2013

The effects of emotional arousal on item and associative memory

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THE EFFECTS OF EMOTIONAL AROUSAL ON ITEM AND ASSOCIATIVE MEMORY

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Arts

in

The Department of Psychology

by
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May 2013

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Abstract

Although the conclusions of research examining the impact of emotional arousal on associative memory are mixed (e.g., Mather & Nesmith, 2008; Zimmerman & Kelley, 2010), it has recently been suggested that associative memory should be enhanced by arousal when encoding is intentional rather than incidental (Mather & Sutherland, 2011). Research has also suggested that arousing items are more subject to interference effects in memory than non-arousing items. These predictions were explored across two experiments. In both experiments, participants intentionally encoded a series of picture pairs that consisted of two neutral pictures, two negatively arousing pictures, or one neutral picture and one negatively arousing picture. A recognition test assessed participants' associative memory for picture pairs as well as item memory for individual pictures. In Experiment 1 it was found that, even with intentional encoding, emotional arousal did not enhance associative recognition. In addition, arousal did not interact with the effects of interference. However, the results did show that repetition enhanced memory for neutral pictures more than arousing pictures. Research concerning the impact of arousal on memory typically finds that the enhancing effect of emotional arousal on memory is usually more apparent after a delay because of improved consolidation (e.g., McGaugh, 2004). Experiment 2 investigated the effect of emotional arousal on associative memory performance after a 48-hour delay. Emotional arousal led to poorer associative recognition. As in Experiment 1, repetition appeared to disproportionally enhance memory for neutral items. Overall, these studies found no evidence that associative recognition is enhanced by emotional arousal.

Introduction

One area of research that has received a lot of attention in the past few decades concerns the role of emotion in memory for events. In general, it is believed that emotion, and the resulting increase in arousal, enhances a person's ability to recall the individual features of an event (e.g., Kensinger, 2004; Levine & Pizarro, 2004; Mather, 2009). Arousal has been said to contribute to the selective retention as well as the subjective experience that accompanies a memory (e.g., LaBar, 2007). More specifically, emotional arousal appears to enhance attention to the central features of an event, improves the efficacy of consolidation processes, and ultimately increases the strength of memory trace, leading to enhanced retrieval for emotional memories (e.g., Christianson, Loftus, Hoffman, & Loftus, 1991; Dolcos, LaBar & Cabeza, 2005; LaBar, 2007).

Although research on this topic has a long history, there has been far more research examining how emotional arousal affects memory for an arousing stimulus (item memory) than how it affects the *associations* between items. This topic is important because in order to accurately recall an event, one must not only remember the individual features of the event (i.e. the people involved, the location, time of day, etc.), but also the associations among all those features (Earles, Kersten, Curtayne, & Perle, 2008). Furthermore, the research that has been conducted on associative memory has come to mixed conclusions about the impact of emotional arousal (e.g., Kensinger & Corkin, 2003; Mather & Sutherland, 2011; Zimmerman & Kelley, 2010). The proposed study is intended to examine the impact of emotional arousal on associative recognition under conditions where it has been predicted to be obtained (Mather & Sutherland, 2011).

Arousal and Memory

Recently, a new theory been put forth to explain how arousal can impact memory for items and their associations. Named the arousal-biased competition theory, the basic tenet is that arousal modulates the strength of competing mental representations such that memory will be enhanced for items that receive the most attentional resources at encoding (Mather & Sutherland, 2011). This modulation of the mental representation from arousal begins during initial perception of an item and continues through memory consolidation. Arousal-biased competition theory goes on further to specify that a certain item's priority determines whether arousal will have an enhancing or impairing effect on that item's perception and subsequent memory for that item.

Priority for an item can be determined one of two ways (Mather & Sutherland, 2011). First, an item can gain priority in visual perception through means of bottom-up processing. Items that "stand out" through differences in contrast, luminance, motion, etc. when compared to other items, tend to gain priority and garner more attentional resources. Second, an item can also gain priority through top-down processing mechanisms if it is relevant to the observer's goals, knowledge, or expectations. Either way, if an item is deemed to have higher priority over other items, then arousal is said to enhance this effect and increase memory for that item above and beyond what it would be otherwise.

One important aspect to note is that items that elicit arousal themselves will generally be considered high priority (Mather & Sutherland, 2011). It has been well established in the literature on emotion and memory that arousing items capture attention and this leads to enhanced processing of those items' features (Mather & Sutherland, 2011; Mather, 2007; Mather

& Nesmith, 2008). Arousal-biased competition theory says that arousal-eliciting items are often high priority and when presented in the context of non-arousing items, receive more attentional resources and therefore enhanced processing, and this comes at the expense of the non-arousing items which receive low priority status and less processing (Mather & Sutherland, 2011).

