Loma Linda University

TheScholarsRepository@LLU: Digital Archive of Research, Scholarship & Creative Works

Loma Linda University Electronic Theses, Dissertations & Projects

3-2014

Emotional Memory: The Effects of Temporal Pressure on Episodic Memory

Audrey E. Martinez

Follow this and additional works at: https://scholarsrepository.llu.edu/etd

Part of the Clinical Psychology Commons

Recommended Citation

Martinez, Audrey E., "Emotional Memory: The Effects of Temporal Pressure on Episodic Memory" (2014). *Loma Linda University Electronic Theses, Dissertations & Projects*. 279.
https://scholarsrepository.llu.edu/etd/279

This Thesis is brought to you for free and open access by TheScholarsRepository@LLU: Digital Archive of Research, Scholarship & Creative Works. It has been accepted for inclusion in Loma Linda University Electronic Theses, Dissertations & Projects by an authorized administrator of TheScholarsRepository@LLU: Digital Archive of Research, Scholarship & Creative Works. For more information, please contact scholarsrepository@llu.edu.

LOMA LINDA UNIVERSITY
School of Behavioral Health
in conjunction with the
Faculty of Graduate Studies

Emotional Memory:
The Effects of Temporal Pressure on Episodic Memory

by

Audrey E. Martinez

A Thesis submitted in partial satisfaction of
the requirements for the degree
Doctor of Philosophy in Clinical Psychology

March 2014

© 2014

Audrey E. Martinez
All Rights Reserved

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 Doctor of Philosophy.

____, Chairperson
Paul E. Haerich, Professor of Psychology

____
Brian J. Distelberg, Assistant Professor of Counseling and Family Science

____
Richard E. Hartman, Associate Professor of Psychology

ACKNOWLEDGEMENTS

I would like to thank my mentor Dr. Haerich for patiently providing me with support and guidance throughout this entire process. I could not have done this work without you. Working with you has been an incredible learning journey and I am eager to continue to work in your lab. I would also like to express thanks to my committee members Dr. Distelberg and Dr. Hartman for their time and commitment to this project.

I would like to thank my mother Judy for encouraging me to succeed in life and providing a loving and warm home. I would like to thank Sienna for being such a wonderful daughter who has patiently waited for me to finish graduate school. Finally, I would like to thank my husband Daricio for his endless support and belief in me. I would not be have been able to chase my dreams without your loving presence beside me.

CONTENT

Approval Page iii

Acknowledgements iv

List of Figures vii

Abstract viii

Chapter

1. Introduction 1

2. Literature Review 4

    Binding Theory 4

        Sequential Binding Theory: Forward and Backward Contextual Effects 5

    Contribution of Valence and Arousal 7
    Emotional Effects on Attention and Memory 9

        Emotion Enhanced Attention and Processing 9
        Emotion and Memory: Benefits and Costs 11

    Physiology of Enhanced Memory 13
    Time as a Factor of Emotion Enhanced Memory 14
    Assessing Emotional Memory in Recognition Tasks 15

3. Specific Aims and Hypotheses 19

    Aim 1 20

        Hypothesis 1 20
        Hypothesis 2 20

    Aim 2 20

        Hypothesis 3 21
        Hypothesis 4 21

    Aim 3 21

Hypothesis 5 21

4. Methods 22

Participants 22
Materials 22
Procedure 23
Data Analysis 24

5. Results 26

Recognition Accuracy 26
Sensitivity and Bias 27
Context: Backward and Forward Contextual Effects 29

Backward Contextual Effects 29
Forward Contextual Effects 31

6. Discussion 32

References 42

Appendices

A. ANOVA Tables of Dependent Variables 48

B. List of IAPSA Images 50

FIGURES

Figures Page

1. Distribution of IAPS Images in Affective Space 8
2. Stimulus Presentation of Mixed and Pure Lists 23
3. Recognition Accuracy for Valence, List type and Rate 27
4. Sensitivity for Valence, List type and Rate 28
5. Bias for Valence, List Type and Rate 29
6. Image accuracy of pictures preceding context pictures 30
7. Image accuracy of pictures following context pictures 31

ABSTRACT OF THE THESIS

Emotional Memory:
The Effects of Temporal Pressure on Episodic Memory

by

Audrey E. Martinez

Masters of Arts, Graduate Program in Clinical Psychology
Loma Linda University, March 2014
Paul Haerich, Ph.D., Chairperson

Priority Binding theory (MacKay et al., 2004) proposes that under temporal pressure arousing negative stimuli delay binding of neutral items presented in close temporal proximity (as in lists with mixed neutral and negative stimuli). With fast presentation rates, a subsequent negative item may interrupt the binding process for the preceding neutral stimulus. This results in more accurate memory for negative images presented in mixed lists. However, in slow presentation rates, binding occurs equally for all items. Therefor, no such advantage is predicted comparing images presented in lists of the same valence. This study examined the predictions of priority binding theory by manipulating temporal pressure across lists of emotional visual images. Results showed performance difference between rates, with better accuracy, sensitivity, a greater bias at the slow rate, and a trend for better accuracy for negative images than neutral images in mixed lists, which supports the predictions of binding theory. The results extend the predictions of priority binding theory to picture stimuli. However, more research need to be conducted to determine if image stimuli are differentially processed and remembered than word stimuli.

CHAPTER ONE

INTRODUCTION

Emotions are important in capturing attention and organizing behaviors, which help an individual increase appetitive behavior and deal with threats. Emotional arousal influences episodic memory, but whether the influence is enhancing or detrimental is uncertain. In some instances, high emotional arousal associated with major life or historical events creates subjectively strong memories for that event and the details associated with it. For example, people claim to remember where they were and what they were doing on certain historically significant days like the assassination of Martin Luther King Jr. or on 9/11. In other highly arousing circumstances, episodic memory suffers from high emotional arousal as in the case of weapons focus (Loftus, Loftus, & Messo, 1987). Specifically, a person in a life-threatening situation, such as robbery at gunpoint, tends to experience narrowed attention directed at the source of threat, i.e. the gun. As a result, memory for details beyond the weapon suffers. Laboratory data also shows mixed findings with regards to emotion-enhanced memory. For example, emotion has been shown to enhance memory for details, for stimuli presented in close temporal and spatial proximity to each other, and for retrieval accuracy and long-term retention (Braddeley, 1990; Knight & Mather, 2009; LaBar & Cabeza, 2005; MacKay et al., 2004; Ochsner, 2000). In contrast, Dougall & Rotello (2007) and Windmann & Kutas (2001) have shown that emotion, rather than enhancing memory, plays a biasing role in retrieval. Studies conducted in our lab have demonstrated that negatively valenced material is remembered more poorly than neutral material (Devore, et al., manuscript in preparation).

Exactly how does emotion affect memory? Priority binding theory (MaKay et al., 2004), stresses the role temporal pressure plays in its explanation of emotion's enhancing effect. The theory states that when lists composed of both negative and neutral material are presented sequentially and rapidly, processing of negative material will take priority over neutral material and will more successfully bind to their episodic context. Since processing is done under temporal pressure, the interfering effect leaves little time for neutral material to be bound to its context of occurrence and results in enhanced memory for negative stimuli. The effect is not predicted for slow presentation rates because material need not compete for processing resources. With material of the same salience, no item has a competitive advantage for resources the way material of different valence and arousal levels do. Thus, the effect has been found to be absent in lists composed of homogenous, or "pure," negative or neutral stimuli. Priority binding theory has been supported in studies utilizing verbal material under free recall (Hadley & MacKay, 2006; MacKay & Ahmetzanov, 2005; MacKay et al., 2004).

Our lab has unsuccessfully attempted to extend priority binding theory to picture stimuli using a Rapid Serial Visual Presentation (RSVP) design testing recognition memory (Devore, manuscripts in preparation). Binding theory emphasizes the use of temporal pressure as a technique to manipulate the amount of stress on the processing mechanism to find an effect of enhanced episodic memory for negative and arousing material. Thus, a primary aim in this study is to vary the presentation rate and examine the effect on recognition in mixed lists. Specifically, this study examined the influence of temporal pressure on neutral and emotionally arousing picture stimuli in an RSVP design using recognition retrieval demands.

A review of Priority binding theory, the contributions of valence and arousal, emotions’ effects on memory and attention, the importance of time as a factor for the effect, and a detailed review of emotion enhancement in recognition studies is necessary to better understand contradictory finding in emotion and memory literature.

CHAPTER TWO

LITERATUER REVIEW

Binding Theory

Emotion has been found to have a robust enhancing effect on explicit memory. Laboratory studies show that emotionally valenced and arousing material is better remembered than neutral material using verbal stimuli (Guillet & Arndt, 2009; MacKay & Ahmetzanov, 2005), picture stimuli (Bradley, Greenwald, Petry & Lang, 1992; Mather & Nesmith, 2007), in studies assessing declarative memory (D'Argembeau & Van der Linden, 2005) and even in studies assessing implicit memory (Thomas & LaBar, 2005; Ramponi, Handelsman, Barnard, 2010). Priority binding theory (MacKay & Ahmetzanov, 2005; MacKay et al., 2004) explains enhanced episodic memory by proposing that emotional reactions to semantic properties of taboo words initiate binding mechanisms that connect the emotionally arousing item to its context of occurrence. In other words, an association is formed between the emotionally valenced and arousing stimulus to its episodic context which translates into better memory for the stimulus's temporal location (Easterbrook, 1959), spatial location (D'Argembeau & Van der Linden, 2005), memory for details central to the object (Kensinger & Corkin, 2003), gist memory (Kensinger, Garoff-Eaton, Schacter, 2006), and long-term retention (Knight & Mather, 2009; Mather 2007; Mather & Nesmith, 2008). In experimental procedures employing (RSVP) design, in which emotionally valenced and arousing stimuli are mixed with neutral stimuli, the presence of temporally and/or spatially contiguous emotional stimuli will interfere with the binding of neutral stimuli to their context of occurrence (Hadley & MacKay, 2006). That is, while a neutral predecessor is being processed, the presentation of an emotional stimulus will take priority during processing so that by the time the brain is finished processing the emotional stimulus, the neutral stimulus may no longer be active in the brain. The neutral stimulus will not be bound to its context of occurrence. The disrupting effect of negative stimuli on processing of neutral stimuli is called an interference effect and also occurs for neutral stimuli proceeding and following emotional stimulus. As a result of the interference effect, memory will be better for negative and arousing material. The theory predicts, however, that the interference effects will not occur in pure lists, lists composed of entirely negative *or* neutral information, because stimuli of the same salience will not have competitive advantage for resources (Hadley & MacKay, 2006).

