsuccessful. However, the predictions of Priority Binding Theory were tested using recall, while studies in our lab have used recognition as a retrieval method. Research suggests that retrieval processes may be distinct and affected differently by various factors. Therefore, the current study manipulated retrieval methods, recognition and recall, to determine if the predictions of Priority Binding Theory were retrieval dependent. Results showed an overall increase in accuracy for negative images versus neutral images. The degree of accuracy for negative versus neutral images differed by retrieval method, with the difference between accuracy for negative versus neutral information greater in recall formats. In terms of retrieval method, recognition accuracy showed ceiling effects and no effect of list type was observed, but in recall significant differences were observed between negative and neutral stimuli in mixed lists and no significant differences observed between pure negative and pure neutral lists. The present results supports the predictions of Priority Binding Theory.

CHAPTER 1

INTRODUCTION

Emotional experiences are powerful and tend to leave a lasting impression on memory. Memories created in response to highly arousing and emotionally charged events are called flashbulb memories and are associated with both greater subjective vividness and a more durable memory trace than non-emotional memories. Examples of flashbulb memories include tragic and historic days such as the assassination of Martin Luther King Jr. and the Twin Tower attacks on September 11, 2001. Those who lived through these experiences, or merely watched them on television, can recall where they were and what they were doing on these days with vividness. Emotions experienced during the creation of flashbulb memories enhance overall memory in comparison to memory for neutral events.

Emotional enhancement of memory, however, is neither linear nor well-understood phenomenon. At low arousal levels memory can be impaired, at medium levels it can be facilitated, and at high levels it can be harmed. In the case noted above, people viewing the incidents at home may experience enhanced emotional memory for events occurring that day. However, in the case of people who directly experienced the events, the intense emotional and arousing experience may impair memory. This same phenomenon operates for soldiers deployed in war zones who face life-and-death events. Not only does the intense emotional and arousing experience impair memory, but their subjective experiencing of vivid memories can also cause severe psychological distress and diminish their functional abilities, in addition to reducing their overall quality of life. Why does arousal impair memory at certain levels and enhance it at others? What are the factors associated with the creation of enhanced emotional memory? What are the basic steps involved in the creation of emotionally enhanced memory? Unfortunately, little is known about the specific steps involved in the creation of enhanced emotional memory, elements that are necessary to facilitate memory, or what leads to emotional impairment of memory (Reisberg & Hertel, 2003).

Research has pointed towards emotion's involuntary ability to capture attention as the basis for enhanced memory (Anderson, 2005; Bradley, 2009; Mather & Nesmith, 2008; Potter, Wyble, Pandav & Olejarczyk, 2010). Specifically, emotional stimuli possess the adaptive advantage of attracting attention and diverting mental resources to emotionally salient environmental information (Bradley, 2009). This results in enhanced processing of the stimuli. It is the enhanced processing of emotional information that leads to facilitated memory. Donald MacKay's Priority Binding Theory of emotional memory grew out of the phenomenon of flashbulb memories and an understanding that enhanced processing of emotional information over neutral information results in superior memory for emotional information in comparison to neutral information (McKay & Ahmetzanov, 2005). To test the theory that emotional stimuli experience enhanced processing relative to neutral stimuli, taboo and neutral words were presented in mixed and pure list format. In mixed lists, taboo words were shown to capture attention resulting in enhanced processing and memory (Hadley & MacKay, 2006; MacKay & Ahmetzanov, 2005; MacKay et al., 2004).

Taboo and neutral words may not have much generalizability to traumatic events in the real world. Extending the theory to picture stimuli is necessary because pictures may more accurately simulate highly emotionally arousing real-world events.

Nevertheless, prior attempts by our lab at extending Priority Binding Theory to picture stimuli have been unsuccessful. Design format, presentation rate, and list lengths were manipulated, but only trended toward significance. Our previous studies, however, used only a recognition retrieval format, while the original McKay study used free recall to test memory. It is possible that the retrieval format used to test memory in the previous studies influenced the results. Specifically, recognition memory is an easier process than recall because the cue is physically present. In fact, because accuracy is so high in recognition formats, it is often used as an embedded measure of performance validity in psychological evaluations. To determine if the predictions of Priority Binding Theory can truly be extended to picture stimuli, it is important to manipulate retrieval method. Therefore, I aim to examine the impact of emotional content, context and retrieval format on memory formation.

CHAPTER 2

LITERATURE REVIEW

Priority Binding Theory

The subjective experience of emotion is powerful: it tends to influence memory in a way that makes a person feel as if a particularly emotion-charged and arousing event has been burnt into his or her mind. These still-shot, or flashbulb, memories are experienced as being vivid, clear, detailed, and encoded with specific perceptual features. In terms of real world functioning, individuals who have created a flashbulb memory can recall specific events that took place during the arousing situation. For example, most people can recall where they were and what they were doing when the Twin Towers were attacked on September 11, 2001. Research regarding the accuracy and durability of this type of episodic memory has produced conflicts with respect to the accuracy of and resistance to decay of flashbulb memories (Christianson, 1989; Neisser & Harsch, 1992). Priority Binding Theory grew out of this dispute and represents the experimental analogue of flashbulb memories.

Donald MacKay and others believed there was a qualitative difference in processing highly arousing and emotional versus non-emotional information (MacKay et al., 2004). As a result of much experimentation with emotional versus non-emotional information, they proposed a theory of emotional memory called Priority Binding Theory. Briefly, binding in memory refers to the creation of neuronal links in the brain that are created when a series of neurons in various parts of the brain are concurrently activated. These neuronal associations, through reactivation, come to represent memory traces (Shimamura, 2002). Priority Binding Theory states that taboo words presented rapidly and sequentially with neutral words will interrupt encoding of nearby neutral words. Taboo words were focused on as opposed to negative words and positive words because both positive and negative words lacked sufficient arousal levels needed to activate brain regions involved in emotional processing (Hadley & MacKay, 2006). The fast presentation rate is believed to facilitate enhanced emotional memory for negative over neutral words (Buchanan, Etzel, Adolphs, Tranel 2006; Guillet & Arndt 2009; Kensinger & Corkin 2003; MacKay, Ahmetzanov 2005). With rapidly presented material, the mind has only a brief period of time to process information. Negative information represents urgent information that may be critical for survival, and therefore takes priority in mental processing. Focused attention on negative information leaves little time and resources to be devoted to temporally adjacent neutral information. Therefore, by the time a negative stimulus has been fully processed and encoded, the neutral stimulus, though registered, will have been presented and passed. Since the physical neutral stimulus is not available for the mind to process once resources are freed up, resulting memory traces for this information will be weaker due to incomplete and/or poorer quality of processing. This results in better accuracy for taboo words versus neutral words. However, if taboo words and neutral words are presented separately in homogenous lists, (i.e., lists composed only of taboo or neutral words) no memory advantage is proposed to occur because lists consisting of equivalent salience do not demonstrate inter-item competition for attention and encoding resources (Hadley & MacKay, 2006). Again, it is the relatively greater emotional significance of a word that leads to priority processing over less emotionally significant words. MacKay was able to show a memory advantage for taboo versus neutral words in mixed lists and no memory advantage in either the pure taboo or pure neutral word lists (MacKay & Ahmetzanov, 2004; Hadley & MacKay, 2006).

Over the past few years, work in our lab has focused on extending Priority Binding Theory from verbal stimuli to picture stimuli. Our previous studies, however, have not been able to replicate the results shown by McKay. First, we believed that study design influenced the results. Specifically, presenting multiple lists of pictures in one study without using a non-related distractor task to separate the lists was believed to cause mass encoding of all lists into one super list, thus obscuring the results. However, controlling for this design element did not produce significant changes. Priority Binding Theory was re-examined. Again, the theory specifically stresses temporal pressure in finding emotion-enhanced effects. In response to this concern, presentation rate was manipulated to ensure enough temporal stress was placed on the processing system for each participant. Results trended toward significance, but the effect was weak. Currently, one factor still needs to be examined in order to definitively say that the predictions of Priority Binding Theory can or cannot be extended to picture stimuli. Specifically, the original studies tested participant memory using recall as the retrieval method while previous studies in this lab have used tests of recognition to assess memory. It is possible that the weaker effect is due to differences in retrieval methods used, which are associated with different process and will be elaborated upon later in the paper.

Varying Dimensions of Emotional Stimuli: Valence and Arousal

Human beings communicate through both verbal and visual modalities. However, Priority Binding Theory is heavily focused on emotional processing and memory of verbal information. Particularly, it is proposed that the lexical component of a taboo word and its resulting emotional reaction connect, or “bind,” the word to when it occurred in time or where it physically occurred in space. Both the “when” and “where” of occurrence are referred to as the “episodic context of occurrence” taboo words bind to. Unlike neutral words, emotional reactions evoked from taboo words activate the amygdala in addition to other structures involved in learning and memory (brain structures involved in memory will be discussed later in the paper) resulting in an extra pathway of encoding that produces immediate reaction to the taboo word (Hadley et. al., 2004). Behavioral results from MacKay’s studies support superior encoding and memory of taboo words, as do anecdotal reports. For example, offensive, inappropriate and lewd remarks are vividly remembered despite varying contexts. It would seem logical that the semantically driven theory could apply to visual contexts and stimuli. Making such an experimental comparison would further support the superior subjective experience associated with flashbulb memories.

To provide the visual analogue to Priority Binding Theory, visual stimuli needed to be selected. The International Affective Picture Systems (Lang, Bradley, & Cuthbert, 2005), or IAPS, was chosen because arousal and valence levels can be controlled for and large numbers of pictures can be shown in a relatively short amount of time. Additionally, normative ratings are available for IAPS pictures, along with both arousal and valence dimensions. This is extremely useful because visual stimuli can be chosen to equate the highly charged nature of taboo words. To help understand how this is so, a brief review of the multiple dimensions of emotional stimuli is warranted.

Valence and Arousal

Emotional stimuli, verbal or visual, can be described within a two dimensional space of valence and arousal. Valence ranges from negative/unpleasant to positive/pleasant, while arousal ranges from and low/calm to high/active/energized. Neutral stimuli tend to be low in arousal, while positive and negative stimuli tend to be high in arousal resulting in a 'boomerang' shaped distribution of emotional stimuli within affective space. It is important to clarify which dimensions one is measuring when describing emotional material. With regards to Priority Binding Theory, taboo words were chosen because they are highly arousing. Negative words lack the powerful arousal level needed to activate the amygdala. Neutral words do not confound results and serve as a perfect control because they lack arousing properties that highly arousing positive words have. To provide a study truly parallel to original MacKay studies, pictures were chosen that equated to taboo words (MacKay & Ahmetzanov, 2004; MacKay, Ahmetzanov 2005; Hadley & MacKay, 2006). Therefore, highly arousing and negative images served as the visual counterpart to taboo words, while neutral pictures served as the visual counterpart to neutral words.

