Loma Linda University

3-2008

Memory for Emotional Images : Recognition and Temporal Contexts

George E. Devore

Loma Linda University
School of Science and Technology
in conjunction with the
Faculty of Graduate Students

Memory for Emotional Images: Recognition and Temporal Contexts

By:

Gregory E. Devore

A Master's Thesis submitted in satisfaction of
the requirements for the degree of
Master of Arts in Clinical Psychology

March 2008

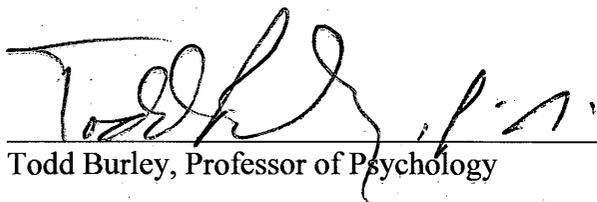Each person whose signature appears below certifies that this thesis in his/her opinion is adequate, in scope and quality, as a thesis for the degree of Master of Arts in Clinical Psychology.
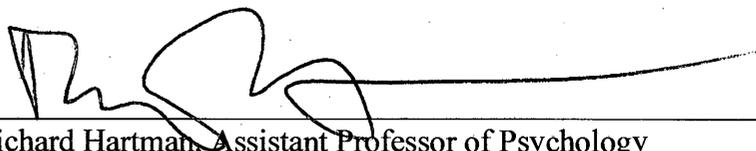

_____, Chairperson
Paul Haerich, Professor of Psychology

_____
Todd Burley, Professor of Psychology

_____
Richard Hartman, Assistant Professor of Psychology

ACKNOWLEDGEMENTS

CONTENTS

Chapter

TABLES

FIGURES

ABSTRACT OF THE THESIS

Memory for Emotional Images: Recognition and Temporal Contexts

By:

Gregory E. Devore

Master of Arts, Graduate Program in Clinical Psychology
Loma Linda University, March 2008
Paul Haerich, Ph.D, Chairperson

Negative emotional stimuli are usually better remembered than neutral emotional stimuli. Previous examination of binding theory found no differences in recall for homogeneous lists of taboo and neutral words. The current study expands on binding theory using negative and neutral visual stimuli in homogeneous lists. A rapid serial visual presentation paradigm and recognition and temporal memory item-discrimination tasks were used. Binding theory predicts no differences between negative and neutral images for recognition and temporal memory. Results were consistent with the assumptions of binding theory and no significant differences were found. This result suggests that binding theory generalizes for visual stimuli in both recognition and temporal memory contexts. Further research is needed to determine if the predictions of binding theory hold true for heterogeneous lists of negative and neutral stimuli.

Introduction

Research in emotion and memory suggests that emotionally relevant stimuli are better remembered than neutral stimuli. A classic example of how emotion can influence memory comes from individuals who were alive when President Kennedy or Martin Luther King, Jr. was assassinated. Individuals typically remember the exact time, place, and what they were doing at the moment they heard the news. The strength of these memories differs in detail from other days where important events did not occur (Brown & Kulik, 1977). Laboratory studies have found similar effects of emotion and memory across multiple sensory modalities including vision, tactile sensation, hearing, taste, and smell with research suggesting memory strength is stronger the more intense the initial stimulus (Koster et al, 2004). Of particular interest to the proposed research is how rapid presentation of emotional visual information is processed in working memory. One prominent theory called binding theory predicts preferential processing for emotionally arousing stimuli over neutral stimuli at sufficiently fast presentation rates in heterogeneous lists but not in homogeneous lists (Hadley & MacKay, 2006). The primary evidence supporting binding theory has come from studies utilizing taboo words (emotionally arousing verbal stimuli) in stroop tasks, lexicial decision tasks, and a rapid visual serial presentation immediate memory recall task (MacKay et al, 2004; Hadley & MacKay, 2006). The preferential processing of emotional stimuli is predicted to apply to temporal information in the same way. Previous research has found that temporal information using an episodic memory task is better remembered for negative images over neutral and positive images (D'Argembeau & Van der Linden, 2005), but has never

been tested under the rapid serial visual presentation paradigm of homogeneous and heterogeneous lists used by Hadley and MacKay (2006).

This raises the question of whether or not binding theory's predictions for recognition and temporal memory holds true in homogeneous lists of negative or neutral images at sufficiently fast presentation rates. As such, the proposed research seeks to test the applicability of binding theory using emotionally evocative visual stimuli.

The specific hypotheses predicted by binding theory are that there would be no difference in recognition memory between homogeneous lists of negative high arousal images and neutral low arousal images in an image recognition task. Furthermore, there should be no temporal memory difference in a list-discrimination task among homogeneous lists of negative high arousal images and neutral low arousal images.

The current study was limited to a single experiment examining the counter intuitive prediction that negative emotion would not produce a memory advantage as long as the negative stimuli were presented together in a homogeneous list.

In the broader perspective, this research and future experiments using heterogeneous lists and positive-valence stimuli will be useful in extending the understanding of mechanisms by which emotion modulates memory recall and recognition. This research takes the first step by attempting to extend binding theory beyond taboo words to emotionally-salient visual stimuli.

Emotion, Memory, and Attention

Attention plays a central role within the cognitive function of learning and memory. Everyday the human brain is exposed to a plethora of stimuli with attention as

the mediator between that which gets remembered, and that which is forgotten. Over a hundred years ago William James wrote of attention:

> "It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneous possible objects or trains of thought. Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others (James, 1890)."

So what directs our attention? Most scientists would agree that emotional arousal directs attention toward stimuli to determine its relevance and subsequent importance. Attention is a limited resource and because only so much information can be processed at any given moment the question must be asked: what sort of information gets processed and why? While much research has been conducted to answer this question, this research specifically seeks to advance the understanding of how emotionally mediated attention may selectively influence the encoding of memory for emotionally evocative stimuli when information is presented quickly.

Biologically the structures of the brain that are primarily responsible for the processing of incoming stimuli as a function of attention are the prefrontal cortex, the amygdala, and the hippocampus. The prefrontal cortex, located right behind the eyes, is responsible for executive decision making (higher types of thought processes), while the amygdala (located deep within the temporal lobes) is considered the 'emotional sentinel' because of its ability to activate the 'fight or flight' response in animals. The 'fight or flight' response is a primitive survival reflex designed to assist rapid decision making to either run from danger, or to stay and fight. This reflex does not directly engage the more complex (and slower) higher order decision-making structures of the brain (LeDoux, 1992). This reflex response is in part due to the amygdala's coordinated role in the body

releasing the neurochemicals epinephrine and norepinephrine. The release of these neurochemicals primes the body for action and also influences other brain regions, such as the hippocampus (located in the temporal lobes) to strengthen memory for what is happening. In essence, it is the hippocampus that initially stores things, but the amygdala is responsible for the flavor of those memories (the emotional context) (LeDoux, 2000). Understanding the dynamic processes that bind these three structures has lead to the development of modern memory and emotion research.

Memory research in modern science is traditionally thought to be composed of three types of storage: sensory memory, short-term memory, and long-term memory. Sensory memory typically has a very short duration (limited to several hundred milliseconds and certainly less than 2 seconds, depending on the modality) and refers to our ability to retain impressions of sensory information after the original stimulus has ceased (Sperling, 1960). Short-term memory (also called immediate or working memory) stores a limited amount of information for roughly 15-30 seconds and may include recently processed sensory input and items retrieved from long-term memory (Brown, 1958). Short-term memory can be contrasted with long-term memory, which seemingly can store an infinite amount of information indefinitely (Bahrick et al, 1975). It seems important to ask if emotion changes the availability of information in these stores. If so, how does it change, and to what extent? The following section discusses the focus of the current research.