When it comes to predictions regarding how arousal will affect associative memory, arousal-biased competition asserts that if the association between two items is considered high priority (e.g., through intentional encoding), then arousal will enhance this association in memory (Mather & Sutherland, 2011). Support for this prediction comes from a study by Guillet and Arndt (2009) where participants were asked to remember word pairs that consisted of a neutral word paired with either a neutral, negatively-valenced or taboo word. Only the taboo words were high in arousal. Guillet and Arndt found that associative memory for word pairs was enhanced when one of the words was a highly arousing taboo word. In other words, the presence of arousal triggered binding mechanisms that increased the associative strength between the word pairs.

However, this prediction is in contrast to an earlier theory by Mather, the object-based framework (Mather, 2007). This theory asserts that the emotional arousal associated with one object will either impair or have no effect on associations between that object and another object or background contextual features. The logic behind this is that since the benefits of attention for memory binding only accrue for the object being attended to, these enhancing effects may not transfer or carry over for other objects present at the same time or for other background contextual details. To account for this, arousal-biased competition theory specifies that an association between objects is only made high priority when participants are explicitly instructed to remember the association among the items (Mather & Sutherland, 2011). More specifically,

intentional associative encoding instructions should make the association a top-down priority, and emotional arousal will thus enhance encoding of this information. Testing this prediction was the focus of Experiment 1. In contrast to prior research reviewed above, however, this experiment made use of pictorial stimuli and included several different types of picture pairs – negative arousing pictures paired with other negative arousing pictures, negative arousing pictures paired with neutral pictures, and neutral pictures paired with other neutral pictures.

Arousal and Interference

The strength of association between items can be affected both by repetition and by increased variability of association (i.e., association of an item with more than one item). The latter tends to decrease memory strength because of interference effects. Experiment 1 also sought to address a second question - whether or not arousal increases the effects of interference in associative memory. Mather (2009) suggested that, in a number of situations, emotional arousal increases the susceptibility of memories to interference. As one example, emotional information appears harder to update in memory than neutral information. Support for this comes from a previous study by Novak and Mather (2009) that was designed to answer the question of whether or not emotional arousal enhances or hinders the updating of event representations in memory after features of those events change. In this study, participants viewed a series of arousing and neutral pictures that appeared on a computer screen in one of eight possible locations. After viewing all 64 pictures, participants completed a recall task where a picture they had previously seen would appear in the middle of the screen and they would have to indicate which location the picture had previously appeared in. If any mistakes were made during this recall task, participants were required to complete another study-test block, meaning they would again view all 64 pictures in the same locations and then complete another recall task to see if

they could accurately identify where each picture had been located. Participants completed this study-test block cycle until they reached a criterion level of correctly recalling all picture-locations twice.

The results from this experiment revealed that overall location memory for arousing pictures was worse than for neutral pictures (Novak & Mather, 2009). After the first study-test block participants were equally good at identifying the locations of both arousing and neutral pictures. However, starting with the second study-test block and following with each subsequent block, participants tended to make more picture-location errors for arousing pictures than for neutral pictures. Furthermore, the decreased performance for arousing pictures was driven primarily by the fact that participants repeatedly made the same picture-location errors for the arousing pictures. In other words, forming initial incorrect associations lead to more interference for learning the correct associations, but only for the arousing pictures. In a second experiment, the same procedure was employed except half-way through the study phase, half of the pictures changed locations. Participants were warned that this would happen and were told to update their memory accordingly. Once again the results demonstrated that participants were worse at updating their memory for changes to locations of the arousing pictures. Novak and Mather interpreted these results as indicating that it's harder to update information in memory for arousing items and attributed this difficulty to proactive interference.

One goal of Experiment 1 is to examine the more general hypothesis that emotional arousal intensifies the effects of interference (Mather, 2009). Specifically, the focus is on associative interference that is created when a given picture is associated with a number of other pictures at encoding.

Experiment 1

The first experiment was aimed at testing the conditions under which arousal can enhance associative memory, as specified by the arousal-biased competition theory, and also at further investigating the issue of whether or not arousal increases interference. To accomplish this, Experiment 1 made the use of a paradigm that deliberately creates interference for associative memory in an attempt to see if arousal increases this interference. This paradigm was also selected because it allows researchers to independently test the effects of arousal on item and associative memory.

Fan 5 Paradigm

In order to investigate the two issues previously described, Experiment 1 adopted a research design developed by Buchler, Light, and Reder (2008) called the Fan 5 paradigm and used it to present pairs of either arousing or non-arousing pictures to participants and then evaluate their memory for how well they remembered the picture pairs.