Sequential Binding Theory: Backward and Forward Contextual Effects

Interference in binding of neutral stimuli that is temporally or spatially close to negative stimuli is found in RSVP tasks in particular because not only does fast presentation of items attenuate encoding in general, but also at the faster rate negative items are preferentially allocated attentional and processing resources. This makes sense evolutionarily. Information that is salient for survival takes precedents in processing versus neutral information that does not affect survival. With regards to priority binding theory, stimulus durations of 240 milliseconds or faster are suggested (MacKay et al., 2004) as being necessary to produce interference effects. However, at slow stimulus duration (2000 milliseconds as suggested by the authors) in a mixed RSVP design, the theory predicts a facilitating effect on neutral stimuli occurring before or after negative stimuli.

As stated previously, fast presentation rates place stress on the mind's ability to process neutral and negatively valenced material in close proximity resulting in interference with the neutral stimulus' binding. The exact type of binding that is interfered with is concurrent-context binding, which is basically the formation of an association of the stimulus with its experimental or list context. However, at slow rates another type of binding is predicted to occur in addition to concurrent-context binding: sequential binding. Sequential binding is the binding of negatively valenced and arousing word with its neutral predecessor and successor, and it is not presumed to occur during quick list presentations. Specifically, sequential binding is proposed to occur when neutral stimulus A, negative and arousing stimulus B, and neutral stimulus C are shown sequentially at slow rates. Stimulus A will bind "backward" to the context occurrence of stimulus B, or A will bind to the fact that it occurred prior to the onset of B. Also, stimulus C will bind to "forward" to stimulus B's context of occurrence, or C will bind to the fact that it occurred following the onset of B. It is the longer item duration that allows the emotional memory enhancement of item B to spill over to items A and C binding them to their list context (i.e., A occurred before negative and arousing B and C occurred after negative and arousing B). Importantly, because both types of binding occur, the redundancy in association allows for better retrieval of each neutral stimulus.

Previous research has generally supported the hypotheses of priority binding theory (Guillet & Arndt, 2009; Hadley & MacKay, 2006; Kensinger & Corkin, 2003; Knight & Mather, 2009; Thomas & LaBar, 2005), though exceptions to emotion-enhanced memory have been found. In some cases, memory accuracy for negative and arousing stimuli was found to be equivalent with neutral stimuli (Dougal & Rotello, 2007; Ocshner, 2000; Windmann & Kutas, 2001). In other instances, neutral stimuli were remembered with greater accuracy than emotional stimuli (Maratos et al., 2000). Possible explanations for the lack of appearance of the emotional enhancement include the list presentation rate during study, differences in retrieval demands, and differences resulting from calculating signal detection indices without controlling for unequal variance in the distributions of old and new items (Grider & Malmberg, 2008). That is, it may be that item presentation in these studies was not fast enough to cause interference, or that negative-valence advantage is specific to free recall (where retrieval demands are more difficult than recognition given the absence of cues). The current study will focus on manipulating presentation rates for picture stimuli in an RSVP design and employing calculations for signal detection indices that do not assume equal variance in old and new response distributions.

Contribution of Valence and Arousal

Before further discussion can begin, a digression regarding the role of valence and arousal in emotional stimuli may be useful. Emotional stimuli 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 highly positive and negative stimuli tend to be high in arousal resulting in a ‘boomerang’ shaped distribution of emotional stimuli within affective space (Figure 1). When describing emotional material, it is important to clarify which dimension(s) one is measuring.

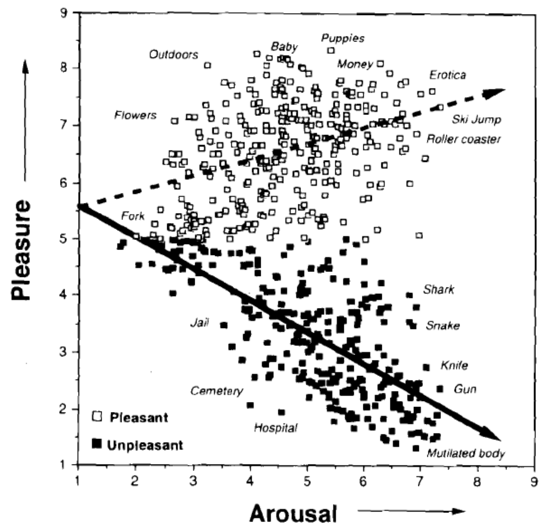

Figure 1. Distribution of IAPS images within the affective space defined by valence and arousal (Lang et al,2005)

In general, arousal and valence have been found to influence memory with arousal playing a dominant role in the effect (Bradley, Greenwald, Petry & Lang, 1992). For example, 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 & Corkin, 2003; Kensinger, E. A., Garoff-Eaton, R. J., & Schacter, D. L., 2006; Kensinger, E. A., Garoff-Eaton, R. J., & Schacter, D. L., 2007), while others suggest that negative and positive stimuli do not significantly differ (D'Argembeau & Van der Linden, 2005; Zeelenberg, Wagenmakers, Rotteveel, 2006). Differences in results may reflect inherent differences in stimuli, that is the use of word or picture stimuli may influence results.

Emotional Effects on Attention and Memory

Emotional Enhanced Attention and Processing

Attention is the allocation of mental resources, which includes focalizing, or selecting, certain stimuli while ignoring others (James, 1880**)**. According to Bradley (2009) attention may be captured by novel stimuli through a process know as an orienting response. Specifically, orienting is an evolutionary "what is it" response that promotes survival. When a new stimulus appears in the environment, the brain automatically orients attention to the novel stimulus by searching memory for matches. In addition to novelty, another important element in capturing attention is significance of the stimulus as determined by both valance and arousal.

Emotional stimuli have the ability to interrupt and capture attention—directing attention to this material via involuntary processes (Mather & Nesmith, 2008). Evidence of the attention grabbing nature of emotional stimuli comes from several types of experimental designs. For example, studies using the emotional Stroop task (a task where participants are expected to name the print color of an emotional word while ignoring the actual meaning of the word) exhibit longer color-naming time for emotional words as compared with neutral words suggesting that emotional words produce an interfering effect on attention. However, this effect is weak, requires time pressure and is difficult to replicate (Sharma & McKenna, 2001). Other studies using the taboo Stroop, which is a task similar to the emotional Stroop except that emotionally valenced *and* arousing words (taboo words) are used, have found that not only do taboo words elicit longer color-naming time, but they also produce enhanced memory for contextual details associated with the word, as well as greater overall accuracy (MacKay & Ahmetzanov, 2005; MacKay et al., 2004; Sharma & McKenna, 2001). With these studies the arousal component appears important. Whereas the emotional Stroop uses valenced words of varying arousal, the emotional and uniformly highly arousing words in the taboo Stroop suggest that it is the arousal component that more reliably produces greater recall of the word, it's spatial location, as well as resistance to habituation than does the valence component alone (Mather & Nesmith, 2008).

Furthermore, emotionally arousing material captures attention and is less susceptible to the attentional blink phenomenon (Anderson, 2005; Potter, Wyble, Pandav & Olejarczyk, 2010). The attentional blink occurs when two targets are presented close in time. When the second target is presented before the first target has been completely processed, the insufficient processing of the second target makes it less likely to be identified at the end of the trial. The resilience of emotionally arousing material to the attentional blink attests to their attention grabbing nature. In addition, when a taboo word is the first target, target two is more likely to be missed and less likely to be reported (Mathewson, Arnell & Mansfield, 2008). This suggests that emotionally valenced and arousing words capture attentional/processing resources leaving little for other material. In short, attention is a limited capacity-resource and emotionally valenced and arousing stimuli preferentially capture these resources. Neutral information may still be processed, but less effectively or thoroughly.

Emotion and Memory: Benefits and Costs

Episodic memory deals with information linked to a spatial and temporal context, the where and when, for example of the picture series presentation. Increasing attention to any stimulus leads to stronger episodic memories. The enhanced memory consolidation decreases the likelihood that the memory will decay over time. Emotion functions to direct the allocation of attention. Its effect on memory comes with both costs and benefits to nearby information. This section discusses studies testing the predictions of binding theory.

Though MacKay et al (2004) predicts enhanced memory for stimuli presented slowly, this very same study demonstrated both enhanced and impaired emotional effects. For example, participants displayed *superior* recall of contextual detail associated with taboo words compared with neutral words. However, the authors demonstrated *impaired* recall of quickly presented neutral words immediately before and after the taboo words in an RSVP design. This effect is called the word-before and word-after effect, and describes the impaired recall of neutral words preceding and following a taboo word – which they interpreted as supporting the theory that negative stimuli capture attention and preempt binding mechanisms. According to the theory, the word-before effect occurred because the taboo word abruptly took over binding mechanisms, preventing further encoding of the neutral word, and causing it and its association to its context to be irretrievable. Similarly, the word-after effect occurred because the taboo word engaged binding mechanisms for entire duration of its presentation and for at least part of the presentation of the subsequent neutral word preventing its encoding binding to its context.

Additional support for binding theory comes from studies in which participants have been found to exhibit better recall and recognition for contextual details associated with emotionally valenced and arousing stimuli. For example, recall of contextual details (Kensinger & Corkin, 2003; MacKay et al, 2004, Experiment 3) and list position (MacKay & Ahmetzanov, 2005) associated with emotionally arousing stimuli is facilitated. Also, recognition of locations associated with the emotionally arousing stimuli is also enhanced (Kensinger & Corkin, 2003; MacKay et al, 2004, Experiment 3; Hadley & MacKay, 2006; MacKay & Ahmetzanov, 2005).

In contrast, studies with picture stimuli have shown mixed results. D'Argembeau & Van der Linden (2005) presented positive, negative and neutral pictures during encoding and asked participants to make recognition and source judgments. Both item and temporal memory was better for negative than positive, and both positive and negative than neutral pictures. However, Mather & Nesmith (2008) found that both emotional valence and arousal facilitated memory, with high levels of arousal producing better memory than low arousal levels, and negative pictures better remembered than positive and positive better remembered than neutral. Nevertheless, emotion enhancement did not "spill over" to pictures in close temporal or spatial proximity.

The word-before and word-after effect found in MacKay et al 2004, experiment 4 and in Hadley & MacKay (2006) demonstrates the interference that emotionally valenced and arousing words exert on nearby neutral words. In general, it appears that the effect involves memory costs for nearby items. Knight & Mather (2009) found that neutral material preceding or following emotional stimuli were more poorly recalled than if the same items preceded or followed neutral stimuli. Similar results were found in studies assessing recognition memory (Kensinger & Corkin, 2003; Kensinger, Garoff-Eaton & Schacter, 2006; Knight & Mather, 2009; MacKay & Ahmetzanov, 2005; MacKay et al., 2004).