Research supports the influence of arousal and valence on memory enhancement, though arousal has been found to play a more dominant role in the effect (Bradley, Greenwald, Petry & Lang, 1992). As previously noted, when taboo words, negative words and neutral words are used in studies of memory, taboo words, which have the highest arousal value, are recalled and recognized better than negative words, while negative words are better recalled or recognized than neutral words (Buchanan, Etzel, Adolphs, Tranel, 2006; Kensinger & Corkin, 2003; Zeelenberg, Wagenmakers, Rotteveel, 2006). Valence's contribution to emotion enhanced episodic memory, however, is less straightforward. Though valence in general has been found to contribute to the enhancing effect, it is unclear if positive or negative valence plays a larger role than arousal because of the confound in which extreme valence, positive or negative, tends to be associated with high arousal. Some studies suggest that negative stimuli are remembered better than positive stimuli (Kensinger, Garoff-Eaton, & Schacter, 2006; Kensinger, Garoff-Eaton, & Schacter 2007), while others suggest that negative and positive stimuli do not significantly differ (D'Argembeau & Van der Linden, 2005).

Understanding that valence and arousal influence memory, though important, provides only partial information about the multicomponent process of emotionally enhanced memory. To better understand how emotion affects memory, a general overview of the structure of memory, emotional memory and the structures supporting each is warranted. An overview of memory is important in examining different memory processes and how they are differentially impacted by experimental manipulation. Specifically, I believe that differences in retrieval processes, as supported by distinct neuroanatomical structures and distinct behavioral findings, will produce different effects on emotional memory.

Memory, Emotional Memory and Neuroanatomy of Memory

Brief Overview of Memory Components

In general, memory can be thought of as the ability to recall information or experiences (Ledoux, 1993). Several processes are involved in memory, including attention, encoding, consolidation and retrieval. Memory is also broken down into several different types, including perceptual memory, short-term/working memory and long-term memory. Perceptual memory represents all external stimuli available to be processed by the brain. Short-term/working memory allows information to be held in the mind to be manipulated. As the name implies, it is not kept in memory for a long time. Information that is held in memory is referred to as long-term memory and it is divided into two different components: implicit and explicit/declarative memory. Implicit memory is composed of unconscious procedural learning and priming abilities. An example of implicit memory is learning to ride a bike. Explicit memory, in contrast to implicit memory, involves conscious awareness of learned information.

Both implicit and explicit memory can also be further broken down into multiple subcomponents of memory. As stated before, implicit memory is composed of procedural memory and priming abilities that govern our ability to remember how to perform procedures or other non-conscious events. Explicit memory, however, is divided into semantic and episodic memory. Semantic memory involves our ability to memorize factual information and episodic memory represents our memory for autobiographical events and the contextual details associated with those events. Priority Binding Theory focuses specifically on episodic memory. Again, testing Priority Binding Theory in labs provides for a controlled environment to assess memory of an emotionally charged episode.

The Process of Memory

The initial process of memory begins with attention. Attention focuses mental energy on a particular perceptual stimulus (visual, auditory, etc.) allowing its representation to be active for cognitive processing (Jonides et al., 2008). Next, the perceptual stimulus is encoded, or converted into a mental representation. The information is kept active in mental focus through a process called maintenance. Short-term/working memory comprises these early phases of memory. Information is highlighted, encoded and held in memory long enough to be manipulated. Short-term memory is limited in capacity and duration, meaning that only a limited amount of information can be held in memory for a brief period of time. New information can be transferred into long-term memory through a process called consolidation. Rote memory processes such as rehearsal can keep information in memory, but deeper levels of processing such as associating new information with previously learned information help move new information into a durable memory trace. Bringing mental representations, or long-term memories, back into cognitive focus is accomplished through a process called retrieval. Retrieval includes recall and recognition components; these processes will be expanded upon later in the paper.

The processes involved in memory differ for implicit and explicit memory and correspond to different brain structures. Implicit memory corresponds to structures such as the basal ganglia and cerebellum, while explicit memory corresponds to areas associated with the medial temporal lobe. The following section will expand upon structures associated with non-emotional and emotional memory, and later in the paper structures associated with retrieval will be reviewed. Understanding the circuitry of memory and emotional memory will aid in understanding a later discussion in this paper about how emotion and the use different retrieval methods may influence the results of memory tests using emotional pictures.

Neuroanatomy Non-Emotional Memory

There are several brain regions and specific brain structures involved with different aspects of non-emotional memory and retrieval including the occipital lobe, the parietal lobe, frontal lobe, brainstem, and the medial temporal lobe (Zola-Morgan & Squire, 1993). The occipital lobe is involved in recognition. Specifically, the visual cortex receives information, which is processed via two streams: the ventral and dorsal stream. The ventral stream, or "what stream," deals with object recognition and representation, while the dorsal, or "where stream," deals with recognition of objects in space and aids in guiding action (Goodale & Milner, 1992). The parietal lobe is also involved in memory. Damage to this area, specifically the supramarginal gyrus, has been associated with short-term memory problems. The parietal lobe is also important in helping people attend to multiple stimuli at the same time (Cowan & Nelson, 2005). Working memory, or active manipulation, and organization of information, is associated with frontal lobe functioning.

The most important brain areas associated with memory are the medial temporal lobes (MTL) (including the hippocampus, entorhinal and perirhinal corticies), basal forebrain, and diencephalon. The MTL is associated with declarative memory, both episodic and semantic, and recognition memory, or identifying recently encountered information (Kolb & Whishaw, 1990). The hippocampus is a structure vital for memory consolidation. Human lesion studies support the role of the hippocampus in the formation and consolidation of short-term memories into long-term memories. Patient H.M., for example, had a bilateral temporal lobectomy to treat epilepsy, which resulted in the removal of his hippocampus. Following the procedure, H.M. was unable to consolidate new events into long-term memory, but implicit memory was spared (MacKay et al., 2004).

The diencephalon and basal forebrain have also been found to play a role in memory. The diencephalon is composed of the thalamus and hypothalamus (Reisberg & Hertel, 2004). Damage to this area produces significant memory impairments (Piekema, Fernández, Postma, Hendriks, Wester, & Kessels, 2007). Finally, the basal forebrain also plays a critical role in memory, as it serves as the primary source of cholinergic innervation to cortex. It consists of the septal nucleus, nucleus basalis of Meynert, substantia innominota, and the amygdala.

Neuroanatomy of Emotional Memory

Emotional memory is the enhanced encoding and memory of emotional stimuli in comparison to neutral stimuli (Reisberg & Hertel, 2004). Neurocognitive, animal studies, and human lesion studies all suggest that emotional memory involves the activation of both non-emotional memory structures and additional structures recruited during non-emotional memory (LeDoux,1993; Phelps, 2004; Hamann, Cahill, McGaugh, & Squire 1997; Papez, 1937). Emotional memory includes the thalamus, hypothalamus, cingulate cortex, hippocampus, basal gangli, and frontal cortex (Papex, 1937). However, the structure cited as being vital for emotional memory is the amygdala, which modulates all aspects of emotional memory (Cahill, Babinsky, Markowitsch, & McGaugh, 1995; LeDoux,1993; LeDoux,1994).

The importance of amygdala functioning in emotion and behavior began with studies on rhesus monkeys (Bucy & Kluver, 1938). Following the removal of the bilateral temporal lobes, the rhesus monkeys were found to display drastically diminished fear and anger responses in addition to hyper orality, hyper sexuality and other symptoms. This set of symptoms became known as Kluver-Bucy syndrome (Bucy & Kluver, 1938) and has been noted in individuals with bilateral temporal lobe injury/disease. It is the amygdala's vast connections to critical brain areas that allows for alteration of physiological responding, and alteration of learning and of memory. The amygdala is centrally located between critical input and output relay pathways. LeDoux (1994, 1995) has played an integral role in describing these pathways in emotional functioning. One pathway consists of a sensory pathway to the thalamus, through which information is relayed to sensory cortices and finally to the amygdala. The other pathway goes from sensory pathways to the thalamus and shortcuts directly to the thalamus. The former pathway involves a circular-like flow of information around the brain and finally to the amygdala (LeDeoux, 1994; Papez, 1937). The resulting information sent to the amygdala is rich in sensory information, such as visual and auditory information, that allows for accurate recognition and perception, but the added pathways slow down processing speed. The latter pathway provides crude sensory information about potential threats of information of significance, but its direct connection to the amygdala, minus connections through sensory cortices, allows for quick and direct transmission of information to the brainstem thus allowing for quick responding in the face of threat. Amygdala connections place it in a prime location for modulating behavior, learning, and memory (LeDeoux, 1994).

The amygdala's rich brain connections are what aid in its diverse role in behavior and cognition. Its projections to other brain areas help modulate cognitive processes like learning and memory. The amygdala is an almond-shaped structure found bilaterally in the medial temporal lobe. It consists of four nuclei: the central, lateral, basal and accessory nuclei. Each nucleus receives information from different parts of the brain and sends the information to the other nuclei in the amygdala to integrate the information. For example, the lateral nucleus receives sensory input from the thalamus, cortex, and hippocampus. It then relays this information to the remaining nuclei in the amygdala (the central, basal and accessory nuclei). The central nucleus, then, receives input from all three nuclei and sends this information to the brainstem, which is associated with the expression of autonomic conditioned responses (LeDoux, 1995; (Zola-Morgan & Squirr, 1993)). Specifically, the amygdala projects to the parabrachial nucleus allowing for increased respiration, the ventral tegmental area allowing for behavioral arousal and increased vigilance, and the reticular formation, which allows for increased reflex and startle responses. In essence, the amygdala connects to areas critical to sympathetic responding. Activation of the amygdala helps trigger physical responding and modulates emotional learning. In particular, fear conditioning has been found to be associated with amygdala activity. Gazzaniga et al. (2002) showed a participant with bilateral amygdala damage and normal controls neutral symbols (i.e., shapes), with certain neutral symbols being followed by a shock on the wrist. The symbols preceding the shock were the conditioned stimuli (CS), the shock represented the unconditioned stimulus (US), while a fear response as measured by increased skin conductance represented the unconditioned response (UR). CS/US pairing typically results in the CS alone producing a fear response (now labeled a CR). However, the participant with amygdala damage failed to show a CR suggesting that she failed to learn the association between the CS/US. Again, this study highlights the important modulatory role of the amygdala in cognitive and emotional functioning.

The amygdala also plays a role in higher order cognitive functioning. Studies on amygdala damage have informed researchers about the areas of cognitive functioning influenced by the amygdala. The amygdala sends and receives input/output from several brain structures implicated in higher cognitive functioning such as the sensory cortices, hippocampal formation (important for memory consolidation) and the prefrontal cortex (important for attention, planning, and other executive functioning; Phelps, 2006). Specifically, consolidation of emotional memory is affected by amygdala-hippocampal activity. In humans, damage to the medial temporal lobe causes not only memory problems, but also problems recalling the emotional aspects to memories. Patient B. P., for instance, suffered from Urbach-Wiethe disease (Lipoid proteinosis), which is a rare autosomal recessive disorder characterized by a hoarse voice and dry and easily damaged skin that heals poorly. The disease process also caused bilateral calcification and atrophy of B. P.'s amygdala. As a result of the bilateral amygdala damage, B.P. experienced deficits in judging intensity of fearful faces and displayed emotional-memory problems (Cahill, 1995; Papez, 1937). In assessing her memory, B. P. was told a graphic and emotional story along with an unemotional story. Normal control subjects were also given the same stories. Memory for the emotional story was enhanced for the normal control subjects in comparison to the neutral story. However, B. P. failed to show enhanced memory for the emotional story, illustrating the important modulatory affect the amygdala plays in emotional consolidation of memories.