Naturalistic and Experimental Evidence: Emotion and Memory

The influence of emotion on memory has been well documented by empirical and naturalistic research. A classic example of how emotion can influence memory comes

from individuals who were alive when the Space Shuttle Challenger exploded, or when passenger planes struck the Twin Towers in New York City. Individuals typically remember the exact time, place, and what they were doing at the moment they heard the news (Brown & Kulik, 1977). These 'flashbulb' memories (an analogy from photography) are very vivid, and often recalled with greater detail than ordinary memories due to the intense emotionality associated with the event (Talarico & Rubin, 2003). Research also indicates that the 'flashbulb' analogy may not be entirely accurate (in the sense that intense memories last forever and are always recalled with perfect accuracy); contextual details degrade over time (Neisser et al., 1996), but there is a correlation between recall accuracy and the intensity of the experienced emotion (Conway et al., 1994).

These naturalistic studies are supported by laboratory evidence that emotionally relevant stimuli are recognized or recalled better than neutral stimuli (Ochsner & Schacter, 2003; Reisberg & Hertel, 2004). All five sensory modalities (smell, taste, vision, hearing, and touch) have been found to affect the strength of memory associations as a function of stimuli intensity, with better memory performance for stronger intensity stimuli as determined by subsequent memory recall or recognition (D'Argembeau & Van der Linden, 2005; Koster et al., 2004; Miles & Hodder, 2005; Reales & Ballesteros, 1999; Wang & Chang, 2004). Much research has sought to understand the subtle effects of emotion on memory in terms of the mechanisms that guide the relative strength of memory encoding and availability of that memory for subsequent retrieval. The neural substrates of memory such as habituation and sensitization (Kandel, 2001) provide the basis of memory consolidation, while cognitive functions such as attention help guide

consolidation of memory. Retrieval of memory may be dependent on distinctiveness of an event, encoding specificity, context and location of the learning, mood, and emotional arousal (for review see Terry, 2006). Emotion and memory seem to have many interactive effects depending on modality, stress on the perceptual and memory systems, and type of memory being assessed (Miles & Hodder, 2005; Reisberg & Hertel, 2004). A classic theory on the relationship of arousal and human information processing is the Yerkes-Dodson Law, which states that a curvilinear relationship exists between arousal and performance (in this case, memory performance). It dictates that performance increases with arousal but only to a certain point. If arousal levels become too high, there is a decrement in performance (Yerkes & Dodson, 1908). This relationship affects a person's ability to remember and retrieve information. This has been supported by laboratory studies which have studied the effect of stress on memory (Mendl, 1999).

Paradigms in Emotion and Memory Research

The remainder of this review will focus on literature regarding the use of emotion and memory paradigms, as the studies that use them are the most relevant to the purpose of the current research proposal. Two of the most popular paradigms of research in the area of emotion and memory are the Stroop task and the rapid serial visual presentation (RSVP) task. The Stroop task is a demonstration of interference in the reaction time of a task using colored words. For example, subjects are asked to name the color of the text a word is printed in and not the word itself. Reaction time is slower in Stroop tasks where subjects must name a word printed in a different color than what is written (i.e.: RED printed in blue color).

RSVP is a method of displaying information (generally text) using a limited space in which each item of information is displayed briefly in sequential order. Typically subjects are asked to search across the time-domain for a target rather than across space. Alternatively, subjects are asked to pay attention and try to remember all of the stimuli presented in the stream. Their memory is then tested for what was presented.

Two other important paradigms include the lexical decision and immediate memory task. The lexical decision task involves measuring how quickly people classify stimuli as words or non-words. The immediate memory task involves measuring the accuracy in deciding if a stimulus was the same as a preceding stimulus.

Emotion, Attention, and the Stroop

The Stroop task has been incredibly successful in providing information facilitating the development of theories of parallel processing for studying emotion, attention, and memory (MacLeod, 1991). Its established empirical history makes it a good choice for studying the effect of emotional stimuli on reaction time and recall memory. For example, in clinical populations, particularly people with phobias, words associated with a particular phobia (i.e.: mouse, for people afraid of mice) took longer to color name than neutral control words (Dalgleish & Watts, 1990). These clinical Stroop effect experiments may be difficult to replicate and have constrained generalizability, given the limited clinical populations and context of presentation (MacLeod and Hodder, 1998). In the general population, studies using unpleasant emotional words such as 'death', 'fear', 'haunt', and 'holocaust' have been shown to have a longer color naming times than neutral words. This emotional Stroop effect however, has not been consistently replicated and in order for the effect to be observed, time pressure (i.e.:

response within 240 ms or less after presentation of a word) may be essential (Sharma & McKenna, 2001). It has also been argued that the emotional Stroop effect is caused by a threat-driven generic slowdown, instead of a selective attention mechanism usually associated with the classic Stroop phenomenon (Algom, Chajut, & Lev, 2004). An earlier study comports with this notion, reporting no emotional Stroop effect using pleasant words, and suggesting that instead of representing emotionality, the effect may be a result of negative affect (McKenna & Sharma, 1995). Supporting this perspective is the taboo Stroop effect, which occurs when people take more time to name taboo words than neutral words (Siegrist, 1995). The finding that color naming for neutral words is shorter than for taboo words has been found to be robust across individuals and contexts (Williams, Mathews, & MacLeod, 1996).

A number of theories have been proposed to explain the emotional Stroop effect. The first set of theories takes a resource-based perspective which suggests emotionally arousing stimuli automatically attract more attentional resources, limiting the capacity available for processing and responding to other stimuli (Bower, 1992). This in turn slows reaction time. This perspective leaves many relevant questions unanswered however. Primarily, what is the role or effect of reduced attentional resources in memory formation? A second theory suggests the emotionality of the words in the emotional Stroop task creates a threat-driven general state change in arousal. This explanation is offered because the emotional Stroop was found to only reliably occur in comparisons of trials block by emotion. Thus, the emotional Stroop effect is not found or is not nearly as strong in heterogeneous blocks containing both emotional and neutral word trials (Algom, Chajut, & Lev, 2004).

The Role of Binding Theory in Emotion and Memory

MacKay et al, (2004) addressed the resource-based perspective's questions by proposing a Binding theory using a Stroop task, a lexical decision task, and an immediate memory task. In a neutral and taboo word location-specific Stroop task, MacKay & Ahmetzanov (2005) found superior location memory for taboo relative to neutral words. The authors claim emotional reactions trigger binding mechanisms that link a specific source of emotion to salient contextual aspects such as location. In this experiment they hypothesized with respect to word location that attention and emotion 'represent the glue that helps bind features together' (MacKay & Ahmetzanov, 2005). Resource-allocation reduction theories predict that lexical decision times will be faster for taboo than neutral words. However, in the lexical decision task, MacKay et al. (2004) found no difference in lexical decision time. The results indicated that allocation of limited-capacity attentional resources to taboo words is task specific, occurring for taboo Stroop tasks, but not for lexical decision tasks. This contradicted a resource-based allocation reduction hypothesis which would have predicted longer reaction times for taboo vs. neutral words. Binding theory however, which proposes that emotional information receives priority in processing and binds with contextual representations, predicts equivalent lexical decision time results for taboo vs. neutral words because lexical decision responses are unrelated to contextual aspects of word meaning. In contrast, the color-name responses in taboo Stroop tasks require processing the font color, a salient contextual aspect of a word that elicits the help of binding mechanisms. In a lexical decision task, the response is that a taboo word is a word; there is no requirement to process contextual information.