The Fan 5 paradigm was originally developed for word-pair stimuli and makes use of two different experimental manipulations – repetition and interference (Buchler, et al. 2008). For repetition, word pairs could be seen either once or five times during the study phase. For interference effects, one or both words in each pair could also be paired with other words during study in order to vary how many word pairs were associated with a given word. There were 4 levels of interference used in this paradigm. Fan 1-1 word pairs consisted of words that were only paired together and these pairs would be seen once during the study phase. Rep 5 word pairs were seen together five times. Fan 1-5 word pairs occurred when the word on the left side of the pair was only seen once during study, but the word on the right side of the pair was also

seen paired with four other words during the study phase. Fan 5-1 word pairs occurred when the word on the right side of the pair was only seen once during study, but the word on the left side of the pair was also seen paired with four other words during the study phase. And finally, Fan 5-5 word pairs occurred when both words in a pair were also seen paired with four other words during the study phase (making each word appear five times). These two manipulations, repetition and interference, were used to separate the effects of item strength from associative strength during a recognition test.

For the Fan 5 paradigm, the test response options were also designed in a way to assess item memory strength separately from associative memory strength (Buchler, et al., 2008). During the recognition test, participants saw word pairs and were required to choose from among five response options which option best categorized the given word pair. The first response option was Old/Old Same, which was used to categorize a word pair that exactly matched a word pair seen during the study phase. The second response option, Old/Old Rearranged, was used to categorize a word pair at test that was composed of words seen during the study phase; however, these two words were never paired together. Thus, item memory for Old/Old Rearranged pairs would be strong, while the associative memory should be weak. The third response option was Old/New and should have been selected for word pairs that contained a previously seen word on the left and a novel, never before seen, word on the right. The fourth response option, New/Old, categorized word pairs where the word on the left was novel and the word on the right was seen during the study phase. Finally, the fifth response option was New/New and indicated test word pairs that were composed of two never before seen words.

Experiment 1 used the Fan 5 paradigm and made use of the repetition and interference manipulations as well as the five response options in order to assess memory for items and item

pairs (Buchler, et al., 2008). However, two important changes were made to the stimuli used in this study. First, instead of word pairs, picture pairs were used. Second, each picture pair contained either two neutral pictures, a negative arousing picture paired with a neutral picture, or two negative arousing pictures. All stimuli were taken from the International Affective Picture System database (Lang, Bradley, & Cuthbert, 2008). The decision to employ pictures rather than words was made because emotional pictures are generally experienced as more arousing than emotional words (as determined through norming), meaning the effects from arousal are usually more pronounced when the stimulus is pictorial in nature.

Predictions

With regard to the first research question for this study, whether or not arousal enhances item and associative information in memory, or just item information, predictions can be made based on the arousal-biased competition theory (Mather & Sutherland, 2011). If this theory is correct, then the results should show an increase in associative memory performance (as assessed by d' rates) for conditions containing an arousing picture (Mather & Sutherland, 2011). This would be consistent with the notion that if the top down goal for participants was to remember each picture pair, then arousal should enhance this goal and lead to better remembering for both pictures. However, this theory also asserts that having multiple high priority stimuli present can sometimes lead to competition between them for attentional resources, leading to an overall decrement in associative memory performance (Mather, Mitchell, Raye, Novak, Greene & Johnson, 2006). This could be the case with the arousing/arousing pairs. Hence, it is possible that enhancement would only be observed in the arousing/neutral condition. In this situation, it would be predicted that associative memory performance would be enhanced for the arousing/neutral condition, followed by the neutral/neutral condition, and then the

arousing/arousing condition. As for item memory performance, although it is not a major focus of this study, it is expected that arousal would enhance item memory for arousing pictures. This is consistent with a large amount of literature showing that arousing stimuli are better remembered than neutral stimuli (e.g., Mather, 2007; Mather & Sutherland, 2011). However, arousal-biased competition theory also states that having multiple high priority items in memory may lead to competition among those items for attentional resources. Therefore it is possible that we may only see memory enhancement for the arousing pictures that are in the arousing/neutral condition. Furthermore, neutral pictures presented in the context of an arousing picture could also show an increase in item memory performance. As suggested by arousal-biased competition theory, associative memory performance should be enhanced by arousal when intentional encoding instructions are given. This creates a top-down goal that makes both the neutral and arousing pictures high priority and thus it is likely that the neutral picture will be better remembered than when it is presented in the context of another neutral picture.