It is the hippocampus that is associated with consolidation of memories, but the amygdala functions to add the emotional flavor to memories (Reisberg & Hertel, 2004).

Damage to the amygdala prevents not only prevents formation of the association between the CS/US in fear conditioning, but also prevents memory consolidation of the emotional content of an event. Hamann, Cahill, McGaugh, and Squire (1997) assessed declarative emotional memory in three groups of amnestic participants: hippocampal damage only, amygdala and hippocampal damage, and diencephalon damage only groups. They found that hippocampus and diencephalon damage alone leaves emotional enhancement of declarative memory intact. However, those with hippocampal and amygdala damage showed no emotional memory enhancement, further illustrating the correlation between amygdala and hippocampal activity in emotional consolidation of memory.

Emotional arousal has been found to alter most memory functions such as perception, attention, encoding, consolidation and retrieval (Easterbrook, 1959; Phelps, 2005). The frontal cortex plays a large role in attentional processes. It also shares many connections with the amygdala and is involved in emotional memory. The amygdala is thought modulate the attentional processes of the prefrontal cortex, which results in focused attentional resources to emotional stimuli and ultimately impacts encoding (Phelps, 2005). The dorsolateral prefrontal cortex is involved in encoding and retrieval, while the orbitofrontal has also been found to play a role in emotional memory. Sensory cortices also share connections with the amygdala and play a role in modulation of attentional processes. Evidence for the amygdala's modulatory role in attention and perception comes from attentional blink paradigms (Anderson, 2005; Potter, Wyble, Pandav & Olejarczyk, 2010). In this type of design, images are presented quickly and sequentially resulting in attentional blindness of images following target stimuli, which is called an attentional blink. Emotional images, however, are resistant to this phenomenon due to their ability to capture attention even under extreme time pressure. Amygdala damage has been found to impair normal attentional facilitation to emotional stimuli (Phelps, 2004).

Effects of Emotion on Memory

Thus far, discussion has centered on an overview of memory and physiological structures implicated in emotional memory. However, it is the intersection of these areas that is interesting both clinically and for research. How does emotion affect memory? Are the effects uniform? When does emotion begin to affect memory? Emotion actually begins to impact memory during the initial stages of processing. Emotion attracts attention and diverts mental resources to salient aspects of the environment through an involuntary process (Mather & Nesmith, 2008).

An example of emotional stimuli's ability to capture attention ability comes from work with attentional blink paradigms. In these tasks, stimuli are presented sequentially and rapidly. Typically, subjects are asked to focus on a specific stimulus. However, because the stimuli are presented so quickly subsequent stimuli are not perceived. Emotional stimuli presented in attentional blink tasks are more likely to be perceived (Anderson, 2005; Potter, Wyble, Pandav & Olejarczyk, 2010). Emotion's ability to attract attention has also been demonstrated through the emotional Stroop task. In this task, participants are asked to name the color of the print of emotional and non-emotional words. Word reading is the dominant response in this task, so increased color-naming time is expected. Color-naming time is longer for emotional words than non-emotional words, suggesting that emotional words produce a greater interference effect on attention

(Sharma & McKenna, 2001). The effect, however, is fragile and difficult to reliably replicate. Other factors contribute to emotional influences on attention. Increasing the arousal level of emotional stimuli has been shown to produce greater and more stable effects on attention. The taboo Stroop, for example, is essentially the same task as the emotional Stroop but it varies in terms of arousal level evoked by the stimuli. Taboo words are highly charged and evocative words. When presented in the Stroop task, longer color-naming time results (MacKay & Ahmetzanov, 2005). The taboo Stroop effect is more robust than the emotional Stroop. The differences in the strength of the effects on attention are due to arousal level. The effects of emotion on memory formation, however, are less clear.

The relationship between emotion and memory is not linear. In fact, the impact of arousal level follows an inverted U shape (Yerkes & Dodson, 1908). At lower levels of arousal, performance is attenuated because the individual is insufficiently aroused. Moderate levels of arousal, however, provide the optimal amount of internal tension eliciting enhanced performance. At the extreme end of the spectrum, performance is actually harmed by high arousal levels. Arousal-related effects on memory are believed to follow the same inverted U-shape, with better memory for moderate arousal levels and impaired memory for highly arousing situations (Bradley, Greenwald, Petry & Lang, 1992). To explain both arousal's impairing and facilitative effects on memory, Easterbrook (1959) proposed attention narrowing. The theory states that at high arousal levels harm memory for peripheral information (non-essential or non-focal information), but central information (i.e., information directly spatially, temporally or thematically related to the emotional event) is enhanced by emotion.

In general, research has shown that central information/stimuli benefit from emotional arousal. D'Argembeau and Van der Linden (2005) showed participants negative, positive and neutral pictures. Negative valence had the greatest effect on memory, with accuracy better for negative pictures over positive pictures. Positive pictures, however, demonstrated enhanced memory relative to neutral pictures. Though this study illustrates the enhancing effects of valence, arousal is believed to drive enhanced emotion. Several other studies assessing the central effect of emotion have found that arousal is the main factor influencing memory. Specifically, Zeelenberg, Wagenmakers and Rotteveel (2006) found that when positive, negative and neutral words were presented to participants, memory for emotional words was better than memory for neutral words. However, no differences were found in terms of valence. Arousal was the main factor cited as affecting memory enhancement. Similarly, Kensinger and Corkin (2003) found that participants more vividly remembered negative words over neutral words. To disentangle effects of valence, highly arousing taboo words, moderately arousing negative words and neutral words were also tested in the same study. Taboo words showed the greatest enhancement of both source and item over negative and neutral words. The authors of the study attributed enhanced emotional memory to arousal levels.

Impairment for emotional stimuli has been observed for peripheral information, or information not directly associated with the arousing event. A real-world example of attention narrowing, or harmed memory for peripheral information, comes from research on weapons focus (Loftus, Loftus, & Messo, 1987). Specifically, victims of crimes involving guns tend to report a narrowed focus on the weapon to the detriment of memory for the perpetrator's face or other environmental information, showing that emotional stimuli elicit narrowed attention leading to enhanced processing and consolidation, but the enhancement does not extend to information in close spatial or temporal proximity (Mather & Nesmith, 2008). For example, Mather et al. (2006) showed participants pictures varying from low to high arousal in different spatial locations. During the test phase, they were asked to determine if the pictures presented were in same spatial location that they were presented in during the study phase. Memory for picture spatial location was harmed as arousal levels increased. High arousal levels recruited attention to the arousing stimuli resulting in enhanced item memory for pictures, but harmed peripheral information (i.e., spatial location of the pictures) by preventing binding of non-central features of the pictures.

Emotional impairment for peripheral information, however, is not a universal finding. Guillet and Arndt (2009) presented a series of sentences containing taboo, negative, or neutral words. Participants conducted a cued-recall test consisting of incomplete study phase sentences. The participants were asked to fill the missing central word, which was either taboo, negative or neutral, and a peripheral word, which was always neutral. Recall for central and peripheral words were enhanced by high arousal, or exposure to taboo words. Many theories attempt to explain the conflicting effect of emotional arousal on memory, but the circumstances explaining memory enhancement are still poorly understood.

Priority Binding Theory, Emotion, and Memory

Priority Binding Theory is used to explain the effects of emotion on memory.

Taboo words used to test the predictions of Priority Binding Theory possess unique properties. Compared to negative words, taboo words possess the ability to evoke strong emotional reactions activating the autonomic nervous system (Buchanan, Etzel, Adolphs, & Tranel, 2006). Priority Binding Theory suggests that resource-limited mental processes orient toward threatening taboo words and involuntarily direct attention toward them (MacKay et. al, 2004). Though processing of neutral words is not disrupted, taboo words are more strongly bound to their context of occurrence, or the "where" and "when" of the event (again, this effect is limited to mixed lists). The resulting effect is enhancement in encoding for new emotional memories resulting in greater accuracy.

Normally, memory consolidation is associated with hippocampal functioning. However, in the case of memory for taboo words, the emotional reactions evoked recruit amygdala functions facilitating hippocampal functioning and aid overall binding mechanisms that create new memories (LeDoux, 1994). In other words, taboo words become linked to their context of occurrence. The extra pathways involved during encoding provide more retrieval paths, enabling enhanced recall of episodic details associated with taboo words (e.g., temporal and/or spatial locations).

It would seem that highly arousing pictures would be capable of eliciting the above effect. This logic, then, guided the use of highly arousing images in pasts studies because they were hypothesized to elicit strong emotional reactions. Similar study designs were used and many variables were manipulated in order to produce emotionally driven memory enhancement, but no such effect was found. Overall, memory for both negative and neutral stimuli was high overall and no significant differences between valences were found. It should be noted that ceiling effects were observed in overall accuracy on *recognition* tasks whereas the original study used recall to test memory. It is possible that the ease of recognition tasks, resulting in near perfect performance, obscured interaction effects of valence/arousal and list type. Therefore, it is important to rule out retrieval method as a possible confound by assessing performance differences resulting from the use of both recognition and recall formats. The following section will discuss how retrieval demands can possibly affect performance on memory tasks.

Retrieval Methods: Differences in Recall and Recognition

A Question of Kind or Degree

Is recall a distinct process from recognition? Commonsense would seem to point to recognition processes being easier than recall because the cue is physically present. Clinically, both intact and impaired patients perform better on tasks assessing recognition, unless motivational factors or severe neurological impairments are present (Montaldi & Mayes 2011; Schoenberg & Scott, 2011). The literature regarding recall and recognition is mixed regarding the separation of the two processes. In general, retrieval of information from declarative memory is a process that involves reactivation of associative links (Roediger, Dudai, Fitzpatrick & 2007). Two processes underlie retrieval: recall and recognition. However, there is much debate about defining these two processes and many theories have been proposed to describe the potential structure of each (Gabrieli, Brewer, Desmond, Glover, 1997; Squire, 1992; Squire & Wixted, 2011; Yonelinas, 1994). In general recall can be thought of as involving an active search of memory to pull information back into cognitive focus (Jonides et. al, 2008). Several theories, however, have been proposed to describe recognition, including dual-process theories (Atkinson & Juola, 1973; Yonelinas, 1994) and single process-theories of recognition (Squire & Wixted, 2011).