In a third experiment MacKay et al. (2004) found impaired immediate recall of neutral words immediately before and after a taboo word in rapidly presented lists. These word-before and word-after effects also supported the binding hypothesis that taboo words capture or preempt the binding mechanisms for encoding the context of occurrence. MacKay concluded that emotion-linked stimuli engage an emotional reaction system (i.e.: the amygdala to hippocampus) that prioritizes the activation of binding nodes (words in long-term memory) based on their emotional salience for both concurrent and sequential contexts (Doerksen & Shimamura, 2001; MacKay & Ahmetzanov, 2005). Essentially this means that at fast presentation rates the brain cannot consolidate each word with its episodic context before beginning to process the subsequent word. In such cases, emotionally salient words receive priority processing. As a result, neutral words are lost from memory whereas taboo words (due to their salience) are remembered better during subsequent recall. Binding theory has since been supported by subsequent experiments using an RSVP task where memory for taboo words was better than neutral words when presented in heterogeneous lists, but not in homogeneous lists (Hadley and MacKay, 2006). To date, the predictions of binding theory have not been demonstrated beyond taboo words to other types of emotional stimuli. This provided the impetus for the current research.

Binding Theory: visual stimuli and episodic contexts. Binding theory specifies that the semantic representation of a word becomes bound to the episodic context during list learning. This distinction is important because words are complex stimuli with at least three factors: phonology, orthography, and semantics. Thus, binding theory clarifies that it is not the acoustics, phonology, or orthography factors that are bound to the

episodic context (Hadley & MacKay, 2006). The theory further explains why emotional stimuli are better recalled or recognized as a function of priority binding in memory. According to binding theory emotional stimuli are more 'important' than neutral stimuli, and this importance is functionalized by previously established direct amygdala to hippocampal links. This brief vignette explains some of the factors that may influence the 'importance' of emotional stimuli. If a young boy says a taboo word and is reprimanded by his parents, the emotional meaning of that word (as stressed by the parental reprimand) is characterized or 'flavored' by the amygdalo-hippocampal connections (also called the emotional reactive system) as 'important' and is then linked in the cortex as a part of lexical node representations (comprised of orthographic, phonological, and semantic features). When that boy subsequently encounters that word it activates the lexical node which is now linked to and activates the suprathreshold emotional reaction system as a part of the semantic representation.

Binding theory states this co-activation of the emotional reaction system gives processing priority of emotional stimuli in memory over 'less important' or neutral stimuli. Under temporal pressure, this results in delaying the processing of the neutral stimuli. Moreover, Hadley and MacKay's (2006) study using taboo words found this effect only exists in heterogeneous lists of taboo and neutral words and not homogeneous lists. This is explained by the fact that taboo and neutral words in heterogeneous lists activate different binding nodes, and it is the meaning of those nodes that activates the emotional reactive system and guides prioritization of emotional information for memory processing. In homogeneous lists, no individual word gets relative priority because all words have similar emotional linkage.

Arousal Theory in Emotion and Memory

While binding theory is the primary theory being explored in this study, it is important to consider other alternatives for how emotion affects the consolidation of memory. Arousal theory explains better memory for emotional stimuli as a function of an emotional stimulus engaging the amygdala, whereupon it releases neurotransmitters or stress hormones that act on the hippocampus to facilitate encoding of that emotional stimulus. The strength of the memory is proportional to the importance of the stimulus and associated arousal level (Cahill & McGaugh, 1998). Binding theory and arousal theory differ in that binding theory assumes no better memory recall for emotional stimuli over neutral stimuli in homogeneous presentations of only emotional or neutral stimuli (as opposed to heterogeneous presentations). Arousal theory has been supported in the threat-driven generic slowdown of processing in the emotional Stroop paradigm using the approach of Algom, Chajut, and Lev (2004).

Episodic memory for emotional stimuli. Binding theory assumes the episodic context (temporal information) of a stimulus is encoded with priority over a neutral stimulus in heterogeneous presentations of emotional and neutral stimuli. To illustrate an example of this, suppose three lists of words are presented and subjects are asked to remember all of the words possible. A subsequent memory test assesses their ability to recall the words as well as which list each word was in. Asking which list a particular word was in assesses the episodic (or temporal) context of the word.

Only a handful of studies have examined the temporal retention of information in memory using emotional visual stimuli. In one non-RSVP task subjects viewed three sets of 21 images for 2000 ms each with a 750 ms inter-stimulus interval. Between each set a

3 minute break occurred where subjects performed arithmetic operations. Subjects were asked to remember the images but were not asked to remember which set any of the images appeared. When subjects confirmed that they recognized an image, a surprise list-discrimination task was presented asking which image was in which set. The researchers found emotionally arousing images had greater temporal memory accuracy than neutral images in the list-discrimination task. This was found for both negative and positive arousing images; however negative arousing images were remembered with the most temporal accuracy (D'Argembeau & Van der Linden, 2005). The researchers concluded negative emotion affects two fundamental properties of episodic memory: memory for the place and the time at which information is acquired. Another study using a source memory paradigm found arousing negative words were remembered more than neutral words. This finding is consistent with studies on flashbulb memories (Kensinger & Corkin, 2003; Brown & Kulik, 1977). A study assessing episodic memory for color information and spatial location also found emotional information was remembered better than neutral information (Doerksen & Shimamura, 2001). Specifically in this study words were colored blue or yellow or surrounded by a blue or yellow frame and participants were asked to associate the words with the colors. In both experiments free recall was better for emotionally valenced words than neutral words. In general these studies explain the enhanced memory effect for arousing episodic information as a function of general arousal which can affect semantic elaboration, evaluative processing, or attentional modulation. This is in contrast to binding theory, which has specific predictions for emotional stimuli superiority as a function of priority-binding mechanisms when stimuli are presented at fast rates in homogeneous or heterogeneous lists (where homogeneous

lists results predict no effect of emotion). Binding theory explains that slower presentations rates, for example, 2000 ms/word, facilitate memory for emotional stimuli in two ways. First, slow presentation rates enable two types of emotion-linked binding: concurrent-context binding and sequential-context binding, enabling better recall of emotional stimuli (see Hadley and MacKay, 2006, for more details). Second, rehearsal strategies may be employed in free recall paradigms (see Rundus, 1971). As such, these studies have not used a paradigm similar to Hadley and MacKay (2005) to demonstrate what may happen to memory for temporal information at fast presentation rates, providing further impetus to determine the effects of emotion on temporal memory for visual stimuli in an RSVP task.

Emotional Stimuli: Measurement and Classification

At this point it is important to understand how researchers classify and categorize emotional stimuli for measurement purposes. One common approach, in the tradition of the Semantic Differential (Osgood, Suci, and Tannenbaum, 1957), characterizes emotional stimuli such as words or images on dimensions of arousal and emotional valence. Arousal refers to the degree to which a stimulus produces or represents a feeling of excitation or activation as opposed to calm. Valence refers to the degree of attractiveness or pleasantness as opposed to unpleasantness of the stimulus. When referring to a 'neutral' stimulus in the literature, researchers are typically referring to a stimulus as having moderate valence (neither strongly pleasant nor unpleasant) and low arousal, unless specified otherwise. Arousal and valence of stimuli often have standardized ratings such as International Affective Picture System, or IAPS (Lang,

Bradley, Cuthbert, 1999), and the Affective Norms for English Words, or ANEW

(Bradley and Lang, 1999).

Major Hypotheses, Aims, and Significance

Rationale: One of the major questions that remain unanswered by binding theory is: do the assumptions of binding theory apply outside the realm of taboo words? If binding theory applies to emotional visual images presented at sufficiently fast rates the recognition frequency of high arousal images should not statistically differ from low arousal images presented in homogeneous lists. Furthermore, binding theory predicts a prioritization of temporal information for high arousal visual stimuli over low arousal visual stimuli in heterogeneous lists. Previous research suggests temporal information for arousing images should be more accurate than non-arousing images (D'Argembeau & Van der Linden, 2005), but this has not been tested using homogeneous lists at presentation rates faster than 2000 ms. Binding theory would predict in parallel with recognition that for these homogeneous lists that there would be no difference in temporal recognition of high arousal versus low arousal images.