With respect to the question of whether or not arousal increases interference in memory, if arousal does interact with interference and increase its effects, then the results should show differences in d' for Fan 1-1, Fan 1-5, Fan 5-1, and Fan 5-5 such that d' declines more rapidly in conditions where an arousing picture is present. This finding would be consistent with the results from the previous study by Novak and Mather (2009) that demonstrated that arousal hinders the ability to create new associations and update memory representations. Finally, the nature of the Fan 5 paradigm also allows for an examination of the impact of repetition on memory (separately from the effects of interference). Previous research (Karam & Lane, 2011) found that repeated presentation enhanced recognition memory for neutral items more than it did for emotionally arousing items. They argued that this effect is similar in nature to research showing that

updating of context is weaker for arousing than neutral items (e.g., Novak & Mather, 2009). In the following experiment, the impact of repetition and arousal on associative memory and recognition memory will be examined. If consistent with the results of prior research, this would suggest weaker effects of repetition for arousing than neutral pictures.

Method

Participants

One hundred and twenty Louisiana State University undergraduate students participated in this study in exchange for fulfillment of a course requirement or for extra credit.

Design

A 3 x 2 x 5 mixed design was used for this study, where picture pair type served as a between subjects variable (neutral/neutral vs. neutral/arousing vs. arousing/arousing) and repetition (once vs. five times) and interference level (Fan 1-1 vs. Fan 1-5 vs. Fan 5-1 vs. Fan 5-5 vs. Fan 1-1 x5) served as within-subjects variables. Participants were randomly assigned to the conditions, and ultimately 38 students participated in the neutral/neutral picture condition, 43 students participated in the neutral/arousing picture condition and 39 participated in the arousing/arousing picture condition.

Stimuli

All pictures were taken from the International Affective Picture System database (Lang et al., 2008). Two hundred neutral pictures and two hundred negative arousing pictures were selected as stimuli for this study. All pictures were normed and ranked on a 9-point scale for arousal and valence. The neutral pictures were selected so that their mean valence rating was 5.2, which falls near the middle of the 9-point rating scale and indicates pictures that are neither highly positive nor highly negative. The mean arousal rating for the neutral pictures was 3.2, which is near the lower end of the 9-point rating scale and indicates pictures that are less arousing and more calming. The negative arousing pictures were selected so that their mean

valence rating of 2.4 was near the lower end of the 9-point scale indicating pictures that are more negative, and their arousal rating of 6.1 was near the upper end of the 9 point rating scale indicating pictures that more likely to elicit excitement or agitation. Across both sets, pictures were selected so that approximately two-thirds of them contained pictures of humans, one-third contained pictures of animals, and one-third contained pictures of objects.

For each set of 200 pictures, 40 of them were randomly chosen to serve as novel pictures during the test phase. The other 160 pictures were randomly paired and randomly assigned to each manipulation condition including the four levels of interference (Fan 1-1, Fan 1-5, Fan 5-1, and Fan 5-5) and 10 of the Fan 1-1 pairs were also assigned to the repetition condition and were seen five times during the study phase (Rep5x). In all, this produced 200 picture pairs that were seen during the study phase.

Test items consisted of 150 picture pairs that were either the same as picture pairs seen during study, or were one of three different types of foils: rearranged pairs, item pairs, or novel pairs. Rearranged pairs consisted of two pictures previously seen during the study phase, but these two pictures were not paired together. Item pairs consisted of one previously seen picture paired with one novel picture. Novel pairs consisted of two novel pictures paired together. Also, just as the Fan 5 paradigm stipulates, foil type was crossed with the repetition and manipulation factors under the condition that rearranged pairs involved the reassignment of pictures within the same level of fan condition (Buchler et al. 2008). This meant that when constructing the rearranged pairs, a Fan 5-1 picture could only be rearranged with another Fan 5-1 picture. Rather than using any sort of counterbalancing procedure, study and test pairs were randomly generated for each participant (as was the case in Buchler, et al. 2008).

Procedure

At the beginning of the experiment, participants were randomly assigned to one of the experimental conditions – neutral/neutral pictures, neutral/arousing pictures, or arousing/arousing pictures. After signing an informed consent form, participants were instructed that they were about to view a series of picture pairs and that they should carefully study each picture pair because they would later be tested on their memory for them. Then the study phase commenced. During this phase, participants viewed 200 picture pairs as they appeared on a computer screen at a rate of six seconds each, with a one second inter-stimulus interval.

After completing the study phase, participants had a ten-minute filler task where they completed a brief post-experiment questionnaire and a word search puzzle. The post-experiment questionnaire consisted of several questions that asked the participants how confident they were in their ability to remember the picture pairs, how difficult they felt it was to associate the two pictures together, and whether or not they used any strategies to assist them in remembering the picture pairs.