Physiology of Enhanced Memory

The amygdala is involved in automatic processing during emotion learning (Cahill, Babinsky, Markowitsch, & McGaugh, 1995) and has been shown to modulate memory for emotionally arousing events in humans (Cahill et al, 1996). Specifically, processing of fear-inducing visual information is first sent to the thalamus. After it is processed, the information is directly sent to the amygdala allowing for quick responding. A second slower pathway of processing also occurs. In this second pathway, information from the thalamus is sent to the visual cortex, where perceptual information can be added to the appraisal of the event (LeDoux, 1994).

Neuroimaging data also confirms emotional memory enhancement. Enhanced attention to and processing of emotionally valenced and arousing material has been shown to produce greater activation of the fusiform gyrus, middle occipital gyrus, and the middle temporal gyrus, which are all areas associated with visual processing (Mather et al 2006). The amygdala and hippocampus have been particularly implicated in the enhancing effect. Wendt, Weike, Lotze & Hamm (2011) found enhanced amygdala activation while viewing negative and arousing pictures. Amygdala activation and heightened systemic arousal are thought to influence consolidation of new episodic memories in the hippocampus thorough a series of neurochemical events (LaBar & Cabeza, 2005).

Time as a Factor for Emotion Enhanced Memory

Temporal pressure is an important factor in binding theory and is also suggested to play a large role in the Taboo Stroop effect (Sharma & McKenna, 2001). The idea that under time pressure, negative and arousing items attract more attentional resources is fairly consistent throughout the literature (Buchanan, Etzel, Adolphs, Tranel 2006; Guillet & Arndt 2009; Kensinger & Corkin 2003; MacKay, Ahmetzanov 2005).

Priority binding theory suggests that attentional resources are deployed to negative and arousing stimuli automatically, interfering with the processing of nearby neutral information. That is in mixed lists, emotionally valenced and arousing stimuli attract attentional resources and processing resources, and suspend or reduce processing of neutral stimuli. Studies focusing on the interfering effect have employed fast presentation rates to increase the resources required for the task. Hadley & MacKay (2006) suggest that, because of the availability of attentional resources, slow presentation rates would produce a facilitory effect on neutral material in close proximity, although they do not specify if the effect is limited to temporal material or if it extends to material in close spatial proximity.

Support for interference effects with fast presentation rates has been found largely in studies using verbal stimuli (Guillet & Arndt 2009; Kensinger & Corkin 2003; MacKay, Ahmetzanov 2005; Sharma & McKenna 2001). Studies using picture stimuli have produced mixed results. Mather & Nesmith (2007) used an incidental encoding procedure with mixed lists and pure lists in a between-subject design to determine if arousal enhances memory for picture location. Items were presented from 500 to 2000 milliseconds across trials. Though memory generally improved with longer viewing times, enhancement was found at slow and fast rates. Arousal was found to enhance memory for spatial and temporal location of arousing pictures without either benefit or cost to neutral material in close spatial and temporal proximity (Mather & Nesmith, 2008). Kensinger, Garoff-Eaton & Schacter (2005; 2006) found that memory for contextual details directly associated with an arousing object within a complex scene presented for 250 to 500 milliseconds was enhanced while memory for neutral information in the periphery of the picture was decreased. Longer item duration rates, 500 to 1000 milliseconds, were sufficient to allow for processing and recollection of some peripheral details. Longer presentations lessened but, did not extinguish, focused attention on the arousing stimulus. These studies have used a variety of encoding tasks and examined a number of questions with respect to emotional enhancement including the effects exerted on neighboring pictures and the effects within the same picture. To date no studies have been done testing interfering and facilitating effects associated with varying the presentation rate of emotionally valenced and arousing stimuli in mixed lists presented in an RSVP format.

Assessing Emotional Memory in Recognition Tasks

Emotion enhancement on memory is a consistent result in studies assessing recall of emotional material. However, the literature is mixed in studies assessing recognition for emotional material. Current questions center on whether the emotional enhancement, when observed, results from actual memory or a response bias(Grider & Malmberg 2008). That is are emotional stimuli more accurately remembered or is there a tendency, bias, to overly respond in the affirmative when asked if emotional material was viewed?

In studies assessing recognition memory, stimuli previously encountered is believed to possess a degree of familiarity, or a general sense of remembering having encountered the stimuli before. Signal detection theory is used as a way to assess familiarity in recognition memory. Signal detection theory was developed in the 1940's and 1950's to measure the ability of a receiver or operator to detect signal embedded in a background of noise, for example assessing the ability of a radar operator to detect incoming aircraft (Green & Swets, 1966). It has been applied in recognition memory tasks where the operator/subject is detecting old, or previously studied items, the signal, within a list of new or previously unseen items, or noise. This type of tasked is referred to as an "old/new" recognition paradigm. Specifically, participants are shown previously viewed, or 'old', images and shown never before viewed, or 'new', images. Participants are asked to make a judgment about every image indicating whether each image they are viewing is old or new. A comparison of familiarity between the test item and subjective criterion is made, and when familiarity exceeds the criterion participants judge the image as old (Grider & Malmberg, 2008). With regards to signal detection theory, a participant can make four types of responses per image: a correct response (hit), failing to detect the stimulus (a missed response), a correct rejection (accurately identifying a stimulus as not having been previously encountered), and a false alarm (inaccurately identifying a stimulus as having been previously encountered). Participant's responses can then be calculated according to how accurately they respond, how good they are at determining whether they have encountered the stimuli or not (discrimination, *d'*), and how much information they need (a little or a lot) to determine if they have encountered the stimuli previously (bias, *c*).

In examining participant responding, it is possible that ‘old’ emotional stimuli may *appear* to be accurately remembered yielding a higher hit rate. This is because of a tendency to label all emotionally arousing material as old. In this case, both the hit rate and the false alarm rate are increased because the participant is displaying a bias in identifying information as previously encountered, regardless of whether they actually have seen the stimuli before or not. The biased tendency to over-identify emotionally arousing material as old is called a liberal response bias. Indeed, Ochsner (2000) found that valence and arousal contribute to enhanced episodic memory for emotional material, with negative and arousing material better remembered over neutral material. However, he also found a liberal response bias suggesting that participants were responding that they remembered seeing negative and arousing items more often than they actually had. This means that participants are not actually better at detecting the presence of emotionally arousing stimuli, but are instead biased (needing little information) in determining whether they have encountered emotionally arousing stimuli. Within the same study, signal detection analysis resulted in no significant difference between emotional and neutral stimuli further demonstrating the limited accuracy participants’ display in responding to emotionally arousing material. Similarly, Dougall & Rotello (2007) and Windmann & Kutas (2001) also found a liberal response bias for emotional words over neutral words.

Accuracy, discrimination (*d’*) and bias (*c*) are calculated for each individual. It is usually assumed that the variances of familiarity distributions are equal. However, Grider & Malmberg (2008) have raised questions about the validity of using standard calculations of *d’* and *c* which assume equal variance for the old and new distributions.

They note that when variance is unequal, *d'* and *c* are no longer independent. Alternate formulas for calculating both *d'* and *c* are offered for use when variance is not equal. Grider & Malmber (2008) reexamined the results of Dougal and Rotello and found that the variance in their study was not equal. Using standard calculations of *d'* and *c* yielded significant differences in the slopes of the corresponding z- transformed Receiver Operating Curve. Traditional calculations of *d'* and *c* yielded overestimates of accuracy and bias for neutral material indicating that neutral material is better remembered than negative material. However, when calculations that adjust for unequal variance, d_e and c_e, were used, accuracy and bias for negative and neutral material was comparable. These finding demonstrate that the importance of using appropriate calculations of accuracy and bias when variance is unequal.

CHAPTER THREE

SPECIFIC AIMS AND HYPOTHESES

The goal of the proposed study was to provide incremental information about how emotion affects processing and memory of valenced and arousing stimuli. As stated previously, past attempts to extend binding theory to emotionally arousing picture stimuli were generally unsuccessful. Because the central aspect of binding theory is temporal stress on one's processing system, this study compared image presentation durations of 200 and 1950 milliseconds to include a higher temporal pressure than previous use as well as a rate with very low temporal pressure. It was expected that the fast rate would aid the detection of an enhancing effect, if such an effect existed. Also, the use of the slower presentation rate would allow for the examination of the prediction of sequential binding theory: backward and forward contextual binding of negative images to its preceding or following neutral images would result in enhanced memory for the neutral preceding and following images in mixed lists.

Of major consideration for the current study was the use of appropriate calculations of *d'* and *c* when variance was not equal. Specifically, this study used the adjusted calculations d_e and C_e. As suggested by Grider & Malmberg (2008), use of the latter calculations were encouraged to aid in the examination of the liberal bias found for negative items presented in pure and mixed lists found in Devore (2011).

Finally, this study sought to examine the sequential binding of pictures presented at slower rates to determine if negative pictures presented before or after neutral pictures would benefit from the prolonged exposure time and, as a result, would become temporally bound to preceding and following emotional images. Based on the previous literature review, the following aims and hypotheses were proposed.

Aim 1:

To determine if fast presentation rates result in enhanced memory for negative versus neutral stimuli in the form of higher accuracy for negative material in mixed lists, and to determine if the emotion enhanced advantage disappears in pure lists.

Hypothesis 1

It is hypothesized that, following priority binding theory, an item duration of 200 milliseconds followed by a 50 ms inter-item interval, or 4 images per second, will produce greater accuracy for negative stimuli than neutral stimuli in mixed lists.

Hypothesis 2

It is also hypothesized that item duration of 200 milliseconds, will produce no memory advantage in pure lists of either negative or neutral stimuli because images of the same salience are not predicted to compete for attentional resources.

Aim 2

To determine if a liberal bias and greater sensitivity for negative stimuli will be present using more sensitive calculations of sensitivity and bias, d_e and c_e as suggested by Grider & Malmber (2008).

Hypothesis 3

It is hypothesized that there will be greater sensitivity for negative versus neutral images.

Hypothesis 4

Based on the findings of Devore (2011), it is hypothesized that a strong liberal bias for negative items will be present across list and rate.

Aim 3

To examine sequential binding with slow presentation rates to determine if neutral memory will be enhanced by binding with preceding and subsequent negative images in mixed lists.