Hypotheses

Therefore, in line with the predictions of binding theory, the major hypotheses of the current research were:

There will be no statistical difference in memory performance between lists composed only of negative high arousal images and lists composed only of neutral low arousal images when the images are presented using an RSVP paradigm and memory is tested using (a) an image recognition task, and (b) a list-discrimination task to assess temporal order information.

Research into memory and emotion generally suggests arousing visual stimuli are better remembered than non-arousing visual stimuli (D'Argembeau & Van der Linden, 2005). D'Argembeau & Van der Linden also reported that temporal information for negative arousing stimuli was better remembered than neutral or positive visual stimuli. Hadley and MacKay's work using taboo words suggests a memory superiority effect of taboo words over neutral words at fast presentation rates. They further propose a general priority-binding theory where emotionally linked stimuli activate an emotional reaction system which prioritizes the binding nodes in memory relative to the conceptual representation of the perceived stimuli (Hadley & MacKay, 2006). To date there have been no reports regarding the use of RSVP tasks using visual stimuli in homogeneous and heterogeneous lists to test the assumptions of a general priority-binding theory and this study seeks to address this lack of research.

To accomplish this goal, visual stimuli were selected based on valence and arousal from the International Affective Picture System (Lang, Bradley, & Cuthbert, 1999) and organized into three sets of two lists, one negative high arousal list and one neutral low arousal list. The purpose of creating three sets of lists was to assess temporal memory by asking in which set an image was presented. Furthermore, the binding theory assumption of approximately equal recognition rates in homogeneous lists of images were assessed in a RSVP followed by a recognition memory task.

Two memory assessments were used. In the recognition memory task participants were asked if they had seen the image before or not. This was then followed by a confidence rating. Information for temporal memory was assessed using a list discrimination task which occurred after all the images were viewed in the recognition

task. Only images presented during the study phase were presented for the list-discrimination task. Participants were asked in which set each image was presented. This was followed by a confidence rating. Participants were not warned they would be tested for temporal information prior to the list-discrimination task.

This study was designed to test the predictions of binding theory using visual images and assessing recognition and temporal memory for negative and neutral images in homogeneous lists.

Research Design and Methods

Participants

Participants (*N = 48)* were recruited from undergraduate subject pools at La

Sierra University and California State University, San Bernardino. Participants received

credit which could be applied toward their course in exchange for their participation in

the study.

Power Analysis

Using mean proportions of temporal memory performance from similar research

(D'Argembeau & Van der Linden, 2005) to guide expected outcomes, a power analysis

was conducted to determine an appropriate sample size for this study. It was determined

that 48 participants would be necessary to achieve a power of .9 with alpha set at .05 to

detect significant results for an effect size of .5.

Materials

Stimuli comprised of 54 negative and 54 neutral pictures which were selected

from the IAPS (Lang, Bradley, & Cuthbert, 1999). Selection of images was based on the

normative ratings with negative images having unpleasant valence (< 4) and high arousal

(> 5), and neutral images having intermediate valence (> 4.5 and < 6.3) and low arousal

(< 3.5). The mean valence for negative and neutral pictures was 2.13 (*SD* = 0.65) and

4.97 (*SD* = 0.49), respectively.

Procedure

Participants were tested individually while sitting eye level facing a computer monitor (Dell 17inch CRT, refresh rate 75 Hz) at approximately 62 centimeters distance in a quiet, air-conditioned room. The stimuli were presented with a full screen resolution display of 1028x786 with a viewing angle of 36.3°. To avoid emotional arousal or alert prior to the experiment no practice trials were presented. Participants were carefully instructed as to the nature of the task to ensure accurate comprehension. The task, presented using E-Prime 2.0 beta (Psychological Software Tools, Pittsburgh, PA) consisted of 3 blocks with two lists per block (one negative and one neutral; list sequence in each block was randomized across participants; See Figure 1 for details). Each trial began with a 1000 ms centered fixation cross followed by the pictures with display duration of 500 ms for each picture. After each picture a black screen inter-stimulus interval of 500 ms was presented. At the end of each list another centered fixation cross was presented for 1000 ms. (See Figure 2 for a five picture example of the task; note: lists in the actual task consist of 9 images).
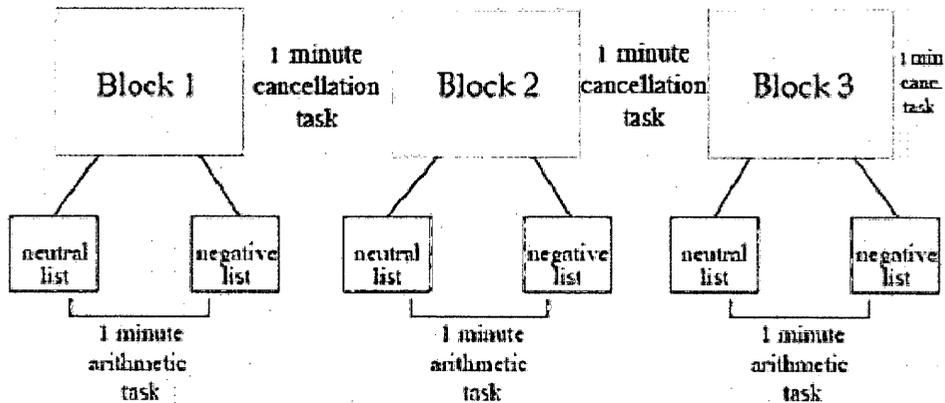
Block and list sequence are randomized.
Each subject will see 3 blocks, each block composed of two lists one negative and one neutral.
No picture is displayed more than once throughout the studied task.

Figure 1. Experimental design of the studied task consisting of neutral and negative images in 3 randomized blocks. Each block consisted of a randomly presented neutral and negative list containing 9 neutral or negative images.
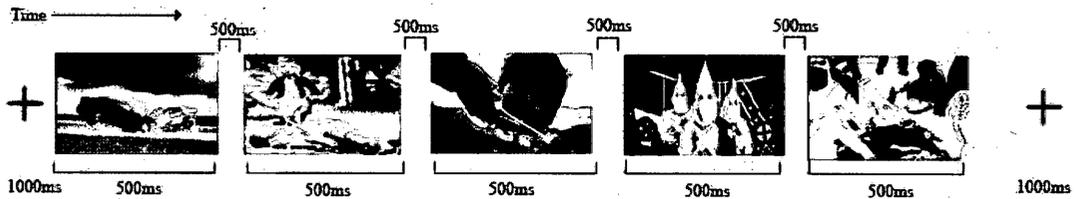
Figure 2. Presentation of the RSVP Task (Note: each list consisted of 9 images).

For each participant, the two groups of 54 negative and neutral pictures were randomly ordered with one half of each group presented during the study phase and the other reserved for 'new' pictures. Thus, each participant received a unique random ordering of each study list, which was then compared against the 'new' images in the recognition test. That is, after randomly ordering all 54 images, the first block lists were the first 9 images, and so on. The study phase was comprised of three blocks of images with each block containing two homogeneous lists, one containing 9 negative and the

other 9 neutral images (see Figure 1). List presentation sequence for each block was randomized (negative first or neutral first) for each block across participants. Each image was displayed no more than once in the study phase.

At the end of the first list in each block participants completed a 1-minute pen and paper arithmetic task (a series of multiplications involving 2-digit numbers) to prevent image rehearsal. After 55 seconds the computer sounded a 5 second warning beep that the second list was about to be presented. Following the second list, a 1-minute pen and paper cancellation task (task involved crossing out a chosen letter among distracter letters) was presented. At the end of 55 seconds a 5 second warning beep sounded, signaling the beginning of next block. The presentation of the second and third blocks was identical to the first.