After ten minutes had elapsed, a training phase began where participants were instructed on how to complete the test phase of the experiment and were provided with examples and descriptions of each of the five test response options. The five response options were Old/Old Same, Old/Old Rearranged, Old/New, New/Old, and New/New. Next, the test phase of the experiment began. During this phase, a picture pair would appear on the screen and participants were instructed to choose the response option that best described the picture pair they were viewing. The picture pairs remained on the screen until participants made a response by pressing the appropriate number key (1-5) on the keyboard. Once participants had made responses to all

150 test picture pairs, the test phase concluded. At this point, participants completed a post-experiment questionnaire where they answered questions regarding how much effort they put into their performance on the test, and how well they thought they performed. Finally, participants were debriefed about the purpose and the experiment and then dismissed. The entire experiment lasted approximately 60 minutes.

Results

Effects of Arousal on Associative Memory and Interference

In order to evaluate the effects of arousal on associative memory and interference, memory performance was assessed using d' scores for each condition (see Figure 1 for a graphical representation of these data; See Appendix A for descriptive data for all response categories). Hits were defined as "Old/Old Same" responses to intact picture pairs and false alarms were defined as "Old/Old Same" responses to rearranged picture pairs. A 4 x 3 mixed model ANOVA was conducted where interference level served as the within subjects factor (Fan 1-1, Fan 1-5, Fan 5-1, Fan 5-5) and condition served as a between-subjects factor (neutral/neutral, neutral/arousing, arousing/arousing). The results of this ANOVA revealed a significant main effect of condition $F(2, 117) = 10.65$, $p < .001$. Follow-up Tukey tests were conducted and showed that performance in the neutral/neutral condition ($M = 1.01$) and the neutral/arousing condition ($M = .96$) was much higher than performance in the arousing/arousing condition ($M = .49$), $p < .01$. This is one critical part of this analysis because it demonstrates that associative memory performance was not enhanced when an arousing picture was present. There was also a significant main effect of interference $F(3, 351) = 24.07$, $p < .001$, where performance declined as interference increased across Fan levels (i.e.; Fan 1-1 ($M = 1.22$), Fan 1-5 ($M = .67$), Fan 5-1 ($M = .89$), Fan 5-5 ($M = .53$)). Post hoc Tukey tests were conducted and it was found that performance for the Fan 1-1 level was significantly better than all other levels, $p < .001$. Also, performance for the Fan 5-1 level was significantly better than performance for the Fan 5-5 level, $p < .001$. Lastly, performance for the Fan 1-5 level was not significantly different from performance for the Fan 5-1 or Fan5-5 levels, $p > .05$. And finally, there was no significant interaction, $F(6, 351) = 1.63$, $p = .14$. The lack of an interaction indicates that performance

declined similarly as a function of interference regardless of emotional arousal. Thus, interference effects on associative memory were clearly obtained, but these effects were not enhanced by the emotional arousal.

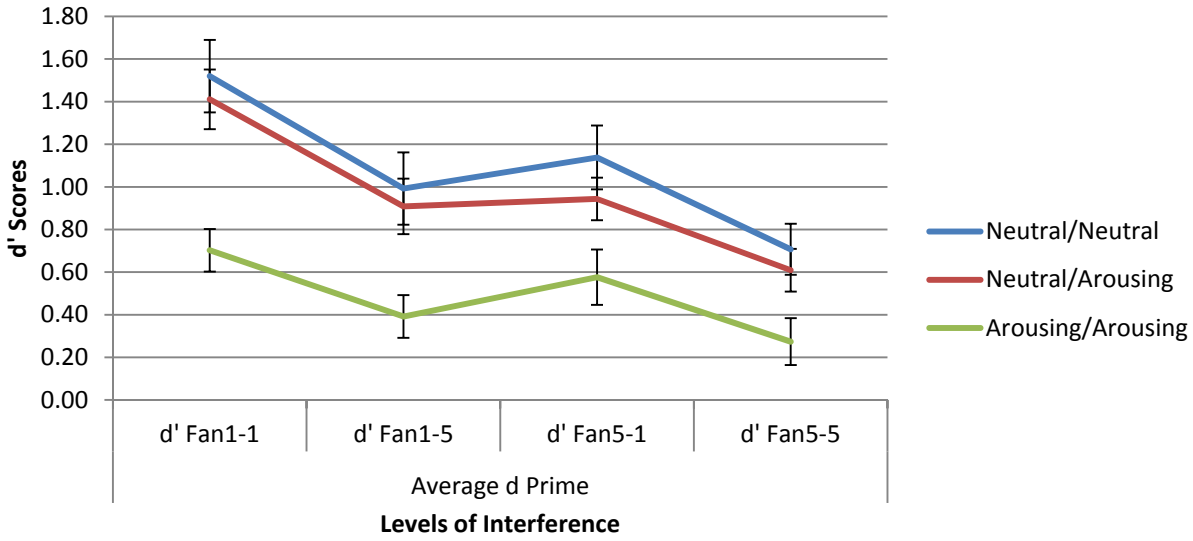

Figure 1. Associative memory performance as assessed by d' scores across interference levels for each condition. Overall associative memory performance was highest in the neutral/neutral condition and the presence of an arousing item did not interact with interference.