In single process models of recognition, the distinction between recollection and familiarity is attributed to be merely due to overall memory strength differences, with recollection consisting of the ability to retrieve strong, content rich memories and familiarity consisting of retrieval for weaker and non-specific memories. With regards to dual-process models, they suggest that recognition memory is composed of two processes called recollection and familiarity (Atkinson & Juola, 1973; Yonelinas, 1994). Recollection involves retrieval of episodic details and is believed to be a slow process similar to recall. An example of recollection is remembering the specific details of one's office, such as the size, color and placement of your desk and any object on top of it. Effective recollection requires considerable attention during *both* encoding and retrieval, and this process benefits from elaborative encoding. Familiarity, on the other hand, reflects a continuous index of memory strength (Ruggs & Yonelinas, 2003; Yonelinas, 2002). It is associated with a general sense of having encountered an object, is sensitive to perceptual changes occurring between study phases and test phases, and it occurs more rapidly than recollection. Underlying perceptual and implicit memory processes are believed to drive familiarity, which again are different processes than explicit memory processes. Though other dual-processing theories differ on what they believe supports the functioning of recollection and familiarity, they agree that these processes can be separated, occur in parallel to each other, and may possibly reflect underlying distinct memory processes, which are supported by distinct neuroanatomical structures (Montaldi & Mayes, 2011). The arguments for or against either the dual-process or single process models rely on combinations of neuroanatomical, behavioral performance and differences in calculation of performance data (Squire & Wixted, 2011).

Neuroanatomy and Behavioral Findings

Studies investigating neuroanatomical structures involved in recognition retrieval processes have shown that recollective and familiarity processes are differently impacted by disease and injury suggesting that these processes are indeed distinct (Yonelinas, 2002; Yonelinas, Kroll, Dobbins, Lazzara and Knight, 1998). Again, it is assumed that recollective processes are distinct from non-recollective processes, with recollective processes reflecting a conscious and explicit process and non-recollective, or familiarity, responses reflecting an unconscious and implicit memory process. Patients with temporal lobe lesions are able to make familiarity judgments about items presented in a list, but show memory impairments for recollective judgments due to their inability to retrieve contextual information and/or because they are unable to recall item membership from a specific list. Health participants show relatively intact performance across both recollective and familiarity responses (Yonelinas, 2002). It is believed that damage to the hippocampus results in impairments in recollection judgments while damage to the perirhinal cortex results in memory impairments for familiarity judgments (Yonelinas, Kroll, Dobbins, Lazzara and Knight,1998).

Behavioral results testing the assumption that recognition memory can be separated into discrete processes in amnestic patients are mixed, with some supporting dual-process theories and others disconfirming these models. In examining many of these studies, Yonelinas, Kroll, Dobbins, Lazzara and Knight (1998) noticed a large number of false alarm responses made by amnestic patients and wanted to use a model that accounted for bias. They used a dual-process signal detection model to re-analyze the data from several studies conducted on amnestic patients that assessed recognition memory. Briefly, signal detection theory provides a way to calculate a person's ability to discern the presence of a stimulus among noise, or extraneous stimuli. Typical hits, misses, correct rejections, and false alarms are obtained. Measures of *d'* allow investigators to determine how sensitive a person is at detecting the signal among noise, while *C* provides information about a person's propensity to answer either in the affirmative or negative.

Yonelinas et al. (1998) noted the need to incorporate a model that accounted for bias, as the data re-analyzed in the study had close to double the false alarm rates in amnestic compared to normal controls. They tested the theory that recollection and recognition were separate processes by fitting memory responses into receiver operating, or ROC, curves. ROC curves are particularly useful in helping to illustrate the differences between recollection and familiarity judgments because they allow for a graphic display of trade-offs between false alarm and hit rates. With ROC curves, false alarm rates are plotted along the x-axis and hit rates are plotted along the y-axis (Figure 1). A coordinate of (0,1) represents perfect sensitivity, while coordinates along a diagonal line represent random guessing. Coordinates to the right of the line represent more biased responses. Applied to the recognition memory tests, ROC curves depicting recollection and familiarity processes result in an asymmetrical, or upward-tilted, curve because recollection responses pushed hit rates up. The absence of recollected responses results in symmetrical curves around a diagonal line.

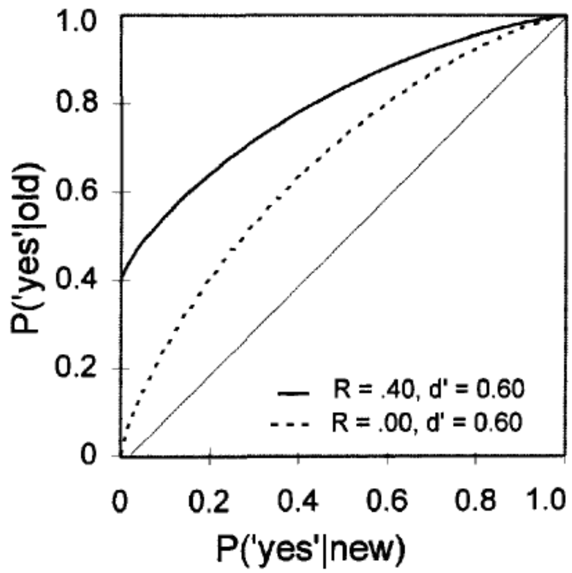

Figure 1. Two receiver-operating curves produced by the dual-process signal detection model, with the solid curved line representing both recollection and familiarity responses and the broken curved line showing familiarity responses only (Yonelinas et al., 1998).

Within the Yonelinas et al., (1998) study, amnestic participants were predicted to have a more symmetrically aligned curve along the diagonal because memory impairments would prevent the push up of hit responses on the curve, while normal controls were predicted to have the pushed-up asymmetrical curve. Indeed, the authors found that amnestic patients had symmetrical curves and healthy patients had asymmetrical curves (See Figure 2). These response patterns suggest that recognition is a distinct form of memory driven by two different processes.

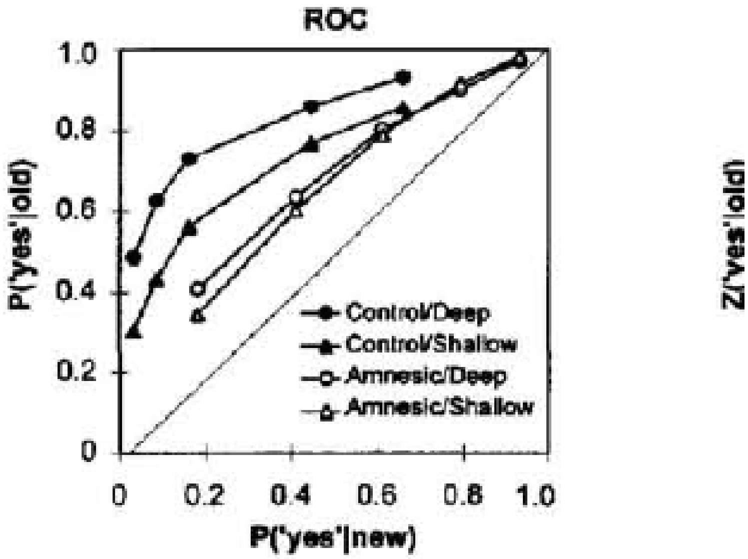

Figure 2. Recognition memory receiver operating curves (ROCs) for amnestic and healthy controls (Yonelinas et al., 1998).

Behavioral data in combination with neuroanatomical findings support the idea that retrieval processes are distinct processes support by two different pathways (Ruggs & Yonelinas, 2003). A common way to assess differing memory processes is to use an ‘R’ and ‘K’ memory task, where items are shown to an individual and s/he is asked to make memory judgments of either ‘R’ if s/he can recall specific aspects of the stimulus or ‘K’ if s/he feels that the stimulus is familiar. Henson (1999) performed this task in conjunction with fMRI scans of the brain and found parietal lobe activity only for recollection responses, supporting the separation of memory processes. Tsivilis et al. (2008) conducted a study on patients with damage to the fornix, a fibrous bundle that carries information from the hippocampus to the thalamus, to help investigate its role in episodic retrieval memory processes. Patients who endured colloid cyst removals from an area adjacent to the fornix were recruited along with healthy controls. Memory and cognitive status was assessed in each participant and fMRI scans of the brain were obtained. Fornix volume was obtained as well as mammillary volume, as an indirect measure of fornix damage (the fornix projects to the mammillary, which is isolated from other medial temporal lobe structures, so damage to the fornix would lead to mammillary atrophy). The authors found that participants with fornix damage performed worse on memory tasks than normal controls. They also found that volume loss of both the fornix and mammillary bodies was correlated with memory impairments. However, correlations for memory performance for tasks assessing recall and recognition were different for each structure. Six measures of recognition and three tasks of recall were administered.

It is also possible that discrepancies observed between recall and recognition may be due to task-related factors such as item type and list context. The word-frequency paradox effect lends support to this idea. Briefly, the word-frequency paradox refers to the fact that word stimuli are differently recalled or recognized depending on how frequently or infrequently the word occurs. High frequency words, or common words, are more easily recalled than rare words, or low frequency words. In contrast, rare words, or low frequency words, are more easily recognized than common words. Cognitively, a two-stage process of retrieval underlies the differing accuracy performances found in recall and recognition tasks (Kintsch, 1970). Common words have more associative links to other similar type (common) words in memory making them more easily activated in memory. It is the high frequency of occurrence that makes common words easier to activate in memory, which then produces a greater activation strength making recall for these objects easier. However, when posed with a decision, rare words are more likely to be chosen due to their saliency and lack of redundancy of irrelevant information in recognition tasks. Karlsen and Snodgrass (2004) extended this effect to picture stimuli using the predictions of the Search of Affective Memory (SAM) model.

The SAM model proposes that cues presented in short-term memory activate long-term memory features by varying degrees, which are influenced by retrieval-dependent strength of activation. Cues provided in short-term memory activate the associative links in long-term memory. Because high frequency/common items possess greater connections that are more easily accessed than low frequency items, high frequency items have higher retrieval strength relative to low frequency items, resulting in a differing degree of activation by external cues in short-term memory. Applied to mixed and pure lists using recall, the model predicts that in pure lists high frequency items will be better recalled than low frequency items due to the fact that high frequency items possess more associative links cognitively than low frequency items. Also, participants are more likely to recall high-frequency items over and over again than low-frequency items. Mixed lists, however, do not have a frequency advantage and items of either frequency are equally likely to be recalled. In recognition retrieval tasks, an advantage of low-frequency items will be present in both mixed and pure lists because of differences in saliency between unstudied low frequency foils and studied low frequency test items. Specifically, unstudied low frequency items appear *less* familiar than unstudied high frequency items, while studied low frequency items appear *more* familiar than studied high frequency items. Low frequency items will demonstrate both a high hit rate and a lower false alarm rate, which should serve to enhance overall accuracy.

Karlsen and Snodgrass' test of the word-frequency paradox, using SAM predictions, with picture stimuli found that performance for high and low frequency pictures differed by list length and retrieval method, which extended the word-frequency paradox to picture stimuli. In recognition, low frequency words were better than high frequency words; in recall, high frequency words were better recalled than low frequency words in pure lists; and in mixed lists, recall of high frequency words was equal or worse than low frequency words. These results support the notion of retrieval-dependent effects in memory tasks. It is possible that previous studies conducted on Priority Binding Theory with picture stimuli may have failed to elicit findings consistent with the theory solely because of differing retrieval demands used. Investigating the effects of retrieval demands may shed light on memory processes by providing information on factors that influence both encoding and retrieval processes.