Following the 1-minute cancellation task at the end of the third block, a recognition task similar to D'Argembeau & Van der Linden's (2005) design was presented. In this task each of the 108 images (the 54 images presented during the study phase plus the 54 not-presented images) was displayed in random order and participants were asked to press 1 on the keyboard if they had seen it in one of the lists and 9 if they had not. For all images a question was presented regarding how confident they were that they had seen the image (3-point scale: 1 = not very sure; 2 = somewhat sure; 3 = very sure). Following the recognition task participants were then shown the 54 images actually presented during the study phase and asked in which block each image was shown (block 1, 2, or 3). Participants were also asked how confident they were of this temporal recollection (See figure 3 for a diagram of the recognition/list-discrimination task). Participants were instructed before the task to remember the images, but were not told

they were asked to remember which block the images were in. Thus, participants were asked after the recognition task if they suspected they would be asked to remember which block each image was in. This was done to determine if rehearsal of image by block could confound the results. Finally, participants were asked to rate all of the images they viewed on valence and arousal using the Self-Assessment Manikin (Lang et al, 1999). These ratings were then compared to the IAPS normative ratings.
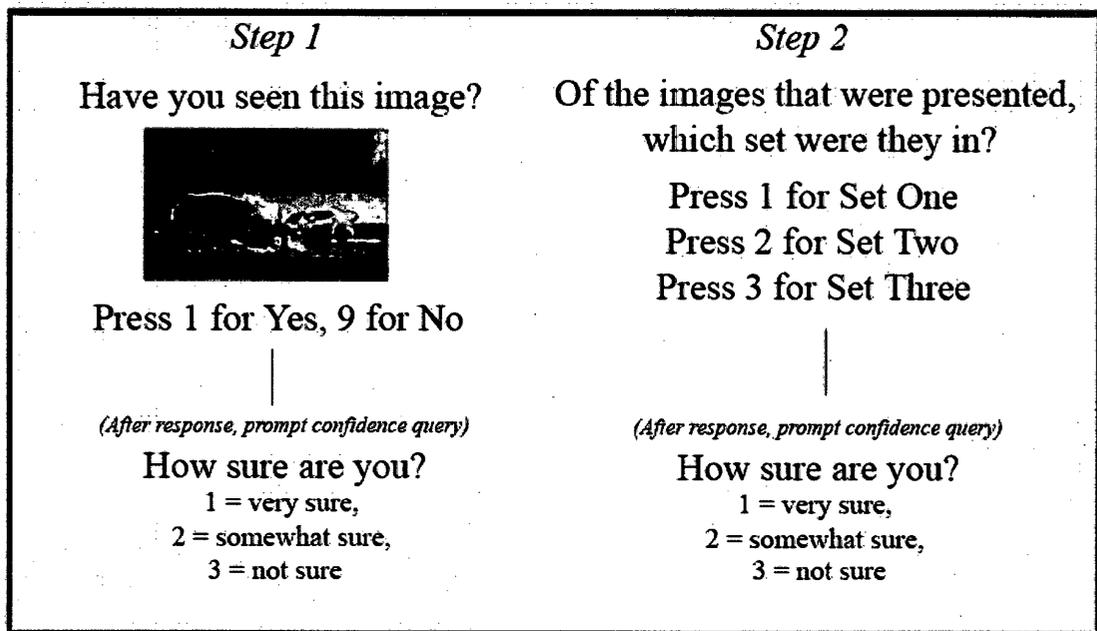
Figure 3. Recognition and List Discrimination Task. In Step 1 subjects' recognition memory was assessed and in Step 2 subjects' temporal memory was assessed.

Results

Recognition Memory Task

Mean proportions of correctly recognized negative and neutral images were of particular interest in this study. To determine if the predictions of binding theory generalize to homogeneous lists of visual stimuli, item recognition memory was analyzed with a paired samples t-test to determine if any significant differences between negative and neutral image-recognition occurred. Consistent with the predictions of binding theory for homogeneous lists, the recognition memory task revealed no significant difference between negative and neutral images, $t(47) = 0.276$, $p = .78$ (Figure 4) ($Ms = 0.878$, 0.876 for negative images and neutral images, respectively). A repeated measures 2 (accuracy) x 2 (valence) ANOVA was then conducted to examine the confidence ratings among subjects for their recognition memory. As expected, subjects were significantly more confident for correctly recognized images, $F(1,47) = 76.04$, $p < .001$ (Figure 5). Neither the main effect nor the interaction involving valence was significant (Table 1).

Figure 4. Mean proportions of recognition memory
performance indicated no statistical difference for
neutral or negative images.

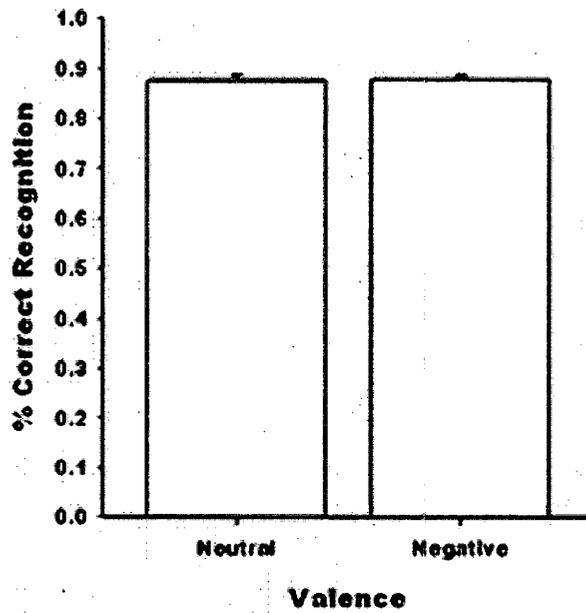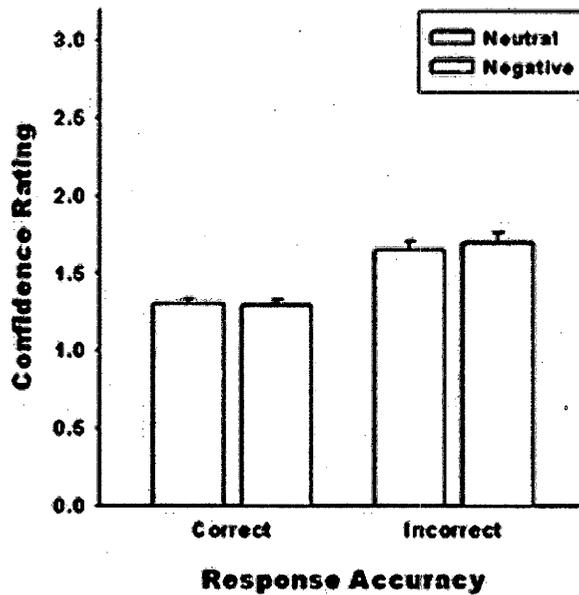*Figure 5*. Mean confidence ratings for recognition
memory performance revealed subjects were more
confident for their correct responses with no significant
effect of valence and no significant interaction.