Effects of Arousal on Item Memory

In order to assess the effects of arousal on item memory, and to confirm that arousal did increase the item memory for arousing pictures, d' scores were also calculated for all test pairs that contained one old picture paired with one new picture for each condition (item pairs). Hits were defined as correctly labeling an item test pair as "Old/New" or "New/Old" and false alarms were defined as calling a novel test pair (two novel pictures paired together) either "Old/New" or "New/Old." The item test pairs that correspond to the response options "Old/New" and "New/Old" were composed of one picture that was seen during the study phase and one novel picture; hence, no association had been formed between the pictures in these pairs. Therefore,

correct memory performance for these test pairs was based on item memory alone. Furthermore, test pairs in the neutral/arousing condition were separated based on whether the arousing picture appears on the left or right side of the computer screen during test. This will divide the neutral/arousing condition into two picture pair types – (old) arousing with (new) neutral and (old) neutral with (new) arousing, thus indicating if the arousing picture represented the old or new picture in the test pair (see Figure 2).

To begin with, paired *t* tests were used to evaluate the within-subjects effects of arousal on item memory and it was found that item memory for arousing pictures presented in the context of a neutral picture (M=1.91) was significantly higher than that for neutral pictures presented in the context of an arousing picture (M=1.63), [$t(42)$= 2.23, p<.05]. This confirms that arousal did increase item memory for the arousing picture. Next, the effect of arousal of an accompanying picture on neutral pictures was investigated to determine if item memory for neutral pictures was enhanced when they were presented in the context of an arousing picture. An independent samples *t* test showed that item memory performance for neutral pictures paired with arousing pictures (M= 1.63) was significantly higher than neutral pictures paired with other neutral pictures (M=1.22) [$t(84)$= 1.74, p<.05]. This signifies that neutral pictures that are presented in the context of an arousing picture do receive a boost in item memory as compared to when they are presented in the context of another neutral picture. Finally, item memory performance for arousing pictures paired with other arousing pictures (M=1.16) was significantly lower than neutral pictures paired with arousing pictures (M=1.63) [t (80) = -2.88, p<.01] and arousing pictures paired with neutral pictures (M=1.91) [$t(80)$ = -4.91, p<.001], but not neutral pictures paired with other neutral pictures (M=1.22) [t (75) = .33, p=.74]. This indicates that the

item memory advantage typically obtained for arousing pictures disappeared when it was presented with a second arousing picture.

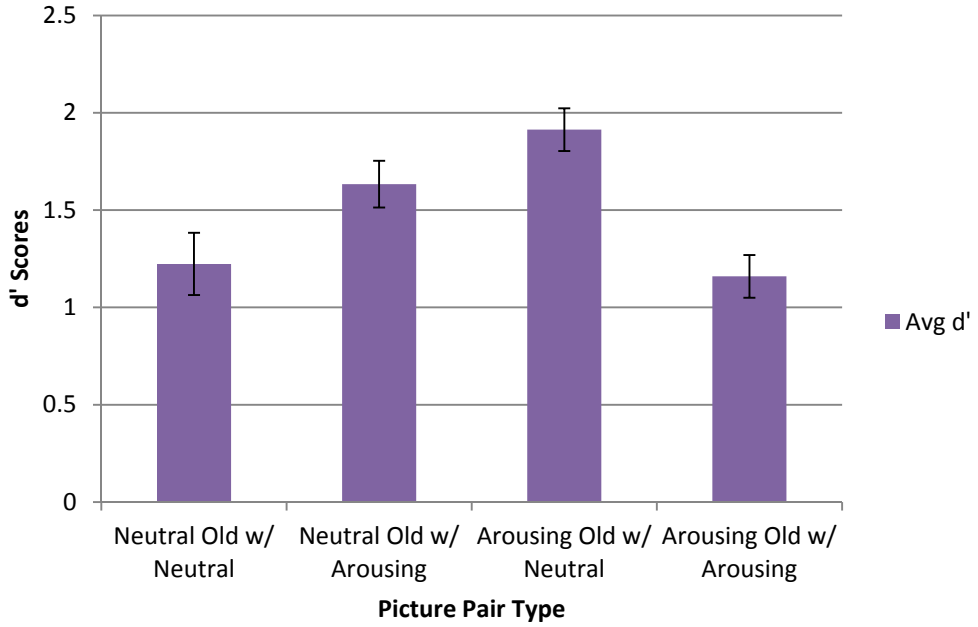

Figure 2. Item memory performance as assessed by d' scores for each picture type. Arousing/neutral items are split based on which appeared as the old item in the test pair.