Specific Aims and Hypotheses

The purpose of the present study is to add to a large and complex body of literature on emotional memory. Specifically, emotion has been found to both enhance memory in certain instances and impair memory in others, but the exact mechanisms for emotion's enhancement and impairment of memory are currently debated. In terms of memory enhancement, flashbulb memories for emotionally charged and arousing events serve as anecdotal evidence for enhanced emotional memory. However, the accuracy and validity of these memories cannot be verified. In response to the limits of flashbulb memories, researchers have turned to laboratory studies using stimuli such words or stories to examine emotional enhancement of memory.

To explain emotion's enhancement on memory, MacKay et al. (2004) proposed Priority Binding Theory, which states that highly arousing and negatively valenced material, relative to neutral material, attracts attention and prioritizes processing of material based on emotional significance. MacKay et al. (2004) supported their predictions of Priority Binding Theory with taboo and neutral words. Questions remain whether these findings generalize beyond lexical stimuli. In an attempt toward generalizing beyond word stimuli, our lab sought to test the predictions of Priority Binding Theory using picture stimuli because pictures provide a closer approximation to the experiences of the heavily visually biased real world. Our attempts at extending the theory beyond words have to date been unsuccessful. Manipulating presentation rate and list length only produced trends toward significance. A key difference between our studies and the original MacKay study, however, is the use of retrieval methods, with MacKay using free recall formats and our lab using recognition format. As noted above recall and recognition represent distinct memory processes served by distinct neuroanatomical structures. Recognition memory is further believed to be influenced by distinct processes of recollection and familiarity and is generally supported by dual-process models. Given that recall and recognition are believed to be distinct retrieval processes, it is possible that the use of a recognition format obscured any true effects present in past studies. It is also possible that recognition tasks are easier to perform given the complexity of picture stimuli. Therefore, the manipulation of retrieval method is necessary to help determine if recognition and recall represent distinct retrieval processes, which may explain why past attempts to extend Priority Binding Theory to picture stimuli were unsuccessful.

It is also possible that alternative theories may better account for past findings in our lab. In particular, the "word"-paradox and SAM model hypotheses noted in the 2004 Karlsen and Snodgrass study suggest that familiarity of stimuli produce specific effects within mixed and pure lists tested with recall and recognition formats. In their study, it is proposed that for recall, high frequency stimuli, which are more common and analogous to neutral stimuli in this study, will be better recalled in pure lists but no advantage for low or high frequency stimuli will be observed for mixed lists. For recognition, accuracy for low frequency stimuli, or rare stimuli, which is analogous to negative images in the present study, should be greater than for high frequency stimuli regardless of list type. one could argue that negative and arousing pictures fit into the category of low frequency while neutral images viewed fit in the category of high frequency pictures. Examining the result patterns of accuracy for images presented in mixed and pure lists for both recall and recognition memory in the present study is important, as it will aid in clarifying the contradictory effects observed in past studies.

The overall goal of the current study is to investigate the impact of emotional content and context on memory formation in healthy participants by examining differences in retrieval tasks using a recall format and a dual-process recognition format (i.e., examining accuracy, sensitivity, and bias) for negative and neutral picture stimuli presented in mixed or pure lists. Therefore, the following hypotheses are proposed:

Hypotheses

Priority Binding Theory proposes that under certain circumstances emotional information is better remembered than neutral information. Specifically, the theory states that when negative and arousing words are presented with neutral words in mixed lists contexts, negative and arousing words will take priority during mental processing resulting in stronger encoding for the emotional words relative to neutral words. Pure lists, however, are not predicted to demonstrate any such effect. The predictions of Priority Binding Theory will be applied to each retrieval method to help determine if recall and recognition are distinct retrieval processes, as significant hypotheses in each retrieval method would indicate that recall and recognition are not distinct processes. It is hypothesized that:

Hypothesis One

With regards to recognition memory for pure lists, Priority Binding Theory predicts no statistically significant differences in recognition memory, using an Rapid Serial Visual Paradigm (RSVP), between pure lists composed of high arousal negative images and low arousal neutral images

Hypothesis Two

With regards to recognition memory for mixed lists, Priority Binding Theory predicts *statistically significant* differences in recognition memory performance using a RSVP paradigm consisting of mixed lists composed of high arousal negative images and low arousal neutral images

Hypothesis Three

With regards to recall memory for pure lists, Priority Binding Theory predicts no statistically significant differences in recall memory, using an RSVP paradigm, between pure lists composed of high arousal negative images and low arousal neutral images

Hypothesis Four

With regards to recall memory for mixed lists, Priority Binding Theory predicts *statistically significant* differences in recall memory performance using a RSVP paradigm consisting of mixed lists composed of high arousal negative images and low arousal neutral images

Hypothesis Five

Since the predictions of Priority Binding Theory have not been upheld thus far, it is important to rule out the possibility that retrieval demands attenuated previous results, so the current study will examine the predictions of Priority Binding Theory in both a recognition format and a free recall format. Therefore, the following hypotheses are made: A valence by list interaction will be present in free recall formats, but not recognition formats.

Hypothesis Six

Previous studies conducted in our lab demonstrated near perfect accuracy in recognition formats. To examine if recognition memory tasks are easier than free recall tasks, overall task accuracy will be examined for both mixed and pure lists in both recognition and free recall tasks. Therefore, it is hypothesized that overall accuracy will be greater for recognition memory tasks than for free recall tasks, despite manipulations of list type and valence.

Hypothesis Seven

Examine the accuracy patterns for mixed and pure lists in both recall and recognition formats to determine if they follow the predictions of the "word"-paradox and SAM model predictions, which predict greater recall memory for high frequency/neutral stimuli in pure lists and no effect in mixed lists and greater recognition accuracy for low frequency words in recognition memory regardless of list type.

CHAPTER 3

METHODOLOGY

Participants

A total of 42 participants were recruited from La Sierra University's subject pools, which included 15 men and 27 women who ranged in ages from 18-27 (*M* = 19.5, *SD* = 1.9). In terms of racial and ethnic breakdown, 2.4% of participants were Caucasian, 2.4% African American, 38.1% Asian, 33.3% Latino, and 23.8% identified as other. La Sierra University and Loma Linda University Institutional Review Boards (IRB) granted approval to conduct the current study. Informed consent was obtained from each participant prior to beginning the study. Inclusion criteria for the present study required participants to be fluent in English, and have normal or corrected-to-normal vision. Participants received credit that was applied to their courses in exchange for participation.

Materials and Design

One hundred and twenty-six picture stimuli were drawn from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). Sixty-three negative images and 63 neutral images were chosen to comprise mixed and pure lists based on two dimensions: arousal and valence. Normative ratings of each dimensions helped determine which images were highly arousing and negative, or neutral in valence. For negative lists, images were chosen that had normative arousal ratings greater than five and valence ratings below four. For neutral lists, images with normative arousal ratings below five and valence ratings of 5 $\pm$ 1 were chosen. Mean valence for negative images was 2.4 (*SD*

= .69) and mean arousal for negative images was 6.35 (*SD* = .42). Mean valence for neutral images was 5.09 (*SD* = .44) and mean arousal for neutral images was 3.13 (*SD* = .55)

A total of nine lists were created consisting of a negative-pure, neutral-pure, and mixed list for the recall study phase; a negative-pure, neutral-pure, and mixed list for the recognition study phase; and a negative-pure, neutral-pure, and mixed lists that served as new foils for the recognition test phase. Pure lists were composed of 14 images, while mixed lists contained seven negative and seven neutral images. See Figure 3 to view overall study design.

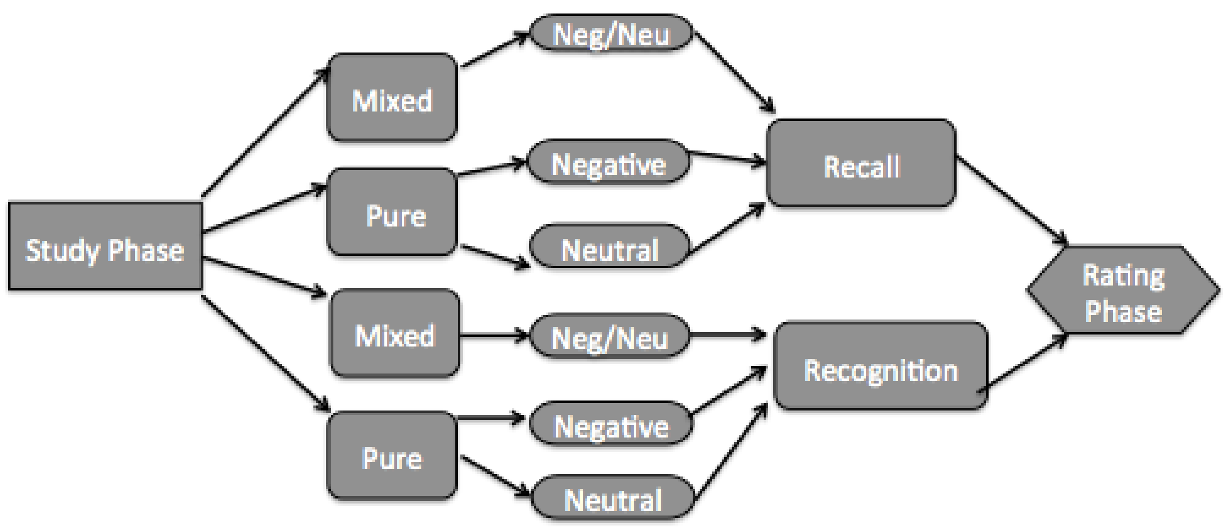

Figure 3. Study Design (presentation of mixed or pure lists and retrieval tests were randomly presented).

Procedure

Subjects were tested individually while seated in a quiet and air conditioned room. Each picture was presented individually on the full screen of a 60-inch computer monitor via E-Prime 2.0 Professional (Psychological Software Tools, Pittsburgh, PA). E-Prime program randomly selected images for each valence category within a list. List type and retrieval task order were also randomly selected. No image was viewed more than once during the encoding phase.

Participants were presented with instructions immediately followed by a practice phase to ensure proper understanding of task instructions. The practice phase consisted of cartoon-like insect images. After the practice phase, participants viewed a randomly assigned study phase consisting of either a mixed list or pure list (negative or neutral). Within the study phase, stimuli were presented sequentially for 500 ms. A black screen with an inter-stimulus interval of 50 ms followed the presentation of each image (see Figure 4).