Table 1

*Analysis of Variance for Recognition Confidence Ratings displaying Degrees of
Freedom, Mean Squares, F values and p-values (Within Subjects)*

			Confidence Rating	
Source	Df	MS	F	p-value
Accuracy (A)	1	6.91	76.04	0.001*
Valence (V)	1	0.017	0.26	0.611
A * V	1	0.034	0.64	0.425
Error	47	0.052		

* $p < .01$

Temporal Memory Task

Temporal memory was analyzed using a paired samples *t*-test to determine if

valence was associated with any significant differences in the mean proportion of

correctly remembered temporal items. A result similar to the recognition memory task

was found for the temporal memory task, $t(47) = 0.485$, $p = .63$ (Figure 6). Consistent

with the predictions of binding theory, temporal memory for visual images did not differ

between negative and neutral images (*Ms* = 0.395, 0.406 for negative and neutral images,

respectively). A repeated measures 2 (accuracy) x 2 (valence) ANOVA was conducted to

examine the confidence ratings among subjects for their temporal memory. As expected,

subjects were more confident in their ratings for correctly remembered items, $F(1, 47) =$

18.224, $p < .001$ (Figure 7). An unexpected finding however, was a main effect of

valence. Subjects were more confident of responses for neutral items in the temporal

memory task, $F(1, 47) = 5.447$, $p = 0.024$. The interaction effect was not significant (Table 2).
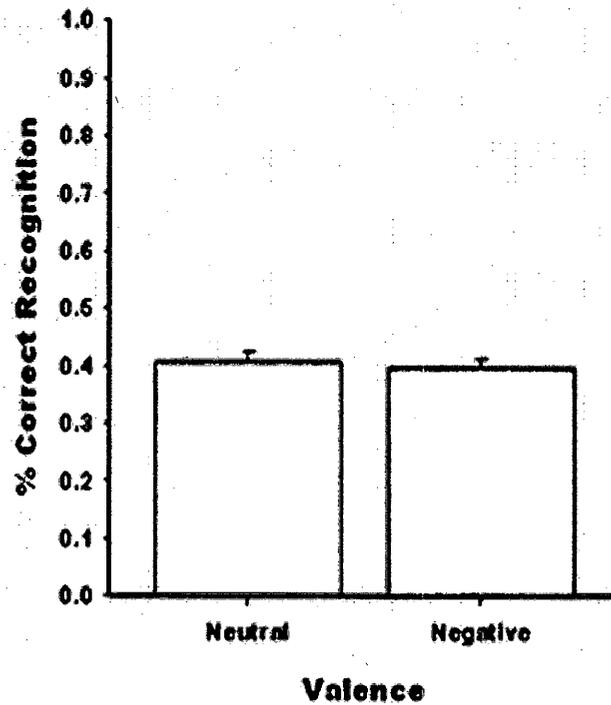
Figure 6. Mean proportions of temporal memory performance indicated no significance differences between neutral and negative images.
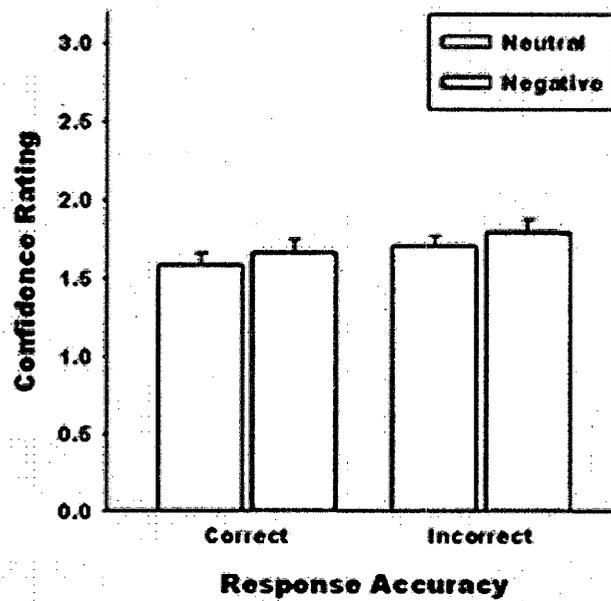
Figure 7. Mean confidence ratings for temporal memory performance indicated subjects were more confident for correct responses with a main effect of valence (higher confidence for neutral over negative images). The interaction was not significant.

Table 2

Analysis of Variance for Temporal Confidence Ratings displaying Degrees of Freedom, Mean Squares, F values, and p-values (Within Subjects)

			Confidence Rating	
Source	Df	MS	F	p-value
Accuracy (A)	1	0.753	18.22	0.001*
Valence (V)	1	0.361	5.447	0.024**
A * V	1	0.001	0.03	0.854
Error	47	0.034		

* p < .01, **p < .05.

Emotion Ratings

Mean ratings of pictures for valence and arousal are presented in Table 3. As expected, negative pictures (as compared to neutral) were rated as significantly more negative and arousing, $t's(36) > 10.24$, $p's < .001$. The ratings obtained are similar to the normative IAPS ratings (see Table 4).

Table 3

Mean Ratings of IAPS Images displaying Means, Standard Deviations, Confidence Intervals, and Standard Errors

	Mean	Std. Dev.	CI 95%	Std. Error
Valence Negative	2.21	0.86	0.33	0.13
Valence Neutral	5.28	1.06	0.33	0.16
Arousal Negative	6.47	1.06	0.49	0.16
Arousal Neutral	3.22	1.61	0.53	0.25

Note: Valence ratings are rated unpleasant to pleasant (1-9); Arousal ratings are rated calm to excited (1-9); Ratings are from 40 subjects.

Table 4

Mean Normative Ratings of Selected IAPS Images displaying Means and Standard Deviations

	Mean	Std. Dev.
Valence Negative	2.13	1.03
Valence Neutral	4.98	0.56
Arousal Negative	6.21	0.66
Arousal Neutral	2.63	0.16

Note: Valence ratings are rated unpleasant to pleasant (1-9); Arousal ratings are rated calm to excited (1-9); Mean ratings are from 54 negative and 54 neutral IAPS images (Lang, Bradley, Cuthbert, 1999).

Other Findings

Sixty-five percent of subjects (31 out of 48) reported that they did not expect their temporal memory to be tested. No significant differences in temporal memory performance were found for those subjects who expected their temporal memory to be tested and those who did not, $F(46) < 1, p = 0.658$. The interaction effect was not significant (Table 5).

Table 5

Analysis of Variance for Temporal Memory Anticipation Question displaying Degrees of Freedom, Mean Squares, F values, and p-values

			Confidence Rating	
			Between Subjects	
Source	df	MS	F	p-value
Yes/No	1	0.003	0.199	0.658
Error	46	0.016		
			Within Subjects	
Valence	1	0.002	0.177	0.676
Valence * Yes/No	1	0.000	0.018	0.894
Error	46	0.012		

Note: Yes/No is whether or not subjects anticipated having their temporal memory tested; Valence is mean proportions of negative and neutral memory performance.

Discussion

Recognition Memory

The results provide a clear distinction between the contrasting predictions outlined in the introduction. The assumption of arousal theory that a general threat-induced state change (Algom et al., 2004) is responsible for differential processing of negative and neutral stimuli in homogeneous lists was not demonstrated in the present results. Arousal theory in the context of this study would suggest an emotional reaction system activates the amygdala to release neurochemicals that aid in the consolidation of emotional stimuli in memory (via the hippocampus), as long as the stimuli are not repression prone or overly traumatic (although many scholars debate this notion). Importantly, arousal theory predicts that this effect would occur equivalently in homogeneous lists and heterogeneous lists. That no significant differences were found for recognition memory performance contradicts the prediction of a general threat-induced effect but does support the predictions for homogeneous lists derived from binding theory (Hadley and MacKay, 2006). The present results suggest a different mechanism is at work than the arousal theory amygdala-triggered encoding process. As outlined in the introduction for binding theory, word meaning triggers emotional reactions unlike in arousal theory, in which sensory- rather than semantic-level inputs can directly engage the amygdala. As the current results suggest, the homogeneous list paradigm is not subject to prioritization of binding resources because the neutral stimuli lack links to the amygdala for triggering strong emotional reactions under binding theory.

As expected, subjects were also more confident in their ratings of correctly recognized images, with no effect of valence for negative or neutral images. This suggests that subjects were able to confidently discriminate between new and old images regardless of valence. Arousal theory would not predict a lack of an effect for valence, as negative images would be predicted to receive more elaborate processing causing a rise in negative image confidence ratings. Because this did not occur, the results do not favor the predictions of arousal theory. In contrast, binding theory suggests that similar episodic links are commensurate with the level of processing which occurred. The prediction might be that if negative images were given more elaborate processing, negative image confidence ratings would rise. The current results in turn favor the predictions of binding theory.