Hypothesis 5

It is hypothesized in mixed lists neutral stimuli presented at 1950 milliseconds, .5 images per second, will benefit from close temporal proximity to negative stimuli, which will result in higher accuracy for those neutral stimuli

CHAPTER FOUR

METHODS

Participants

Loma Linda University and La Sierra University's Institutional Review Boards approved the study. Informed consent was provided by each participant prior to beginning the study. Forty-two participants (*M* aged =19.79, *SD* = 3.01, 16 males and 26 females) were recruited from Loma Linda University and La Sierra University's subject pools. All were fluent in English, had normal or corrected-to-normal vision, and received credit that could be applied to their courses in exchange for participation.

Materials

Two hundred twenty-four picture stimuli (112 negative and 112 neutral in valence) were drawn from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). 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 2.43 (*SD* = 0.24) and 5.24 (*SD* = 0.20), respectively. The mean arousal for negative and neutral pictures was 5.74 (*SD* = 0.24) and 2.84 (*SD* = 0.11), respectively.

Pictures were presented to participants via E-Prime 2.0 Professional (Psychological Software Tools, Pittsburgh, PA). Subjects were tested individually while sitting facing a 17-inch LCD computer monitor (refresh rate 60 Hz) at eye level approximately 0.6 meters distance in a quiet, air-conditioned room. The stimuli were presented with a full screen resolution display of 1028x786 pixels producing a horizontal viewing angle of 36°.

Procedure

For each participant, the E-Prime program randomly selected half of the images of each valence category and constructed eight lists of 14 images each. Four of the lists were “pure” lists and consisted of images of the same valance including 2 negative pure lists, and 2 neutral pure lists). The remaining 4 lists were “mixed” in valence, composed of 7 negative and 7 neutral images (see Figure 2). The remaining 56 negative and 56 neutral pictures were used a foil or “new” pictures during the recognition phase.

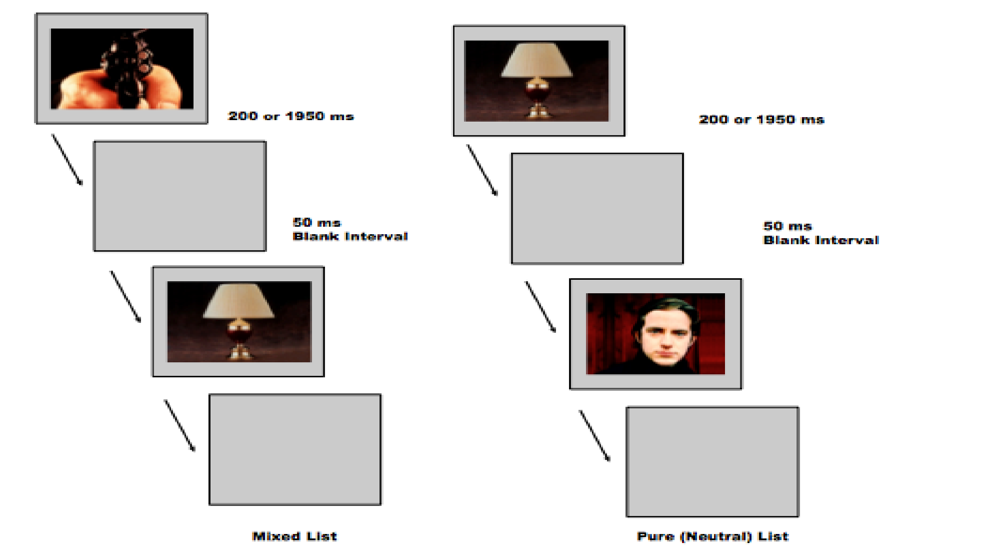

Figure 2. Stimulus presentation of mixed (left) and pure (right) lists

The study consisted of three phases: a practice phase, a list presentation and recognition phase, and a ratings phase. Participants were presented a practice phase using stimuli not included in the 224 study pictures, to help familiarize them with the recognition task. They viewed pictures of dragonfly-like insects, and were asked to indicate if they had seen the image before or not. If they recognized the image, they were asked to make a familiarity judgment. In the next phase, eight lists were presented. Half of the lists were presented with an image duration of 200 ms, or four images per second, and the remaining four were presented with an image duration of 1950 ms, or 0.5 images per second. Each list included inter-picture intervals of 50 ms consisting of a blank screen. List composition, valence, rate, and within image sequence were randomly ordered for each participant. I will refer to lists presented at 200 ms as "fast" lists, while lists presented at 1950 ms will be referred to as "slow" lists.

Immediately after the presentation of each list, a recognition test was given. During each recognition test, participants were shown 28 images in a random order: the 14 "old" images viewed during the preceding list, along with 14 "new" never-before-seen foil images. Participants were asked to indicate for each image if they had viewed it by pressing "0" for no, and "1" for yes on the keyboard number pad. For "Yes" responses" they were then asked to indicate how confident they were in their decision.

Data Analysis

The average accuracy or percentage correct, for all eight recognition tests was obtained. Analyses of variance (ANOVA) were conducted using a 2 (Valence: negative or neutral) X 2 (List Composition: mixed or pure) X 2 (Rate: fast or slow) repeated measures within subjects design for the dependent variables of accuracy, sensitivity and bias. Sensitivity, or d_e, was calculated with the following formula: (2/1(1+slope)) * z(HR)-((slope) * z(FAR)), where slope = SD_{new} / SD_{old}. Bias, or C_e, was calculated with the following formula: -((2 * slope) / ((1+ slope) ^{2})) * (z(HR) + z(FAR)) (Grider & Malmberg, 2008). The use of these equations is encouraged when variance of the nose, and signal plus noise distributions are unequal, which is often the case.

To examine the "forward" and "backward" effects of emotional context, on memory, accuracy of negative and neutral images presented immediately before or after negative or neutral images was examined to determine the likelihood that emotional context will influence the probability of recognizing the preceding or following image. Pictures presented before negative or neutral images are referred to as "backward images," while pictures presented after negative or neutral images are referred to as "forward images." Analyses of variance were conducted using 2 (target valence: negative or neutral) X 2 (context valence: negative or neutral) X 2 (Rate: fast or slow) repeated measures ANOVAs within subjects designs on mixed lists only to assess the context effect of emotion on memory. Assumption testing was conducted prior to analyses. The assumption of sphericity was not violated. Finally, although familiarity ratings were collected, they will not be presented here.

CHAPTER FIVE

RESULTS

Recognition Accuracy

Accuracy, or percentage correct, was generally high for all participants. However, accuracy was affected by presentation rate, image valence and list composition. The most pervasive effect was the main effect of rate. Participants performed more accurately for slow than fast lists suggesting that processing benefited from the extra encoding time, F (1, 41) = 250.07, $p < .001$, $\eta^2 = .86$ (Figure 2). This was a robust effect that occurred for all dependent variables. There was a three way interaction, which resulted from performance differences between rates, F (1, 40) = 8.33, $p < .006$, $\eta^2 = .17$, and differences among the lists at the fast rate. In fast, pure lists, neutral valence images displayed an accuracy advantage over negative images (t (40) = -3.88, < .001). In fast, mixed lists, negative image accuracy was non-significantly greater than neural images. No effects were elicited at the slow rate.

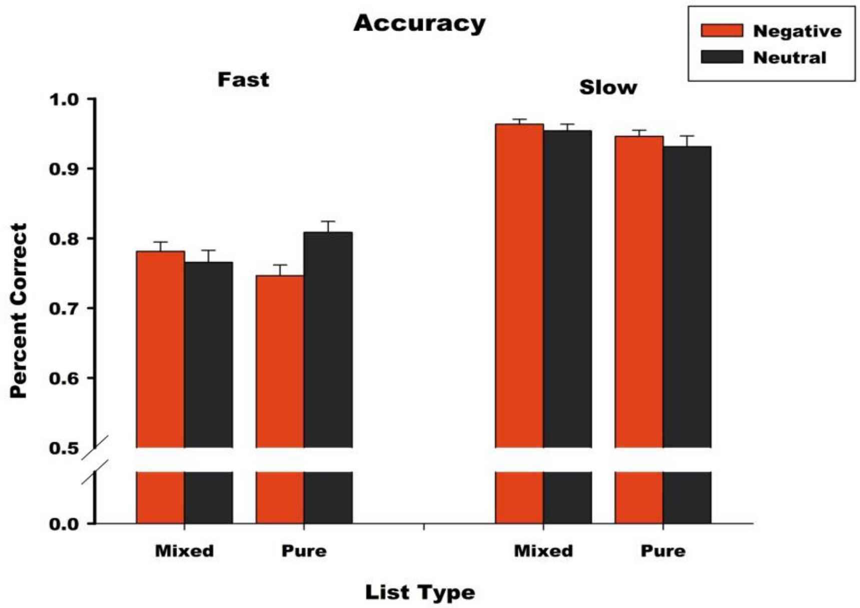

Figure 3. Recognition accuracy for valence, list type and rate

Sensitivity and Bias

Sensitivity, or d'_e, was affected by both presentation rate and image valence. Participant ability to discern target from distractor images were better at slow than fast presentation rates, (F (1, 41) = 69.93, p < .000, η^2 = .63) and for negative than neutral images, (F (1, 41) = 5.12, p < .03, η^2 = .11). This result is tempered by a two-way Rate X List Composition interaction, F (1, 41) = 96.32, p < .03, η^2 = .11, in which there was a non-significant trend at fast rates for greater sensitivity with negative versus neutral items in mixed lists but the reverse was observed, greater sensitivity for neutral than negative items, in pure lists (Figure 3). This pattern of results would support the predictions of Binding Theory. There was a reverse trend for slow lists. Sensitivity was substantially greater for negative than for neutral images in both mixed and pure lists.