Effects of Repetition on Memory

The impact of repetition on item and associative memory was also investigated. For item memory, d' scores were calculated for all item pairs that were repeated together once (Fan1-1) or five times (Rep5x) during the study phase. Item memory was tested for pairs that consisted of one old picture paired with one novel picture. Once again, hits were defined as correctly labeling an item test pair as "Old/New" or "New/Old" and false alarms were defined as calling a novel test pair (two novel pictures paired together) either "Old/New" or "New/Old" (see Figure 3).

A 2 x 3 repeated measures ANOVA was performed in order to assess the effects of arousal and repetition on item memory. Repetition level (once vs. five times) served as a within-subjects factor and condition (neutral/neutral vs. neutral/arousing vs. arousing/arousing) served as a between-subjects variable. There was a significant main effect of repetition, $F(1, 117) = 547.70$, $p<.001$, where, overall, item memory performance for pictures that were seen five times ($M= 2.53$) was better than item memory performance for pictures that were only seen once ($M=1.38$), $t(119)=23.60$, $p<.001$. There was also a significant effect of condition, $F(2, 117) = 8.74$, $p < .001$. Tukey post hoc tests found that performance in the neutral/arousing condition ($M=2.30$) was significantly better than performance in the neutral/neutral ($M=1.82$), $p<.01$, and the arousing/arousing ($M=1.72$), $p<.01$, conditions. However, performance between the neutral/neutral and the arousing/arousing conditions did not significantly differ, $p=.80$. The results also showed that there was not a significant interaction between the effects of repetition and arousal on item memory performance, $p=.88$.

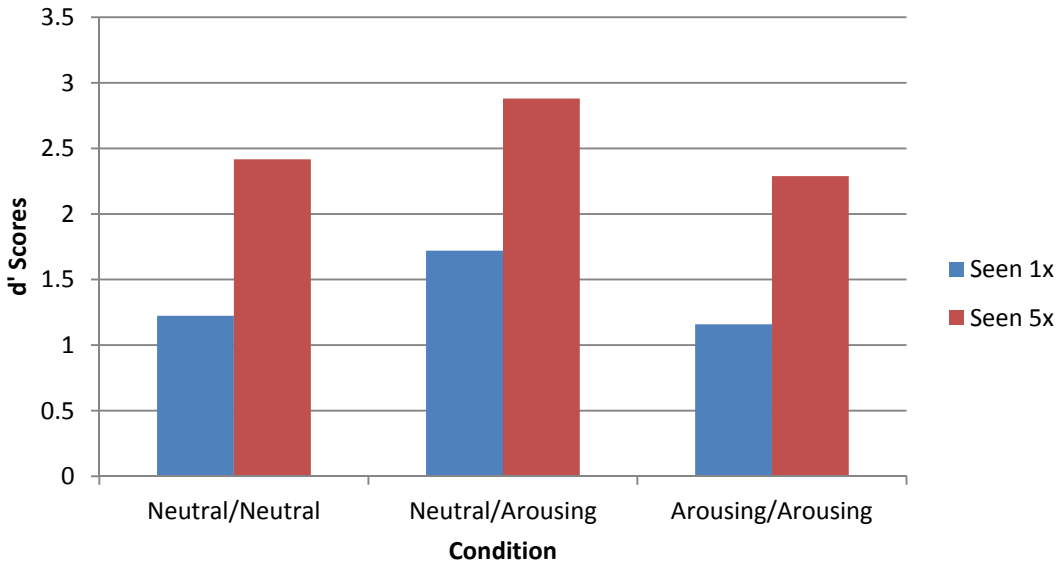

Figure 3. The effects of repetition on item memory performance as assessed by d' scores for each condition.

Furthermore, given the results above demonstrating that item memory performance differed in the neutral/arousing condition depending on whether the neutral or arousing picture served as the old item, we decided to conduct an exploratory analysis to determine whether or not there was also a difference in the impact of repetition on these two item types. Thus, the neutral/arousing condition was again divided into two item types - (old) arousing with (new) neutral and (old) neutral with (new) arousing – and we investigated the effect of repetition on item memory performance for these picture pairs.