Temporal Memory

The present results are consistent with the assumptions of binding theory that sequential information is encoded with equal weight when similar binding nodes are activated in the cortex (as in homogeneous lists of negative or neutral images). The lack of a significant difference for temporal memory performance between negative and neutral images are in contrast to the findings of D'Argembeau & Van der Linden's (2005), who found that negative images were better recognized than neutral images and that list discrimination was better for negative images. Remember that this study differed from D'Argembeau and Van der Linden; they used heterogeneous lists and a slower presentation rate (2000 ms compared to 500 ms). Binding theory suggests that this slower presentation rate may have facilitated, rather than interfered with, memory for emotional images through concurrent-context binding and sequential-context binding. Concurrent-

context binding is memory for a particular stimulus that occurred in a list and sequential-context binding is memory for a particular stimulus's immediate neighbors in a list. Until research utilizing a RSVP heterogeneous list design is conducted, it is difficult to determine if the predictions of binding theory adequately explain the results of D'Argembeau and Van der Linden 2005 study.

An unexpected result for this study was that subjects indicated greater confidence in their ratings for neutral images in the temporal memory task. The basis for this result is not clear; if this is not a chance result, we might speculate that it reflects a greater subjective confidence that the temporal location of the negative stimuli was not known or that subjects did not remember as many negative images (but not significantly so) (mean proportions for temporal memory were $M = 0.395$ and 0.406 for negative images and neutral images, respectively). One speculation is that the emotional arousal may have induced some similarities and therefore interference among the emotional pictures. This would minimize their distinctiveness, which in turn may render list-discrimination more difficult than for neutral pictures. Previous research investigating the Remember/Know paradigm has found that neutral images were recollected with greater confidence than negative or positive images (Aupee, 2007). However, even in that study, the result was presented with caution. In contrast are several studies which have found an enhancement effect for emotional images. These studies suggest that negative images are encoded more distinctively than neutral ones, and more contextual information is available for subsequent recollection (the thoughts or emotions they have while viewing the pictures or color and spatial location) during the Remember/Know task (e.g., Dewhurst & Parry, 2000; Kensinger & Corkin, 2003; Ochsner, 2000). Within the context of binding theory,

these studies did not employ rapid RSVP homogeneous lists, reflecting their findings for enhanced recollection of emotional stimuli and higher confidence ratings for emotional stimuli.

General Discussion

The present results are difficult to explain using the predictions of arousal theory. In contrast to arousal theory, recognition and temporal memory performance in this study were not superior for negative images. An important question is whether or not the experimental manipulation of image valence was successful in creating an affective response strong enough to create any differences in recognition memory. If the emotional stimuli were not strong enough to elicit an affective response, perhaps this lack of an affective response could account for the lack of statistical significant in the recognition memory condition. That is, for all intents and purposes the images would not have differed on perceived valence and this in turn could explain why the present results were not supportive of arousal theory. However, subjective ratings of the images demonstrated that negative images were rated as negatively arousing and unpleasant, while neutral images were not arousing and emotionally benign, suggesting the negative stimuli were arousing enough to create an affective response. Moreover, physiological measures (that is, phasic heart rate responses not included in this thesis) indicated differential responding to negative and neutral images.

Some may argue that the graphic nature of some of the IAPS images may be repression prone and that some participants may have found the images so disturbing that they may have blocked them out of their minds, preventing accurate memory retrieval. This threat to internal validity was not supported however, given the statistically

insignificant difference of means in both recognition and temporal memory. Moreover, recognition performance was actually very good (87-88%), which would not be expected if much repression had occurred.

The image presentation rate of 500 ms was chosen for the current study based on the design and results of Akyurek & Hommel (2005). Presenting images too fast may have resulted in the attentional blink (AB) phenomenon; however the high proportions of images correctly recognized provide no evidence of a floor effect. Subjects correctly recognized (condensing neutral and negative images), on average, 87.7% of the images. This result is consistent with other studies of human recognition memory. In a larger study consisting of 600 pictures, researchers found human recognition memory rates of 90%, 92%, and 98% (Shepard, 1967) between old and new pictures. D'Argembeau and Van der Linden (2005) found recognition memory performance rates of 89%, 84%, and 77% for negative, positive, and neutral images, respectively. This suggests that the proportions of correctly recognized images in this study are consistent with human recognition memory performance. Given the extremely small effect size found for recognition memory ($d = 0.024$), I am reasonably confident that this thesis had sufficient power to detect any significant effects of emotion on recognition memory.

The temporal memory performance rates in this study were below those reported by D'Argembeau and Van der Linden (2005). The mean proportions in this study were $M = 0.395$ and $M = 0.406$ for negative and neutral images, respectively. I speculate the lower mean proportions of correctly identified temporal memory items are due to interference effects from the recognition memory task. In this study, I presented the temporal memory task after the recognition memory task. D'Argembeau and Van der

Linden's (2005) study presented the temporal memory task after a subject claimed to recognize an image. This difference in design may explain the lower temporal memory performance as a function of an interference effect (Brown, 2007). Given the extremely small effect size found for temporal memory ($d = 0.08$), I am reasonably confident that there was sufficient power to detect any significant effects of emotion on temporal memory.

One design limitation of this study is that we are unclear if subjects were able to use a verbal-encoding strategy to remember the images. Rehearsal strategies could have allowed subjects to selectively rehearse some images at the expense of others. To prevent rehearsal strategies I incorporated arithmetic and cancellation tasks (between lists and blocks, respectively). Also, previous research suggests that the 500 ms presentation rate of the images should be sufficient to prevent any verbal-encoding strategies (Morey and Cowan, 2005). As stated before, our recognition memory performance rates were consistent with previous studies, suggesting that if any rehearsal strategies were employed, they did not significantly alter the results.

Of note is also the type of stimuli used in this study. Images varied across pictures of animals, abstract designs, humans, common objects, and landscapes. Wolfe et al. (2007) reported that visual attention modulates memory performance. It is likely attention varied with arousal during list presentation but it is unknown in this study if the type of images used may have had any effects on memory as a function of increased visual attention for any salient features of the presented images. I speculate that selective visual attention did not significantly affect memory performance however, given the lack of statistical difference between mean proportions of recognition and temporal memory

performance for neutral and negative pictures. Statistical tests could determine if memory performance did differ for image type (humans, landscape, animals, etc) if we had more images from each category. Given the small number of images in each category and the diversity of the images selected, this sort of comparison is not feasible.

The general aim of this study was to better understand the mechanisms of recognition and temporal memory consolidation for negative and neutral visual images. The present results do not favor the predictions of arousal theory but also do not prove that binding theory is responsible for the lack of differences found for recognition and temporal memory. Supporting evidence of the general application of binding theory would come from recognition and temporal performance with positive images as compared to neutral and negative images in homogeneous lists. To determine if binding theory adequately explains our results in this paradigm, replication of Hadley and MacKay's (2006) experiment 2, using a heterogeneous list paradigm, is necessary. In a heterogeneous list paradigm we would expect the priority-binding assumption of binding theory to apply to negative images and possibly positive images (i.e. increased memory performance in recognition and temporal memory for emotional images). These are the goals of the next stages this project.

References

Algom, D., Chajut, E., & Lev, S. (2004). A rational look at the emotional stroop phenomenon: A generic slowndown, not a stroop effect. *Journal of Experimental Psychology: General, 133(3)*, 323-338.

Akyurek, E.G., & Hommel, B. (2005). Short-term memory and the attentional blink: Capacity versus content. *Memory and Cognition, 33(4)*, 654-663.