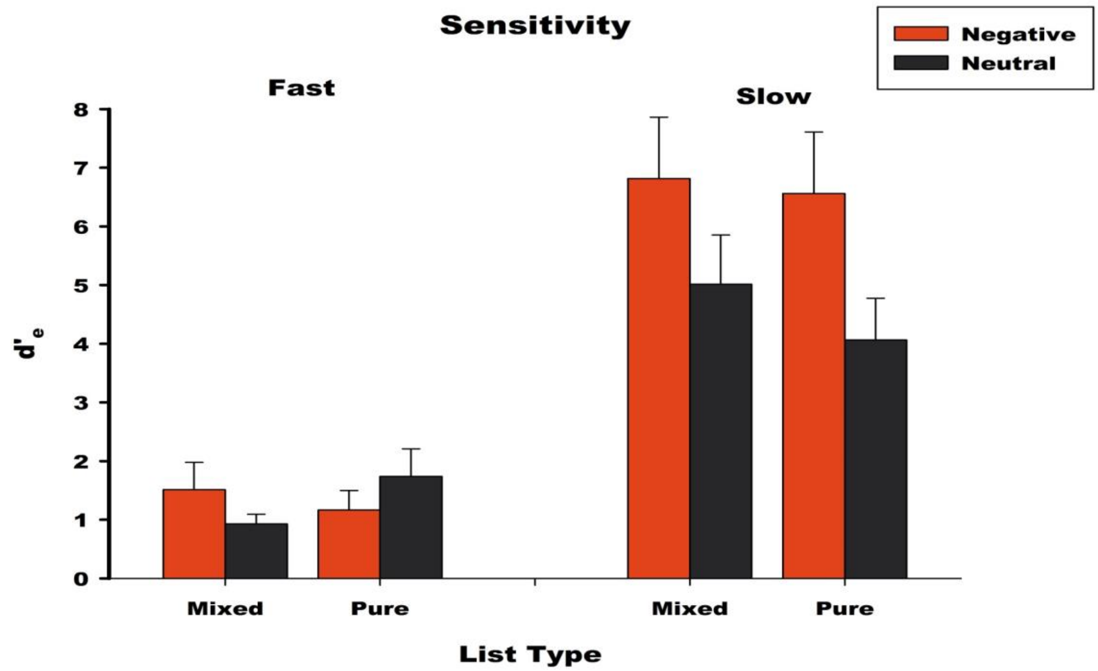

Figure 4. Sensitivity for valence, list type and rate

Bias, or C_e, was affected by presentation rate, (F (1, 41) = 13.01, $p < .001$, η^2 = .24) (Figure 4). Participants displayed a more conservative response bias with fast than slow presentation rates. However, no other main effect or interaction reached significance.

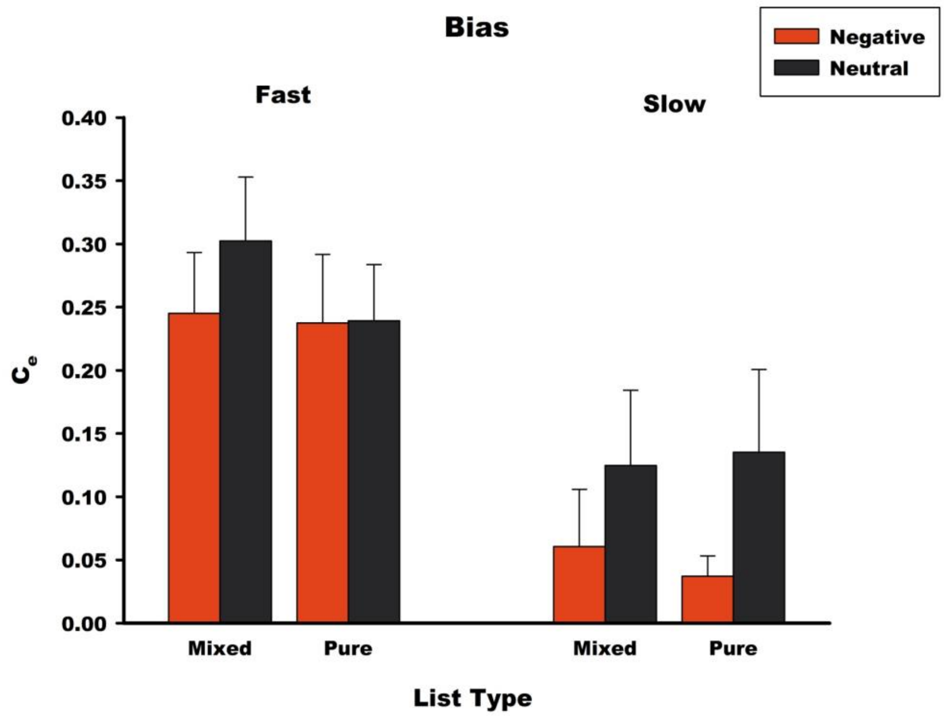

Figure 4. Bias for valence, list type and rate

Context: Backward and Forward Contextual Effects

Backward Contextual Effect

The robust effect of rate was also demonstrated with before-image accuracy. Participants were more accurate for slow than fast rates (F (1, 41) = 186.67, $p < .01$, η^2 = .82). However, the effect of valence on recognition of the preceding image depended on presentation rate as evidenced by a Rate X Context interaction, (F (1, 41) = 6.01, $p < .02$, η^2 = .02). At fast rates, valence-consistent image sequences (i.e., when the target image was followed by an image of the same valence) were more likely to be accurately recognized than when followed by an image of a different valence suggesting that resource depletion occurred (Di Lollo, Kawahara, Ghorashi, & Enns, 2005). Briefly, in RSVP designs attentional blinks occur when an item following the target does not match the category of the target. Resource depletion, or temporary loss of control, is experienced during stimulus processing leaving the following images more susceptible to the attentional blink phenomenon. In this study, negative images presented before another negative image were more likely to be accurately recognized than if presented before a neutral valence image, which was confirmed by the interaction (Figure 6). Similarly, neutral images presented before neutral images were more likely to accurately recognized than if presented before a negative image. Mixed lists initiated resource depletion in processing subsequent images leading to poorer recognition of images not matching the target. However, at the slow rate, context did not produce a memory advantage.

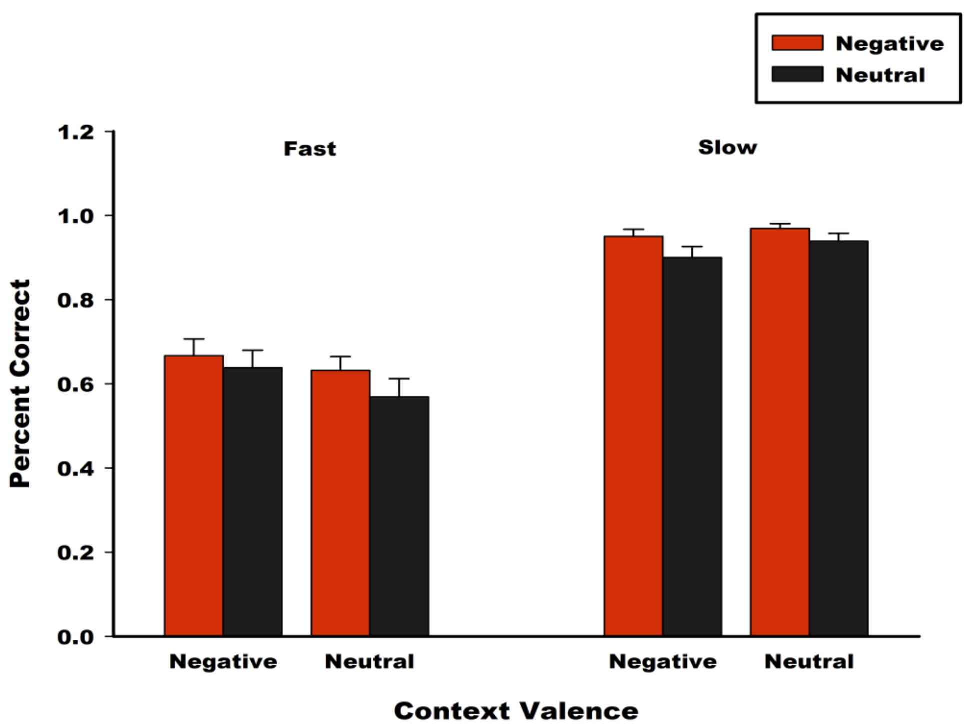

Figure 6. Image accuracy of pictures preceding context pictures

Forward Contextual Effect

The probability of recognizing an image that appeared after a negative image was better at the slow than the fast rate~~,~~ (F (1, 41) = 33.45, p < .01, η^2 = .45) (Figure 6). As can be seen from the graph, the likelihood of recognizing an image also depended on the context. For negative contexts at the fast rate, the probability of recognizing a negative after-image was facilitated, but the ability of recognizing neutral images was impaired. However, when the context image was neutral, the likelihood of recognizing a neutral after-image was facilitated, but negative after images did not benefit. This context effect did not appear in the slow rate.

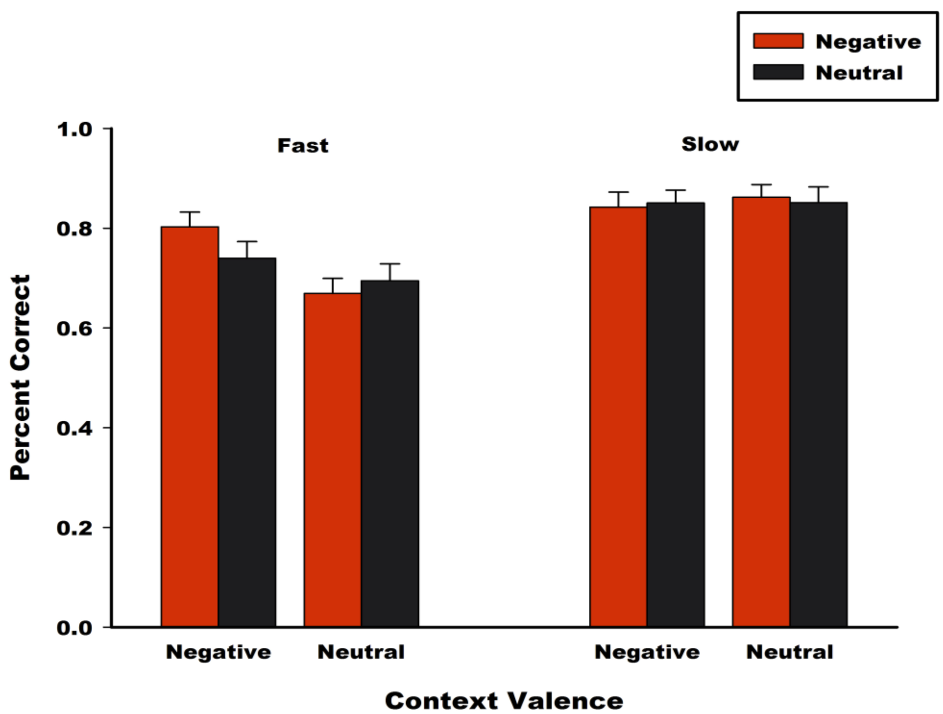

Figure 7. Image accuracy of pictures following context pictures

CHAPTER SIX

DISCUSSION

The present study examined the effects of temporal pressure on the recognition of emotional material and produced a number of noteworthy results. Overall, manipulation of the presentation rate produced the largest, most robust and pervasive effect that influenced recognition accuracy, sensitivity, bias, and both backward and forward contextual recognition accuracy. This suggests that the extra viewing time effectively allowed participants to better process and encode images. Specifically for recognition accuracy, participants were much more accurate for all images at slow versus fast rates.