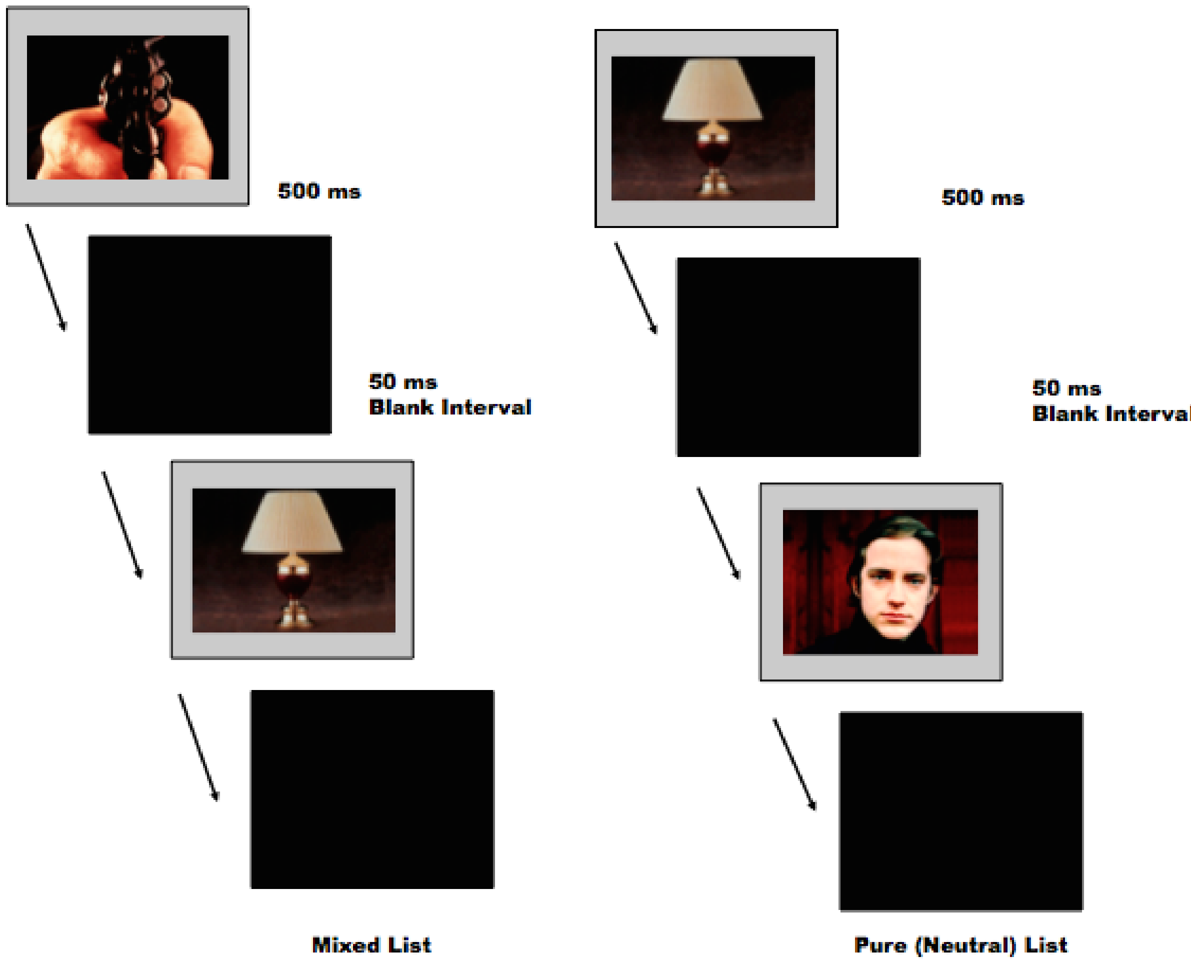

Figure 4. Examples of stimuli presentation in mixed and pure lists.

A retrieval phase consisting of either a recognition test or recall test, which was randomly selected, immediately followed the presentation of each study list. For recognition lists, participants were shown a series of images and were asked to indicate if they have viewed the image in the preceding list by pressing "1" for old and "0" for new. They were then asked to rate their memory confidence on a scale of 1 to 5, with 1 being "I'm guessing" and 5 being "I'm absolutely sure I can remember the experience of seeing the image." For recall lists, participants were asked to write down, in as much detail as possible, every image from the preceding list they could recall in any order in a word document on a separate computer. Image descriptions were then compared to the images presented in each recall block of images viewed. Images were rated as either accurately recalled or not recalled depending on whether participant descriptions provided the gist of the theme represented in each image. For example, if a participant described seeing a mutilated hand in recall block 1, the description was compared with all images viewed in that specific block. If participant description was too vague or if it did not match any image in that block, then the description was counted as an incorrect identification. At the conclusion of the study, participants were asked to rate all 126 images in terms of arousal and valence as a manipulation check.

Data Analysis

A two by two by two within-subject design was used. The independent variables consisted of valence (negative or neutral), list-type (mixed or pure) and retrieval task (recall or recognition). The proportion of correctly recalled items, or accuracy, served as the dependent variable for the recall and recognition tasks. Accuracy was determined by assessing how many pictures were accurately identified as correct. To test the predictions of Priority Binding Theory, which propose enhanced memory for negative images in mixed lists and no advantage in pure lists, a three-way within-subjects repeated measures analysis of variance, or ANOVA, was conducted to determine whether or not a valence by list interaction will appear for accuracy with mixed lists. Also, an ANOVA was conducted to test the prediction that accuracy will be greater in recognition formats versus recall formats. Additionally, measures of sensitivity (d_e) and bias (C_e) were calculated and served as dependent variables for recognition tasks to help determine how well participants are able to discriminate between previously viewed images versus new images and to determine the level of conservative or liberal responding participants may demonstrate while engaging in memory tests.

CHAPTER 4

RESULTS

Retrieval Accuracy

Accuracy responses, or proportion correct, were entered into an overall two by two by two within-subject repeated measures analysis of variance (ANOVA) with retrieval method (recall and recognition), valence (negative and neutral), and list type (mixed and pure) serving as the within-subject factors. Results of the repeated measures ANOVA, with a Greenhouse-Geisser correction for violations of the assumption of sphericity, resulted in significant main effects for retrieval method, $F(1, 41) = 1129$, $p < .001$, $\eta^2 = .97$, and for valence $F(1, 41) = 38.94$, $p < .001$, $\eta^2 = .49$. Participants had higher accuracy scores on memory tests using recognition as a retrieval method (M = 3.80, SD = .42) than when recall was used as a retrieval method for memory tests (M = 1.58, SD = .42). Accuracy was also greater for negative (M = 2.83, SD = .31) versus neutral images (M = 2.55, SD = .28). The main effect for list type was not significant (see Figure 5).

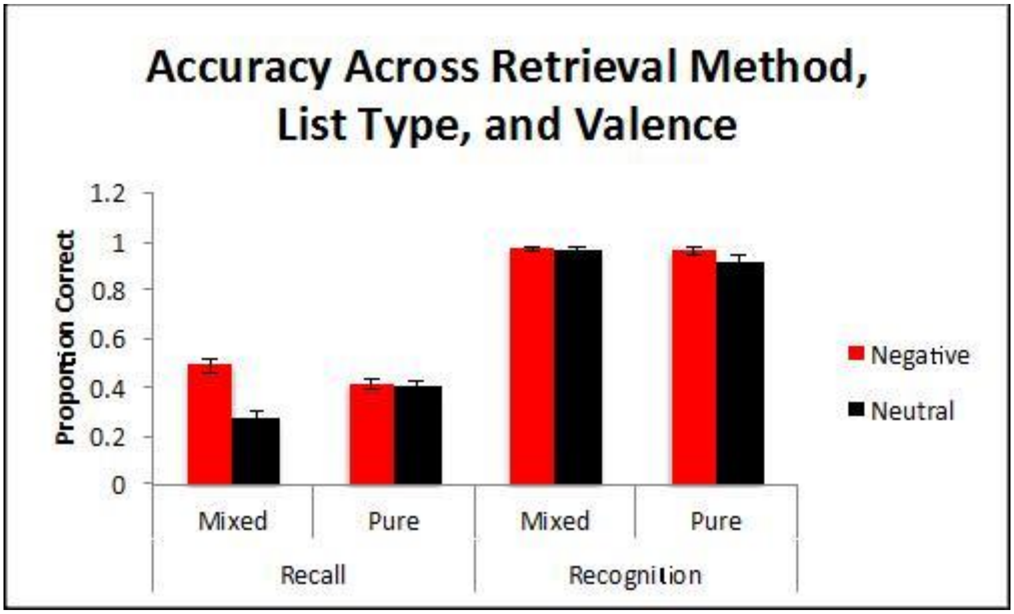

Figure 5. Three-way interaction for retrieval method, list type, and valence predicting accuracy.

Three significant interactions resulted from the overall repeated measures ANOVA. There was a significant three-way interaction for retrieval method, valence, and list type, $F(1, 41) = 14.15$ $p < .001$, $\eta^2 = .26$ (Figure 5), a significant two-way interaction for valence and list type, $F(1, 41) = 13.85$, $p < .001$, $\eta^2 = .25$ (Figure 6), and a significant two-way interaction for retrieval method and valence, $F(1, 41) = 16.64$, $p < .001$, $\eta^2 = .29$ (Figure 7).

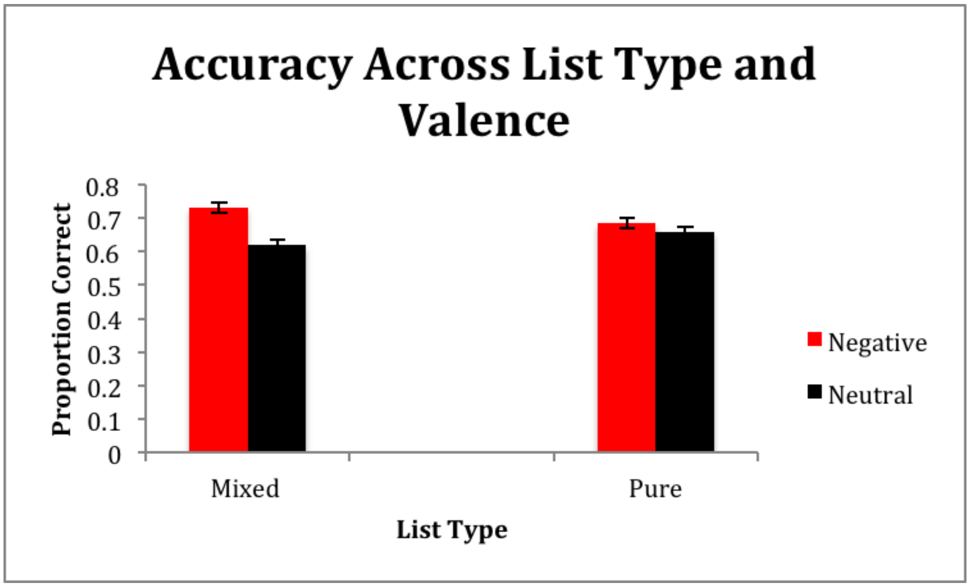

Figure 6. Interaction between list type and valence predicting accuracy. Bars represent standard error of the mean.

To break down the three-way retrieval method by valence by list type interaction (Figure 5), separate two by two repeated measures ANOVAs were conducted for recognition and recall retrieval methods with valence (negative and neutral) and list type (mixed and pure) serving as the within-subject factors. For recognition, the main effects for valence, F (1, 41) = 7.41, $p < .05$, $\eta^2 = .1.53$, and list type $F(1, 41) = 4.73$, $p < .05$ $\eta^2 = .10$, were significant but the resulting valence by list type interaction was non-significant. Participants were able to better accurately recognize negative ($M = 1.92$, $SD = .11$) versus neutral picture stimuli ($M = 1.87$, $SD = .14$) overall $t(41) = 2.72$, $p < .01$, 95% CI [.38, .43], $d = .40$. Recognition accuracy was also greater for images presented in mixed ($M = 1.93$, $SD = .10$) list versus pure list ($M = 1.87$, $SD = .17$) conditions, $t(41) = 2.18$, $p < .05$, 95% CI [.41, .47], $d = .44$ (see Figure 7).