Aupee, A.M. (2007). A detrimental effect of emotion on picture recollection. *Scandinavian Journal of Psychology, 48*, 7-11.

Bahrick, H.P, Bahrick, P.O, & Wittlinger, R. P. (1975). Fifty years of memory for names and faces: A cross-sectional approach. *Journal of Experimental Psychology: General, 104*, 54-75.

Bower, G. H. (1992). How might emotions affect learning? In S. Christianson (Ed.), *Handbook of emotion and memory: Research and theory* (pp. 3-32). Hillsdale, NJ: Erlbaum.

Bradley, M. M. & Lang, P. J., (1999). *Affective Norms for English Words: Instruction manual and affective ratings*. Gainesville: The Center for Research in Psychophysiology, University of Florida.

Brown, G. (2007). A temporal ratio model of memory. *Psychological Review, 114(3)*, 539-576.

Brown, R. (1958). Some tests of the decay theory of immediate memory. *Quarterly Journal of Experimental Psychology, 10,* 12-21.

Brown, R., & Kulik, J. (1977). Flashbulb memories. *Cognition, 5*, 73–99.

Cahill, L., & McGaugh, J. L. (1998). Mechanisms of emotional arousal and lasting declarative memory. *Trends in Neuroscience, 21,* 294–299.

Conway, M.A., Anderson, S.J., Larsen, S.F., Donnelly, C.M., McDaniel, M.A., McClelland, A.G.R., & Rowles, R.E. (1994). The formation of flashbulb memories. *Memory & Cognition*, 22, 326–343.

D'Argembeau, A., & Van der Linden, M. (2005). Influence of Emotion on Memory for Temporal Information. *Emotion, 5(4)*, 503-507.

Dalgleish, T., & Watts, F. N. (1990). Biases of attention and memory in disorders of anxiety and depression. *Clinical Psychology Review*, 10, 589-604.

Dewhurst, S. A., & Parry, L. A. (2000). Emotionality, distinctiveness, and recollective experience. *European Journal of Cognitive Psychology, 12,* 541–551.

Doerksen, S., & Shimamura, A. P. (2001). Source memory enhancement for emotional words. *Emotion, 1,* 5–11.

Hadley, C.B., & MacKay, D.G. (2006). Does emotion help or hinder immediate memory? Arousal Versus Priority-Binding Mechanisms. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 32(1), 79-88.

James, W. (1890). *The principles of psychology.* Pages 403-404. Cambridge, MA: Harvard University Press.

Kandel, E.R. (2001). The molecular biology of memory storage: A dialogue between genes and synapses. *Science, 294,* 1030-1038.

Kensinger, E., Clarke, R.J., & Corkin, S. (2003). What neural processes support encoding and retrieval? An fMRI study using divided attention paradigm. *Journal of Neuroscience,* 33, 2407-2415.

Koster, M.A., Prescot, J., Koster, E.P. (2004). Incidental learning and memory for three basic tastes in food. *Chemical Senses,* 29(5), 441-453.

LaBar, K.S., & Phelps, E.A. (1998). Arousal-mediated memory consolidation: Role of the medial temporal lobe in humans. *Psychological Science,* 9, 490–493.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). *International affective picture system (IAPS): Instruction manual and affective ratings* (Tech. Rep. No. A-4). Gainesville: The Center for Research in Psychophysiology, University of Florida.

LeDoux, J.E. (1992). Brain mechanisms of emotion and emotional learning. *Current Opinion in Neurobiology, 2,* 191-197.

LeDoux, J.E. (2000). Emotion Circuits in the brain. *Annual Review of Neuroscience, 23,* 155-184.

MacKay, D. G., & Ahmetzanov, M., V. (2005). Emotion, memory, and attention in the taboo Stroop paradigm: An experimental analog of flashbulb memories. *Psychological Science, 16,* 25–32.

MacKay, D. G., Shafto, M., Taylor, J. K., Marian, D. E., Abrams, L., & Dyer, J. R. (2004). Relations between emotion, memory, and attention: Evidence from taboo Stroop, lexical decision, and immediate memory tasks. *Memory & Cognition, 32,* 474–488.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109,* 163-203.

MacLeod, C. M., & Hodder, S. L. (1998). On the difficulty in obtaining priming effects in the Stroop task. *Abstracts of the Psychonomic Society*, 3, 37.

McKenna, F. P., & Sharma, D. (1995). Intrusive cognitions: An investigation of the emotional Stroop task. *Journal of Experimental Psy-chology: Learning, Memory, & Cognition*, 21, 1595-1607.

Mendl, M. (1999). Performing under pressure: Stress and cognitive function. *Applied Animal Behavior Science, 65(3),* 221-244.

Miles, C., & Hodder, K. (2005). Serial position effects in recognition memory for odors: A reexamination. *Memory & Cognition,* 33(7), 1303-1314.

Morey, C.C., & Cowan, N. (2005). When do visual and verbal memories conflict? The importance of working-memory load and retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 31(4), 703-713.

Neisser, U., Winograd, E., Bergman, E.T., Schreiber, C.A., Palmer, S.E., & Weldon, M.S. (1996). Remembering the earthquake: Direct experience vs. hearing the news. *Memory*, 4, 337–357.

Ochsner, K. N. (2000). Are affective events richly recollected or simply familiar? The experience and process of recognizing feelings past. *Journal of Experimental Psychology: General*, 129, 242–261.

Ochsner, K. N., & Schacter, D. L. (2003). Remembering emotional events: A social cognitive neuroscience approach. In R. J. Davidson, K. R. Scherer, & H. H. Goldsmith (Eds.), *Handbook of affective sciences* (pp. 643–660). Oxford, England: Oxford University Press.

Osgood, C., Suci, G.J., & Tannenbaum, P.H. (1957). *The measurement of meaning.* Oxford, England: University of Illinois Press.

Pavlov, I.P. (1928). *Lectures on conditioned reflexes* (W.H. Gantt, Trans.). New York: International Publishers.

Petrusic, W.M., & Dillon, R.F. (1972). Proactive interference in short-term recognition and recall memory. *Journal of Experimental Psychology,* 95(2), 412-418.

Reales, J.M., & Ballesteros, S. (1999). Implicit and explicit memory for visual and haptic objects: Cross-modal priming depends on structural descriptions. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 25(3), 644-663.

Reisberg, D., & Hertel, P. (2004). *Memory and emotion.* Oxford, England: Oxford University Press.

Roediger, H.L, & McDermott, K.B. (1995). Creating false memories: remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 21(4), 803-814.

Rundus, D. (1971). Analysis of rehearsal processes in free recall. *Journal of Experimental Psychology,* 89, 63-77.

Sharma, D., & McKenna, F. P. (2001). The role of time pressure on the emotional Stroop task. *British Journal of Psychology,* 92, 471-481.

Shepard, R. (1967). Recognition memory for words, sentences, and pictures. *Journal of Verbal Learning and Verbal Behavior,* 6, 156-163.

Siegrist, M. (1995). Effects of taboo words on color-naming performance on a Stroop test. *Perceptual & Motor Skills,* 81, 1119-1122.

Sperling, G. (1960). The information available in brief visual presentation. *Psychological Monographs, 74,* 29.

Talarico, J.M., & Rubin, D.C. (2003). Confidence, not consistency, characterizes flashbulb memories. *Psychological Science,* 14, 455–461.

Terry, S. W. (2006). *Learning and Memory.* Boston, MA: Pearson Education.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychology, 26,* 1-12.

Wang, M., & Chang, H. (2004). The mere exposure effect and recognition memory. *Cognition & Emotion,* 18(8), 1055-1078.

Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin,* 120, 2-24.

Wolfe, J.M. (2007). Is visual attention required for robust picture memory? *Vision Research,* 47, 955-964.

Yerkes, R.M. & Dodson, J.D. (1908) The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology,* 18, 459-482.