Theoretically more important, however, was the resulting trend for negative images to exhibit a memory advantage over neutral images in the fast-rate mixed lists. This was in contrast with pure lists, in which no such memory advantage for negative material was found. Sensitivity (d'_e) results followed the same pattern. Participants were better able to recognize old negative images than neutral images presented in mixed lists; at the same time they displayed no such benefit for negative over neutral images in pure lists and demonstrated a less conservative, or liberal, bias for negative images relative to neutral images. Also of note, the analysis of contextual effects in fast presentation lists indicated that images preceding or following other images of the same valence were better recognized than images of different a valence.

Turning to the specific, *a priori* hypotheses, the first aim of this study was to determine whether or not a fast presentation rate would result in enhanced memory for emotional material. In accordance with binding theory, it was hypothesized that negative images presented in mixed lists at an item duration of 200 ms and 4 images per second, would be more accurately recognized than neutral stimuli. It was also hypothesized that no such memory advantage would appear in fast rate pure lists of either negative or neutral images. Hypothesis 1 was supported to the extent that negative images showed a trend toward greater recognition accuracy. Hypothesis 2 was also supported. Emotional and arousing pictures no longer produced an enhanced memory for the emotional images, in the form of greater accuracy, when they were presented in pure lists. This supports priority binding because material of the same salience not expected to outcompete each other for attentional and processing resources.

The second aim of this study was to determine if negatively valenced material would exhibit greater sensitivity and a relatively more liberal bias as has been found in past research assessing recognition memory (Dougall & Rotello, 2007; Windmann & Kutas, 2001; Ochsner; 2000). This study differs from others in that sensitivity and bias were calculated as d_e' and C_e (Grider & Malmberg, 2008), in which the variance of old and new distributions was not assumed to be equal. It was hypothesized (Hypothesis 3) that, as previous research suggested, sensitivity would be greater for negative images than neutral images when presented in fast rate mixed lists. It was also hypothesized (Hypothesis 4) that negative image recognition would display a relatively liberal bias. Hypothesis 3 was supported. Participants were better able to discriminate previously viewed negative than neutral images from new negative or neutral images in mixed lists. This is in line with results obtained by Dewhurst and Perry, (2000), Windmann & Kutas (2001), and Ochsner, (2000) who all found greater sensitivity for negative stimuli when assessing recognition memory. In contrast, no such advantage was found for negative images presented in pure lists. Again, these findings support the premises of binding theory: emotional images interfere with processing of neutral stimuli in close proximity when presented in the same context. Hypothesis 4 was partially supported. A conservative bias emerged from the data. Conservative biases are defined as a criterion value greater than zero and many studies report bias values that exceed zero (Grider & Malmber, 2008; Dougal & Rotello, 2007). However, the criterion value for negative images was less conservative, or more liberal, than the bias for neutral images. This is in line with findings that demonstrate a less positive, or less conservative bias, for negative than neutral pictures (this topic will be expanded upon later in the discussion).

The third aim of this study was to examine the "backward and forward contextual effects" of emotional material on accuracy for images presented before and after negative or neutral images. Specifically, I sought to determine if slow presentation rates would result in enhanced memory accuracy for neutral stimuli processed in close temporal proximity to negative stimuli. It was hypothesized (Hypothesis 5) that in mixed lists presented at the slow rate, neutral images would benefit from close proximity to negative, as compared with neutral images, resulting in higher accuracy. Hypothesis 5 was not supported. There was no evidence that neutral images were more accurately recognized than negative images presented in mixed lists at slow rates. MacKay et al., (2004) predicted sequential binding at slow rates, stating that the presence of negative material could actually enhance memory for neutral material in close proximity. Sequential binding links a negative item to the preceding and/or following neutral images. Briefly, if neutral images are presented before or after a negative image at a slow, as compared with a fast rate, the longer processing time will allow the enhanced processing of the negative image, which will create a link between the neutral image appearing before and after it.

That is, the neutral images will become bound to the negative contextual image appearing in close spatial and temporal sequence. However, in the current study, it appears that neutral material did not benefit from close temporal proximity to negative images presented at slow rates. These findings, however, should be interpreted with caution. Participants demonstrated near perfect accuracy, therefore; it is possible that any context effect may have been obscured by the ceiling effect in accuracy exhibited in the slow rate.

In general, the results of this study are in line with the predictions of binding theory, which states that emotional stimuli presented mixed lists display a memory advantage over neutral words. Temporal pressure is cited as a critical component in bringing about this effect because under time constraints, taboo words take processing priority leaving little time for the brain to process subsequent neutral words. This results in a poorer memory trace for neutral images. Binding theory also predicted no such advantage would occur in pure lists because similar valence and arousal levels will not compete for processing resources. Priority of processing was not proposed to occur at slow rates. Instead, sequential and contextual binding was believed to occur at slow rates allowing neutral material to be bound to surrounding negative material resulting in better memory of neutral material.

In the current study, negative images showed a trend toward being better recognized than neutral images. This finding supports both binding theory and studies demonstrating emotion's enhancing effect on memory. For example, Dahl, Johansson & Allwood (2006) found that negative-and-arousing images presented in an RSVP mixed-list design were more quickly and accurately detected than positive pictures. Meng, Yuan, & Li (2009) found emotion enhanced memory for both highly and moderately negative-and-arousing pictures during a task that required direct attention to the stimuli (pressing a key following the presentation of a target image) and in a task that discouraged attention to the stimuli (attend to auditory signals and press a button to discriminate tones while viewing images, but not focusing on the emotional or neutral images). The fact that emotional items, which were not the focus of the participant's attention, demonstrated an enhancing affect on memory supports the attention grabbing nature of highly arousing and negative images. Bradley & Baddeley (1990) found that although immediate recall of highly arousing words was impaired; recall of arousing words was superior to neutral words 28 days later. These studies support my findings that emotion has an enhancing effect on memory and preferentially capture attention.

A relatively liberal bias, was found in the present study. However, the literature is mixed on whether emotion enhancement results from a criterion bias (higher or lower threshold for indicating the presence or absence of a stimulus). Choi, Kensinger, & Rajaram (2013) found a conservative response bias for emotional and neutral pictures in a study assessing emotional enhancement of true and false memory when conceptual relatedness is controlled for. Also, Charles, Mather, & Carstensen (2003) found that while younger adults are more likely to remember negative images than older adults, the authors found a conservative response bias. However, negative material tends to show a less conservative bias than neutral material. In contrast, several studies have found a liberal criterion for negative stimuli. Specifically, Ochsner (2000); Windmann & Kutas (2001); and Dougall & Rotello (2007) found a liberal response bias for emotional words over neutral words. Similarly, Kapucu, Rotello, Ready & Seidl (2008) showed young and old participants negative, positive and neutral words, though accuracy did not differ for emotional and non-emotional words or between young and old groups, a liberal response bias was found. Also, Thapar & Rouder (2009), using a foced-choice paradigm and a similarity choice model, determined that emotion enhanced memory for negative versus neutral words was due to a liberal response bias. It is possible that the variation of image presentation rate influenced the confidence and threshold of participants causing them to more cautiously indicate whether they remember viewing an image or not. The previously mentioned studies also used longer stimulus lists while the current study used shorter lists. It is possible that shorter length move the criterion towards a more conservative bias.

Finally, this study sought to determine if neutral images would benefit from exposure to negative pictures presented at a slow rate as suggested by Hadley & MacKay (2006). This was not supported. Research has shown that when a negative stimulus serves as the focus of attention then memory will be enhanced for that stimulus and information directly associated with it. However, other lines of research have shown that information not directly associated with negative stimuli is harmed. For example, when a negative stimulus is presented in a RSVP design, memory is harmed for neutral stimuli succeeding the negative stimulus (Di Lollo, Kawahara, Ghorashi, & Enns, 2005; Mathewson, Arnell, & Mansfield, 2008). In fact, negative images have been shown to harm memory for neutral images as far as three images back (Erdelyi & Blumenthal, 1973). Again, it is proposed that under time pressure, emotionally arousing stimuli are believed to prioritize attention, thus postponing processing of less salient information until the attention grabbing arousing material has been fully processed. This results in insufficient time left to process the less salient material (Hadley & MacKay, 2006). The aforementioned studies, however, focused on rapid presentation rates. This does not entirely explain why neutral images did not benefit from exposure to negative images as it was predicted. It is possible pictorial stimuli are processed differently than other forms of stimuli. Also, other lines of research have shown that emotional enhancement of memory is a specific phenomenon and does not spill over to other temporally and/or spatially adjacent information (Mather, Nesmith, 2008, Experiment 2).

The lack of confirmation for some of this studies hypotheses may be due to the complexity in processing emotional stimuli. Although emotion enhances memory, enhancement seems to be task dependent. For example, Rozenkrants & Polich (2008) found no behavioral differences in performance (accuracy) across valence or arousal. Although null effects were found in behavioral performance, when examining ERP's the authors *did* find that highly arousing pictures produces larger N2 and P3 early slow and late waves. They suggest that ERP modulation of emotional-and-arousing stimuli arise from attentional mechanisms that are sensitive to the task. This finding highlights the fact that significant results related to emotion enhancement is task specific. Also, Sison & Mather (2007) found that when showing an emotional category (e.g., fear) comprised of heterogeneous pictures (e.g., fear evoking pictures of people and animals), if the category was cued with one group (e.g., fear evoking pictures of people) recall for the other group (fear evoking pictures of animals) was harmed. The authors state that emotion is used to group events creating associations, but grouping along emotional or non-emotional lines depends on the focus of the individual at the time of encoding. Factors such as exposure time have also been shown to influence memory strength, which ultimately influences accuracy (Martini & Maljkovic 2009; Criss, Wheeler, & McClelland, 2013). This result, again, demonstrates the sensitive and task dependent effects of emotion on cognition. Viewing time may have been the critical factor responsible for finding or not finding an effect. Also, deeper levels of processing have been associated with stronger memory for stimuli (Parks, 2012). That is, actively working with or manipulating the information in memory produces greater accuracy. Again, these studies demonstrate task dependent effects (i.e., emotional enhancement on cognition being dependent on attention, viewing time and levels of encoding in producing or not producing the effect), which suggests that emotional memory is highly complex and sensitive. It is possible that alterations in study design may produce different/affirmative results.