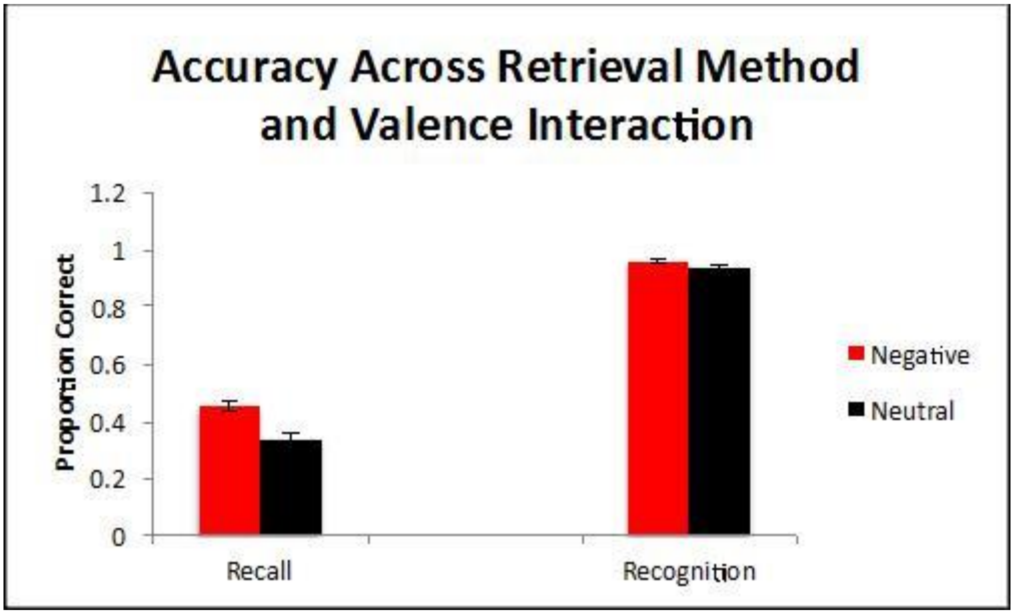

Figure 7. Interaction between retrieval method and valence predicting accuracy.

For recall, a two by two repeated measures ANOVA, with list type and valence serving as the within subject factors, indicated the presence of a significant main effect of valence, $F(1, 41) = 31.56$, $p < .001$, $\eta^2 = .43$ (see Figure 8). Participants showed greater accuracy for negative ($M = .90$, $SD = .27$) versus neutral ($M = .68$ $SD = .22$) picture stimuli, $t(41) = 5.62$, $p < .01$, 95% CI [.85, 96], $d = .90$. A significant valence by list type interaction, $F(1, 41) = 17.66$, $p < .001$, $\eta^2 = .30$, was also observed. Participants had higher accuracy scores for negative images presented in mixed list ($M = .49$, $SD = .19$) versus neutral images presented in mixed list ($M = .28$, $SD = .19$) conditions, $t(41) = 6.24$, $p < .01$, 95% CI [1.1, 1.2], $d = 1.1$. Differences in accuracy for negative image ($M = .41$, $SD = .16$) versus neutral image ($M = .40$, $SD = .14$) presented in pure list conditions was non-significant, $t(41) = .43$, $p > .05$, 95% CI [.03, 0.1], $d = 0.1$. The main effect of list type was non-significant.

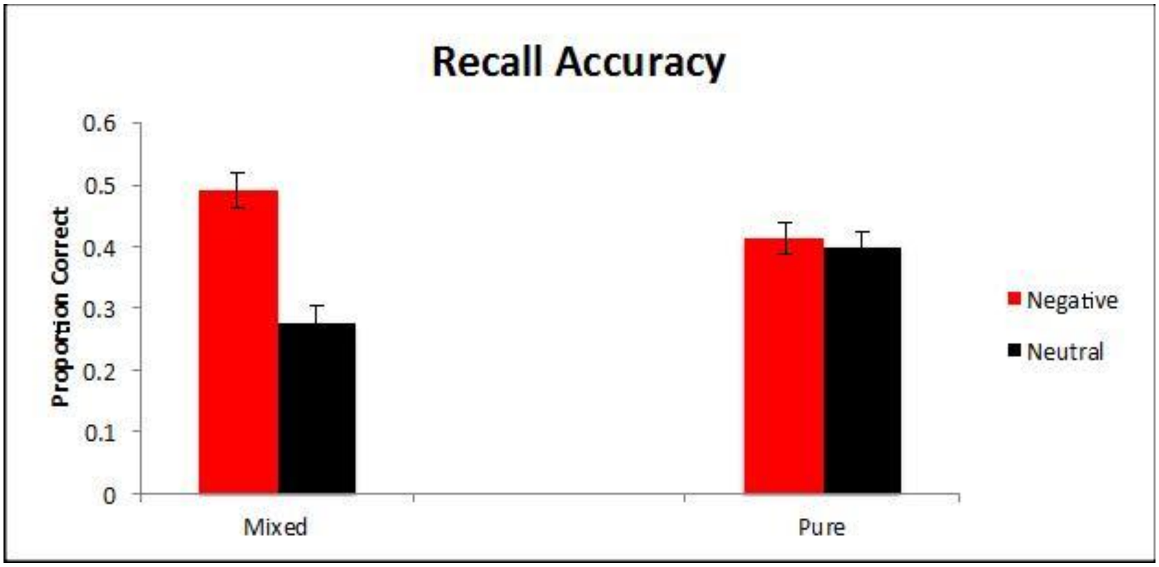

Figure 8. Valence by list type interaction predicting accuracy in recall condition.

Recognition Memory: Signal Detection

Sensitivity (d') and Bias (C)

A sensitivity index measure, or *d'*, did not reveal any significant differences in participants' ability to detect negative versus neutral images in mixed or pure lists for either recognition or recall retrieval methods. However, a measure of bias, or *C*, indicated that participants had a liberal response bias for negative images. This suggests that they were more likely to report that they had viewed a negative image during memory testing regardless of whether they had actually viewed the image or not.

CHAPTER 5

DISCUSSION

In the present study the predictions of Priority Binding Theory were used to examine the effects of emotion on memory. Within Priority Binding Theory it is proposed that negative information takes priority in information processing and leaves little resources for neutral information to be processed, resulting in enhanced memory for negative information. The theory also states that no advantage of memory will be produced when information of same salience (i.e., all negative or all neutral) are presented in homogenous/pure lists. Our lab attempted to extend Priority Binding Theory to picture stimuli across many studies and manipulated variables including list length, list rate, format (blocked versus presenting all stimuli together), but we were unable to produce results similar to MacKay's original study (MacKay et al., 2004). However, previous studies in our lab were designed to test recognition memory. Given that the original study used recall as the primary retrieval method and that recognition and recall are separate processes, retrieval method was manipulated in the present study to help us determine if the predictions of Priority Binding Theory could be extended to picture stimuli.

In general participants were better able to recall negative versus neutral information, but this effect was dependent on retrieval method and list type which was evident in the overall three-way valence by list type by retrieval interaction (see Figures 5). Participants had higher overall accuracy scores when tested with a recognition retrieval format than when tested with recall. Effects of valence were also observed to influence accuracy scores, with greater accuracy scores observed for negative versus neutral images. Within recognition retrieval tasks, participants had greater accuracy for negative versus neutral images in pure lists, but differences were not significant between negative and neutral images presented in mixed lists. However, when tested with recall retrieval formats, participants showed greater accuracy for negative versus neutral images in mixed lists but did not demonstrate significant differences in accuracy for negative versus neutral images presented in pure lists. With regards to participant performance within recognition formats, additional measures of sensitivity (d_e) and bias (C_e) did not aid in clarifying differences in participants' ability to discriminate between previously viewed images and novel images during memory tasks. Participants did demonstrate a liberal response bias, which suggests that participants had a tendency to respond as if they had previously viewed an image whether they actually had or not.

Additionally, the predictions of the "word"-paradox and SAM model were examined to determine if an alternative theory could better explain findings observed in mixed and pure lists within recall and recognition findings. However, the results of the present study did not support the above predictions. Within recall formats, accuracy patterns were in line with the predictions of Priority Binding Theory, while results in recognition formats did not follow the predicted patterns suggested in the "word"-paradox and SAM model.

With regards to the specific hypotheses of the present study, and according the predictions of Priority Binding Theory, it was hypothesized that within recognition formats no differences would be observed between negative and neutral images presented in pure lists but significant differences were predicted to occur between negative and neutral images presented in mixed lists. Hypothesis one was not supported. Participants *did* show enhancement for negative images versus neutral images presented in pure lists. Hypothesis two was not supported. Participants *did not* show a statistically significant memory advantage for negative images versus neutral images presented in mixed lists. It was hypothesized that within recall formats no statistically significant differences would be observed for either negative or neutral images presented in pure lists. Hypothesis three was supported. Participants did not demonstrated statistically significant differences in memory for negative images versus neutral images presented in pure lists. It was also hypothesized that in mixed lists, statistically significant differences would be observed between negative and neutral images. Hypothesis four was supported, as participants showed greater accuracy for negative images presented in mixed lists. These results support the predictions of Priority Binding Theory, which predicts better memory for negative versus neutral material in mixed lists, and effectively extend the theory to picture stimuli.

We also hypothesized that differences in retrieval demands (i.e., the relative ease of recognition formats versus the more difficult nature of recall tasks) attenuated the results in previous studies. Specifically, it was hypothesized that a valence by list interaction would be present in free recall formats, but not recognition formats. Hypothesis five was upheld. No interaction effect was observed in recognition formats, but a valence by list interaction was observed within recall formats. It was hypothesized that recognition retrieval methods would be easier for participants versus recall, and that recognition would produce ceiling effects. Hypothesis six was upheld. Participants demonstrated greater accuracy scores for recognition tasks versus recall tasks. As observed with past studies, participants demonstrated ceiling effects within recognition task. Near perfect accuracy was observed for participants across valence and list type. The presence of ceiling effects obscured both past and present attempts to examine effects of emotion on memory. However, participants did demonstrate liberal response biases for negative images in recognition tasks. It is possible that the limited themes depicted in negative images (mutilations, violence, etc.) created a confound attenuating participant ability to distinguish between old negative images viewed from novel negative images. Participants' familiarity with the limited themes depicted in negative images may have produced a bias toward positive response identification; that is, participants may have been more inclined to say 'yes' to an image despite never having viewed an image. Finally, it was hypothesized that greater recall memory for high frequency/neutral stimuli would be observed in pure lists and no effect would be observed in mixed lists, while greater recognition accuracy for low frequency words would be observed in recognition memory regardless of list type. Hypothesis seven was not upheld. Participants did not show a memory advantage for high frequency/neutral stimuli in pure lists nor did they show null effects in mixed lists. Participants also did not show an advantage for low frequency/negative stimuli regardless of list type in recognition formats, as participants showed greater accuracy for negative versus neutral stimuli in pure lists but no difference in accuracy for mixed lists.