An additional possibility for the lack of confirmation for some of the study's hypotheses is that although accuracy appears to be influenced by emotional valence and arousal, it is possible that picture stimuli are differentially remembered than word stimuli. Specifically, Gavazzeni, Andersson, Bäckman, Wiens, & Fischer (2012) found a gender specific effect of emotional enhancement of memory for negative material. Particularly, no emotional enhancement for negative material was found for women. Also, Bradley, Greenwald, Petry, & Lang, (1992) found that women were more likely to remember neutral images, which supports better accuracy of neutral images observed in pure lists. In addition, Colden, Bruder, & Manstead, (2008) found that women and men respond differently to IAPS pictures (which are the stimuli used in the present study): women were found to feel less in control than men when viewing arousing pictures. These results are particularly relevant to the current study because the study was composed of predominantly more women than men.

There are, however, caveats to the current findings. Fist, interpretation of results must be made cautiously since the slow rate used in this study is comparable to rates typically used by other studies. Also, as mentioned above, the majority of my sample was female, which could have influenced the results of the study. As mentioned above, women have been shown to perform differently than men. It is possible that if a lager sample of males were collected, a larger negative memory enhancement may be detected.

Also, the context effects (before/after images) need to be interpreted with caution because the current design was not an optimal design to test the predictions of sequential binding theory. This study assessed recognition accuracy of neutral images that happened to be presented preceding or following negative images, but did not specifically control list position of the neutral item of interest. Therefore, a neutral image may have been preceded by a negative image, but followed by another negative image. Sequential binding theory predicts that negative stimulus B should bind to *both* neutral stimulus A, occurring prior to B, and neutral stimulus C, occurring after stimulus B. Employin*g* a design that holds critical list positions constant would (e.g., position B) and manipulating the surrounding positions (position A and C) would more accurately determine if neutral that both precede and follow negative images benefit from prolonged exposure to the negative image.

In general, emotion was found to have an enhancing effect on memory. Future studies should better control for possible gender differences. Also, differences in retention should be investigated as research has shown that emotion enhancement of memory is most pronounced after sufficient consolidation time (Dolcos, LaBar & Cabeza, 2005). Finally, investigating differences between retrieval methods (recognition vs. recall) could help provide incremental information about how emotion is processed and the limits of its effects.

Researching the mechanisms of memory and how it is influenced by emotions is important. These types of investigations will aid in detecting individual differences in individuals with various mood disorders. More importantly, this type of research can provide useful information about specific nature of the deficits exhibited by individuals suffering from mental health issues.

REFERENCES

Anderson, A. K. (2005). “Affective Influences on the Attentional Dynamics Supporting Awareness.” *Journal Of Experimental Psychology: General, 134*(2), 258-281.

Burke, A. Heuer, F., Reisberg, D. (1992). "Remembering Emotional Events." *Memory & Cogntion 20*(3): 277-290.

Bradely, B. P. and A. D. Baddeley (1990). "Emotional Factors in Forgetting." *Psychological Medicine* 20: 351-355.

Bradley, M. M. (2009). "Natural selective attention: Orienting and emotion." *Psychology* 46: 1-11.

Bradley, M. M., Greenwald, M. K. Petry, M. C. & Lang, P. J., (1992). "Remembering Pictures: Pleasure and Arousal in Memory." *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18 2(379-390).

Buchanan, T. W., J. A. Etzel, et al. (2006). "The Influence of Autonomic Arousal and Semantic Relatedness on Memory for Emotional Words." *International Journal of Psychophysiology* 61: 26-33.

Cahill, L., Babinsky, R., Markowitsch, H. J., & McGaugh, J. L. (1995). The amygdala and emotional memory. Nature, 377(6547), 295-296. doi:10.1038/377295a0

Cahill, L., Haier, R. J., Fallon, J., et al (1996) Amygdala activity at encoding correlated with long-term, free recall of emotional information. *Proceedings of the National Academy of Sciences of the United States of America*, 93, 8016 -8021.

Cahill, L. & McGaugh, J. L. (1998). "Mechanisms of Emotional Arousal and Lasting Declarative Memory." *Trends in Neuroscinece 21*(7): 294-299.

Charles, S., Mather, M., & Carstensen, L. L. (2003). Aging and emotional memory: The forgettable nature of negative images for older adults. Journal Of Experimental Psychology: General, 132(2), 310-324. doi:10.1037/0096-3445.132.2.310

Choi, H., Kensinger, E. A., & Rajaram, S. (2013). Emotional content enhances true bunot false memory for categorized stimuli. *Memory & Cognition*, *41*(3), 403-415. doi:10.3758/s13421-012-0269-2

Clark, B., Michael, H. (2006). "Neural Coding-Hybrid Analog and Digital Signalling in Axons." *Current Biology* 16(15): 585-587.

Colden, A., Bruder, M., & Manstead, A. R. (2008). Human content in affect-inducing stimuli: A secondary analysis of the international affective picture system. Motivation And Emotion, 32(4), 260-269. doi:10.1007/s11031-008-9107-z

Criss, A. H., Wheeler, M. E., & McClelland, J. L. (2013). A differentiation account of recognition memory: Evidence from fMRI. Journal Of Cognitive Neuroscience, 25(3), 421-435. doi:10.1162/jocn_a_00292

Dahl, M., Johansson, M., & Allwood, C. (2006). The Relation Between Realism in Confidence Judgements and the Phenomenological Quality of Recognition Memory When Using Emotionally Valenced Pictures. *Applied Cognitive Psychology*, 20(6), 791-806. doi:10.1002/acp.1228

D'Argembeau, A. and M. V. d. Linden (2004). "Influence of Affective Meaning on Memory for Contextual Infromation " *Emotion 4*(2): 173-188.

Devore, G. (2011). "Memory for Emotional Images: Mechanisms of Episodic Processing and its Psychological Correlates." Manuscript in Preparation.

Dewhurst, S. A. & Parry, L. A. (2000). "Emotionality, distinctiveness, and recollective experience." *European Journal of Cognitive Psychology* 12(4): 541-551.

Dietrich, D. E., et al. (2001). "Differential Effects of Emotional Content on Event Related Potentials in Word Recognition Memory." *Neuropsychobiology (43*), 96-101.

Di Lollo, V., Kawahara, J., Ghorashi, S., & Enns, J. T. (2005). The attentional blink: Resource depletion or temporary loss of control?. *Psychological Research, 69*(3), 191-200. doi:10.1007/s00426-004-0173-x

Doerksen, S. & Shimamura, A. P. (2001). "Source Memory Enhancement for Emotional Words." *Emotion 1* (1): 5-11.

Dolcos, F., LaBar, K. S., & Cabeza, R. (2005). Remembering one year later: Role of the amygdala and the medial temporal lobe memory system in retrieving emotional memories. PNAS Proceedings Of The National Academy Of Sciences Of The United States Of America, 102(7), 2626-2631. doi:10.1073/pnas.0409848102

Dougal, S. & Rotello, C. M. (2007). "Remembering" emotional words is based on respose bias, not recollection." *Psychonomic Bulletin & Review 14*(3): 423-429.

Easterbrook, J. A. (1959). "The Effect of Emotion on Cue Utilization and the Organization of Behavior." *Psychological Review 66*(3)

Erdelyi, M. H. (1974) A new look at the New Look: Perceptual defense and vigilance. *Psychological Review 81*:1–25

Eysenck, M. W. (1976). "Arousal, Lerning, and Memory." *Psychological Bulletin 83*(3): 389-404.

Gavazzeni, J., Andersson, T., Bäckman, L., Wiens, S., & Fischer, H. (2012). Age, gender, and arousal in recognition of negative and neutral pictures 1 year later. Psychology And Aging, 27(4), 1039-1052. doi:10.1037/a0027946

Grider, R. C. & Malmberg, K. J. (2008). "Discriminating Between Changes in Bias and Changes in Accuracy for Recognition Memory of Emotional Stimuli." *Memory & Cognition 36*(5): 933-946.

Gruhn, D., S. & Scheibe, Baltes, P. B.(2007). "Reduced Negativity Effect in Older Adults' Memory for Emotional Pictures: The Heterogeneity-Homogeneity List Paradigm." *Psychology and Aging 22*(3): 644-694.

Guillet, R. & Arndt, J.(2009). "Taboo Words: The Effect of Emotion on Memory for Peripheral Information." *Memory & Cognition 37*(6): 866-879.

Hadley, C. B. & MacKay, D. G. (2006). "Does Emotoin Help or Hinder Immediate Memory? Arousal Versus Priority-Binding Mechanism." *American Psychological Association 32*(1): 79-88.

Hall, J. F. (1983). "Recall Versus Recognition: A Methodological Note " *Journal of Experimental Psychology: Learning, Memory, and Cognition 9*(2): 346-349.

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

Kapucu, A., Rotello, C. M., Ready, R. E., & Seidl, K. N. (2008). Response bias in “remembering” emotional stimuli: A new perspective on age differences. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34,* 703–711. doi: 10.1037/0278-7393.34.3.703

Karlsen, P., & Snodgrass, J. (2004). The word-frequency paradox for recall/recognition occurs for pictures. *Psychological Research*, 68(4), 271-276. doi:10.1007/s00426-003-0138-5

Kensinger, E. A. & Corkin, S. (2003). "Memory Enhancement for Emotional Words: Are Emotional Words More Vividly Remembered than Neutral Words?" *Memory & Cognition 31*(8): 1169-1180.

Kensinger, E. A., Garoff-Eaton, R. J., & Schacter, D. L. (2006). "Memory for Specific Visual Details Can Be Enhanced by Negative *Arousing Content." Journal of Memory and Language* 54: 99-112.

Kensinger, E. A., R. J. Garoff-Eaton, & Schacter, D. L. (2007). "Effects of Emotion on Memory Specificity: Memory Trade-offs Elicited by Negative Visually *Arousing Stimuli." Journal of Memory and Language* 56: 575-591.

Knight, M. & Mather, M. (2009). "Reconciling Findings of Emotion-Induced Memory

Enhancement and Impariment of Preceding Items." *Emotion 9*(6): 763-781.

Lane, R. D., et al. (2000). *Cognitive Neuroscience of Emotion*. Series in Affective Science New York, Oxford University Press.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2005). *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. (1997). "Emotion, Memory and the Brain." *Scientific American.* Special Issue: *Mysteries of the Mind*

Loftus, E. F., Loftus, G. R., & Messo, J. (1987). "Some Facts About "Weapon Focus"." *Law and Human Behavior 11*(1): 55-62.

MacKay, D., Burke, D. M. & Stewart, R. (1998). "H.M.'s Language Production Deficits: Implication for Relations Between Memory, Semantic Binding, and the Hippocampla System." *Journal of Memory and Language:* 38 38: 28-69.

MacKay, D., James, L. E., Hadley, C. B. (2008). "Amnesic H.M.'s Performance on the Language Competence Test: Parallel Deficits in Memory and Sentence Production." *Journal of Clinical and Experiemental Neuropsychology* 30(3): 280-300.

MacKay, D. G. & Ahmetzanov, M. V. (2005). "Emotion, Memory, and Attention in the Taboo Stroop Paradigm." *Psychological Science* 16(1): 25-32.

MacKay, D. G., et al. (2004). "Relations between emotion, memory, and attention: Evidence from taboo Stroop, lexical decision, and immediate memory tasks." *Memory & Cognition* 32(3): 474-488.

Maratos, E. J., Allan, K., & Rugg, M. D. (2000). Recognition memory for emotionally negative and neutral words: An ERP study. *Neuropsychologia*, 38, 1452-1465.

Martini, P., and Maljkovic, V. (2009). Short-term memory for pictures seen once or twice. *Vision Res.* 49, 1657–1667.

Mather, M. (2007). "Emotional Arousal and Memory Binding." *Perspectives on Psychological Science* 2(1): 33-52.

Mather, M. et al (2006). "Emotional Arousal Can Impair Feature Binding in Working Memory." *Journal of Cognitive Neuroscience* 18(4): 614-625.

Mather, M., Gorlick, M. A. & Nesmisth, K. (2009). "The Limits of Arousal's memory-imparining Effects on Nearby Information." *American Journal of Psychology* 122(3): 349-369.

Mather, M. & Nesmith, K. (2008). "Arousal-Enhanced Location Memory for Pictures." *Journal of Memory and Language* 58(449-464).

Mathewson, K. J., Arnell, K. M., & Mansfield, C. A. (2008). Capturing and holding attention: The impact of emotional words in rapid serial visual presentation. *Memory & Cognition*, 36(1), 182-200. doi:10.3758/MC.36.1.182

Meng, J., Yuan, J., Li, H., (2009). "Automatic processing of valence differences in emotionally negative stimuli: Evidence from an ERP study". *Neuroscience Letters*., 464(3), 228-232

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(2): 242-261.

Parks, C. M. (2012). Transfer-Appropriate Processing in Recognition Memory: Perceptual and Conceptual Effects on Recognition Memory Depend on Task Demands. Journal Of Experimental Psychology: Learning, Memory, And Cognition, doi:10.1037/a0030911

Potter, M. C., Wyble, B., Pandav, R., & Olejarczyk, J. (2010). "Picture Detection in Rapid Serival Visual Presentation: Features or Identity?" *Journal of Experimental Psychology: Human Percpetion and Performance* 1-9.

Ramponi, C., G. Handelsman, et al. (2010). "The Memory Enhancement Effect of Emotion Is Absent in Conceptual Implicit Memory." *Emotion* 10(2): 294-299.

Ritchey, M., Dolcos, F. Barnard, P. J. et al. (2008). "Role of Amygdala Connectivity in the Persistence of Emotional Memories Over Time: An Event-Related fMRI Investigation." *Cerebral Cortex* 18(2): 2495-2503.

Rozenkrants, B., & Polich, J. (2008). Affective ERP processing in a visual oddball task: Arousal, valence, and gender. Clinical Neurophysiology, 119(10), 2260-2265. doi:10.1016/j.clinph.2008.07.213

Schmidt, S. R., & Saari, B. (2007). The emotional memory effect: Differential processing or item distinctiveness?. *Memory & Cognition, 35*(8), 1905-1916. doi:10.3758/BF03192924

Sharma, D., & McKenna, F. P. (2001). "The Role of Time Pressure on the Emotional Stroop Task." *British Journal of Psychology 92*: 471-481.

Shimamura, A. P. (2010). "Hierarchical Relational Binding in the Meidal Temporal Lobe: The Strong Get Stronger." 20: 1206-1216.

Sison, J. G., & Mather, M. (2007). Does remembering emotional items impair recall of same-emotion items?. *Psychonomic Bulletin & Review,* 14(2), 282-287. doi:10.3758/BF03194065

Thapar, A., & Rouder, J. N. (2009). Aging and recognition memory for emotional words: A bias account. *Psychonomic Bulletin & Review*, 16(4), 699-704. doi:10.3758/PBR.16.4.699

Thomas, L. A. & LaBar, K. S. (2005). "Emotional Arousal Enhances Word Repetition Priming." *Cogntion and Emotion* 19(7): 1027-1047.

Tulving, E. (1985). "Memory and Consciousness." Canadian Psychology 26(1-12).

Windmann, S. & Kutas, M. (2001). "Electrophysiological Correlates of Emotion-Induced Recognition Bias." *Journal of Cognitive Neuroscience* 13(5): 577-592).

Zeelenberg, R., Wagenmakers, E. J., Rotteveel, M. (2006). "The Impact of Emotion on Perception." *Psychological Science* 17(4): 287-291.

APPENDIX A

ANOVA TABLES FOR ALL INTERACTIONS

Table 1.

ANOVA Table of Recognition Accuracy

Independent Variable	*df*	Mean Square	*F*	Observed Power
Valence	1	.01	.45	.10
List	1	.02	1.07	.17
Rate	1	9.83	250.7**	1.0
ValenceXListXRate	1	.14	8.33**	.80

*Sig. <0.01***
*Sig.<0.05**

Table 2.

ANOVA Table of Sensitivity, d'_e

Independent Variable	*df*	Mean Square	*F*	Observed Power
Valence	1	97.39	5.12*	.60
List	1	2.93	.14	.66
Rate	1	1538.53	69.93**	1.0
ListXRate	1	96.32	5.07*	.59

*Sig. <0.01***
*Sig.<0.05**

Table 3.

ANOVA Table of Criterion bias, C

Independent Variable	*df*	Mean Square	*F*	Observed Power
Valence	1	0.26	2.31	..3
List	1	0.03	1.18	.19
Rate	1	2.33	13.0**	.94

*Sig. <0.01***
*Sig.<0.05**

Table 4.

ANOVA Table of Backward Contextual Accuracy

Independent Variable	*df*	Mean Square	*F*	Observed Power
Target Valence	1	0.15	5.05*	.59
Context Valence	1	0.01	0.53	.11
Rate	1	8.24	186.67**	1.0
ContextValenceXRate	1	0.14	6.01*	.67

*Sig. <0.01***
*Sig.<0.05**

Table 5.

ANOVA Table of Forward Contextual Accuracy

Independent Variable	*df*	Mean Square	*F*	Observed Power
Target Valence	1	0.01	0.31	.08
Context Valence	1	0.13	4.71*	.56
Rate	1	1.31	33.46**	1
ContextValenceXRate	1	0.21	11.67**	.92

*Sig. <0.01***
*Sig.<0.05**

APPENDIX B

LIST OF IAPS IMAGES

IAPS Images					
Negative			Neutral		
2053.jpg	6243.jpg	9301.jpg	1333.jpg	5130.jpg	7052.jpg
2141.jpg	6250.1.jpg	9320.jpg	1450.jpg	5390.jpg	7053.jpg
2276.jpg	6260.jpg	9340.jpg	1670.jpg	5395.jpg	7055.jpg
2352.2.jpg	6300.jpg	9400.jpg	1910.jpg	5410.jpg	7056.jpg
2375.1.jpg	6311.jpg	9415.jpg	2000.jpg	5471.jpg	7059.jpg
2683.jpg	6312.jpg	9419.jpg	2038.jpg	5500.jpg	7060.jpg
2688.jpg	6315.jpg	9420.jpg	2102.jpg	5510.jpg	7080.jpg
2710.jpg	6350.jpg	9421.jpg	2104.jpg	5520.jpg	7090.jpg
2717.jpg	6360.jpg	9423.jpg	2190.jpg	5530.jpg	7100.jpg
2730.jpg	6370.jpg	9425.jpg	2200.jpg	5533.jpg	7110.jpg
2750.jpg	6415.jpg	9428.jpg	2210.jpg	5534.jpg	7140.jpg
2751.jpg	6510.jpg	9429.jpg	2221.jpg	5711.jpg	7150.jpg
2799.jpg	6530.jpg	9430.jpg	2240.jpg	5720.jpg	7160.jpg
2811.jpg	6540.jpg	9432.jpg	2270.jpg	5731.jpg	7161.jpg
2900.1.jpg	6550.jpg	9435.jpg	2320.jpg	5740.jpg	7170.jpg
2900.jpg	6560.jpg	9500.jpg	2381.jpg	5750.jpg	7175.jpg
2981.jpg	6570.1.jpg	9520.jpg	2393.jpg	5800.jpg	7179.jpg
3017.jpg	6570.jpg	9560.jpg	2397.jpg	5870.jpg	7180.jpg
3051.jpg	6821.jpg	9561.jpg	2440.jpg	5875.jpg	7185.jpg
3061.jpg	6825.jpg	9570.jpg	2480.jpg	6150.jpg	7187.jpg
3150.jpg	6830.jpg	9600.jpg	2495.jpg	7000.jpg	7205.jpg
3160.jpg	6831.jpg	9611.jpg	2499.jpg	7002.jpg	7217.jpg
3170.jpg	6838.jpg	9620.jpg	2513.jpg	7004.jpg	7224.jpg
3181.jpg	7380.jpg	9635.1.jpg	2570.jpg	7006.jpg	7234.jpg
3215.jpg	8485.jpg	9700.jpg	2580.jpg	7009.jpg	7235.jpg
3220.jpg	9000.jpg	9800.jpg	2597.jpg	7010.jpg	7490.jpg
3230.jpg	9006.jpg	9810.jpg	2620.jpg	7020.jpg	7491.jpg
3300.jpg	9007.jpg	9830.jpg	2745.1.jpg	7025.jpg	7500.jpg
3400.jpg	9050.jpg	9900.jpg	2840.jpg	7030.jpg	7547.jpg
3500.jpg	9140.jpg	9901.jpg	2850.jpg	7031.jpg	7700.jpg
3550.1.jpg	9181.jpg	9902.jpg	2870.jpg	7035.jpg	7705.jpg
4664.2.jpg	9220.jpg	9903.jpg	2880.jpg	7036.jpg	7900.jpg
6021.jpg	9250.jpg	9910.jpg	2890.jpg	7038.jpg	7950.jpg
6022.jpg	9253.jpg	9911.jpg	2980.jpg	7039.jpg	9210.jpg
6200.jpg	9254.jpg	9920.jpg	5010.jpg	7040.jpg	9360.jpg
6212.jpg	9265.jpg	9921.jpg	5020.jpg	7041.jpg	3550.jpg
6230.jpg	9280.jpg		5030.jpg	7043.jpg	
6242.jpg	9300.jpg		5120.jpg	7050.jpg	