Priority Binding Theory and Retrieval Dependent Effects

As noted above, the predictions of Priority Binding Theory were upheld in the present study and effectively extend the theory to picture stimuli, but the effect was dependent upon retrieval method tested. In terms of recall retrieval formats, the predictions of Priority Binding Theory were upheld suggesting that during recall more salient stimuli takes priority in the *retrieval process* than less salient stimuli but it is unclear if the proposed mechanisms of priority of information during *early processing* can be concluded given disparate findings in recognition tasks. The presence of a significant effect of negative valence for pure lists found in recognition formats is not in line with the predictions of Priority Binding Theory, which states that information of the same salience should not compete for processing resources and should not result in a statistically significant difference between negative and neutral pure lists. Given that the same task produced opposite findings depending on retrieval method used suggests that distinct processes are occurring during retrieval, but it is difficult to infer if priority processing is occurring while participants are initially encountering stimuli. It may be useful to incorporate imagine or physiological tasks in the future to help gain an understanding of what is going on in the brain/body at each stage of memory processing (attention, encoding, retrieval) and in which brain region.

Our new findings help place past attempts to extend Priority Binding Theory in context. Since our lab previously used recognition formats as the sole measure of examining participant memory for negative versus neutral images it makes sense that we were unable to extend Priority Theory to picture stimuli. The discrepant findings observed between recognition and recall tasks appear to be due to distinct memory processes used within recall versus recognition. In past studies, we were only investigating half of this emotion-driven phenomenon, but although we now have a better idea of what responding looks like within each retrieval format investigation geared toward understanding brain mechanisms involved in each processing is necessary to conduct to help clarify specifically how emotion is affecting memory and how memory is impacted within each step of processing. In particular, emotional arousal associated with an object elicits narrowed, or focused, attention to features within the object making memory for elements centrally associated with the object easier to remember (Mather, 2007), but does not produce enhanced memory between that object and other objects and at times even impairs memory (Kensinger & Corkin, 2003). This may explain the overall advantage of negative images over neutral images in that focused attention for negative images produced a memory advantage at the expense of temporally adjacent neutral stimuli in mixed lists. The attention grabbing nature of emotionally arousing stimuli (Anderson, 2005; Bradley, 2009; Mather & Nesmith, 2008; Potter, Wyble, Pandav & Olejarczyk, 2010), may also explain the overall enhancement of memory for negative pictures in pure lists. Talmi et al. (2008) found further support for emotion-enhanced attention/memory for pictures. MRI scans of participants' brains were obtained while they viewed emotional or neutral pictures under differing attentional conditions. Activation of brain structures involved in attention to emotional stimuli were observed along with activation of brain areas associated with overall emotion-enhanced memory. Together, these areas included the fusiform gyrus, ventral amygdala, bilateral middle occipital gyrus, bilateral fusiform gyrus, right dorsal parietal cortex (centered on the intraparietal sulcus) and inferiotemporal corticies. Activation of these areas suggests that an attention-mediated process plays a role in emotional enhancement of memory. Again, it would be useful to obtain imaging or brain wave data to help clarify what is going on during each memory process stage within the design used in this study to help determine what is going on at each level of processing in various brain regions to help clarify differences between recall and recognition tasks.

Our findings that recall and recognition processes are distinct processes are supported by free recall versus recognition literature. Emotion enhanced memory is found in free recall studies that assess participant memory for negative versus neutral information (Danion, Kauffmann-Muller, Grange, Zimmermann, & Greth, 1995; Doerksen & Shimamura, 2001; Guy & Cahill, 1999; Hertel & Parks, 2002; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002; Kensinger & Corkin, 2003). However, mixed findings within recognition formats found in the present in study are also found in studies assessing participant memory for negative versus neutral stimuli using recognition tasks (Comblain, D'Argembeau, Van der Linden, & Aldenhoff, 2004; Gruhn, Smith, & Baltes, 2005; Hamann, 2001; Gruhn, Scheibe, & Baltes, 2007; Kensinger & Corkin, 2003; Pesta, Murphy, & Sanders, 2001; Ochsner, 2000), with some studies showing enhanced memory for negative stimuli, enhanced memory for neutral stimuli, or no enhancement. It is possible that differing levels of arousal were used in recognition studies and produced mixed effects, as it is arousal levels that are mainly believed to drive emotion enhanced memory effects (Zeelenberg, Wagenmakers & Rotteveel, 2006). This explanation, however, is worth investigating further as emotion-enhanced memory is more consistently observed in studies that use recall formats. Future research investigating differing effects of arousal level across retrieval methods should be conducted to help elucidate participant sensitivity to arousal and valence observed in this and several other studies. As noted above, the use of imaging may be beneficial to investigate specific brain structures activated during both study and retrieval tasks.

The "Word"-Paradox Effect

The discrepancies between the current study and past studies in our lab may also be partially attributable to the "word"-paradox effect and guided by the predictions of the SAM model as proposed by Karlsen and Snodgrass (2004). Again, the word-frequency paradox effect describes an observed tendency for participant's tendency to recall and recognize words differently depending on the level of familiarity the participant has with each word. High frequency words (i.e., common words) are more easily recalled than low frequency words (i.e., rare words) because they possess greater associative links in memory and are therefore easier to bring into conscious awareness. The opposite effect is found in recognition with participants recognizing low frequency words more easily than high frequency words because the saliency of the words help participants distinguish between old and novel images. This theory was extended by Karlsen and Snodgrass (2004) by adding the SAM model to the theory, which states that memory strength is more important than the number of possible meanings, resulting in predictions that recognition memory will be better for low frequency items regardless of list type, while high frequency items will be better recalled than low frequency items in pure lists and no effect will be present for either frequency in mixed lists.

In the current study, we examined the pattern of participants' accuracy within mixed and pure lists for both recall and recognition formats. We found that for recall, low frequency/negative images were better recalled than high frequency/neutral images in mixed lists and no effect in pure lists. In recognition formats, we found an advantage for low frequency/negative images in pure lists only and not in mixed lists. Caution, however, should be used in evaluating these findings, as frequency of images was assumed based on the themes of images presented because it is assumed that individuals have little familiarity with mutilation themes depicted in negative images and more familiarity with objects like baskets presented represented in neutral images. However, given that the frequency of images presented in each category was not rigorously controlled we can only conclude that results observed in mixed and pure lists in recall and recognition formats did not follow the “word”-paradox effect and SAM model predictions, but we cannot conclusively say that the theories are disproved. Future investigators should seek to use images of varying valence and arousal that have been normed in terms of frequency of participant exposure to themes depicted in the images.

Limitations

Limitations to the current study include a sample with limited generalizability, with the sample being 64% female, reporting an average age of 19, and reporting an ethnic makeup comprising mainly Asian students (38%). It is possible gender and cultural differences influenced attention to specific picture content and it is worth investigating what type of effect, if any, a largely female and Asian population produces. Researchers in future studies should aim to collect diverse samples in terms of age and ethnicity to improve generalizability of results. Additionally, semantic relatedness was not controlled for (categories of negative images were not analogous to neutral images), limiting conclusions that can be drawn about the strength of arousal enhancement on memory. To control for possible confounds of greatly diverse images producing incomparable effects, investigators conducting future studies should seek to include analogous neutral and negative images (e.g., mutilated hand compared with an intact hand).

Future Directions and Clinical Implications

Our findings aid in providing greater understanding of the complex and sensitive processes involved in emotion-enhanced memory. Specifically, the predictions of Priority Binding Theory were determined to only partially account for emotion enhanced circumstances (differences between free recall and recognition accuracy results), but the mechanisms by which enhancement occur have now been called into question. Future investigators should seek to incorporate imaging or physiological measures to verify brain regions associated with viewing emotional versus non-emotional picture stimuli, attentional processes involved during study tasks, examine brain regions involved in retrieval processes, and examine performance scores in the form of both objective and subjective accuracy, sensitivity, and bias. Clinically, these results can be viewed as informing a part of emotional processing where enhancement occurs. These results, however, should be viewed as initial steps necessary to create a more comprehensive theory of emotion and memory, which helps incorporate enhancing and impairing effect of emotion. Furthermore, findings of this nature can help guide clinicians conducting therapy on types of treatments to use to help facilitate memory or to help clients cope with fragmented memory produced by highly arousing and impairing emotional events.

Additionally, the liberal response bias present in the current study adds support to past research, which has shown that within recognition memory tasks participants exhibit a liberal bias, suggesting that recognition memory may not be based on a dual-process of memory but on an increased subjective sense of familiarity (Dougall & Rotello, 2007; Ochsner, 2000; Windmann & Kutas, 2001). Future studies should include physiological or imaging studies to help correlate behavioral responses. Specifically, Remember, ‘R,’ and Know, ‘K,’ judgments should be compared ERP data or fMRI data to help determine if different brain processes are involved in R and K judgments while viewing picture stimuli.

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APPENDIX A

IAPS IMAGES

IAPS Images			
Negative		Neutral	
3120.jpg	3261.jpg	2440.jpg	2745.1.jpg
9040.jpg	9405.jpg	7031.jpg	2870.jpg
6230.jpg	9433.jpg	7110.jpg	7052.jpg
9050.jpg	6821.jpg	7025.jpg	7057.jpg
3170.jpg	3015.jpg	7030.jpg	7493.jpg
3230.jpg	2141.jpg	2383.jpg	2357.jpg
3220.jpg	3266.jpg	7150.jpg	7710.jpg
9250.jpg	2352.2.jpg	2480.jpg	7490.jpg
3160.jpg	9592.jpg	7130.jpg	7096.jpg
1300.jpg	1019.jpg	4000.jpg	7190.jpg
9410.jpg	3069.jpg	7491.jpg	2980.jpg
3000.jpg	6315.jpg	6570.2.jpg	2235.jpg
2800.jpg	2683.jpg	2393.jpg	2518.jpg
9300.jpg	1525.jpg	7036.jpg	7285.jpg
2730.jpg	3005.1.jpg	2516.jpg	2506.jpg
9430.jpg	2095.jpg	7055.jpg	2020.jpg
8480.jpg	9635.1.jpg	7059.jpg	2394.jpg
3350.jpg	3101.jpg	7009.jpg	2513.jpg
6350.jpg	9301.jpg	7950.jpg	2435.jpg
9800.jpg	2688.jpg	7235.jpg	7495.jpg
9910.jpg	3191.jpg	7020.jpg	7039.jpg
9910.jpg	2811.jpg	7002.jpg	7472.jpg
9560.jpg	2703.jpg	7000.jpg	5635.jpg
3400.jpg	6022.jpg	9070.jpg	2560.jpg
9600.jpg	2717.jpg	7160.jpg	1602.jpg
9490.jpg		7004.jpg	
9570.jpg		7187.jpg	
9810.jpg		7056.jpg	
6570.jpg		2038.jpg	
7380.jpg		7233.jpg	
9630.jpg		7207.jpg	
3053.jpg		7043.jpg	
2691.jpg		5532.jpg	
9622.jpg		2385.jpg	
2661.jpg		7547.jpg	
9181.jpg		5740.jpg	
6312.jpg		7053.jpg	
9620.jpg		7080.jpg	