A 2x2 within-subjects ANOVA was performed where item type (neutral vs. arousing) and repetition (one time vs. five times) served as the variables (see Figure 4). There was a significant effect of repetition, $F(1, 42) = 129.85$, $p < .001$ with item memory significantly better for picture pairs presented five times (M=2.9) than those that presented once (M=1.78). There was not a significant effect of item type, $F(1,42) = 1.05$, $p = .31$, but there was a significant interaction, $F(1, 42) = 10.67$, $p < .01$. As is clear from the figure and the analyses reported above (see p. 17-18), the interaction is the result of item memory performance for once-presented old arousing pictures paired with new neutral pictures being significantly better than performance for once-presented old neutral pictures paired with new arousing pictures, but no differences after five repetitions.

In order to assess whether or not repeated association impacted memory performance differentially for each condition (neutral/neutral, neutral/arousing, arousing/arousing), d' scores were again calculated (see Figure 5). Hits were defined as "Old/Old Same" responses to intact picture pairs that appeared during study and false alarms were defined as "Old/Old Same" responses to rearranged picture pairs. These scores were calculated for Fan5-5 items and Rep5x items. Fan5-5 indicates picture pairs where both pictures are seen five times during study, but

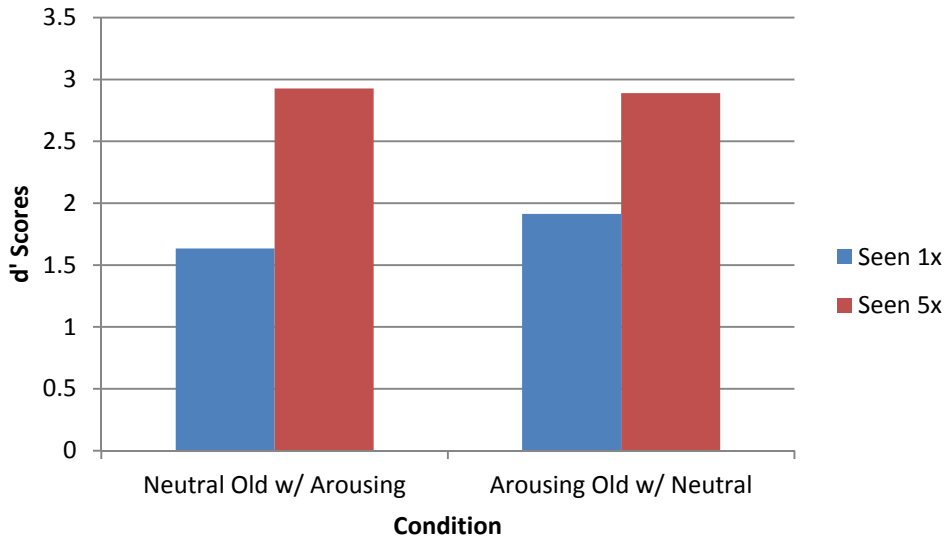

Figure 4. The effects of repetition on item memory performance as assessed by d' scores for old neutral pictures paired with new arousing pictures and old arousing pictures paired with new neutral pictures.

each time they are presented with a different picture. Rep5x picture pairs indicate pictures that are only presented together, and they are seen five times during study. Hence, both Fan5-5 items and Rep5x items contain pictures that were seen five times, so they have the same degree of repetition. However, only the Rep5x items contain no interference.

A 2 x 3 repeated measures ANOVA was performed where item type (Fan 5-5 vs. Rep5x) served as a within-subjects factor and condition (neutral/neutral vs. neutral/arousing vs. arousing/arousing) served as a between-subjects factor. There was a significant main effect of item type, where associative memory performance for Fan 5-5 (M=.53) was significantly lower than Rep5x (M= 2.65), $F(1,117) = 529.02$, p <.001. There was also a significant main effect of condition $F(2,117) = 15.32$, p<.001. Follow-up t tests revealed that the associative memory performance was significantly lower in the arousing/arousing condition (M=1.10) than associative memory performance for the neutral/neutral condition (M=1.86), [$t(75) = 2.7$, p<.01] and the neutral/arousing condition, (M=1.80), [$t(80)=2.22$, p<.05]. Finally, there was also a

significant interaction $F(2,117) = 6.43$, $p = .002$. To follow-up on this interaction, post hoc paired *t* tests were conducted for each condition. In the neutral/neutral condition, performance for the Rep5x (M=3.01) was significantly better than performance for the Fan5-5 (M=.71), [$t(37)= 14.02$, $p<.001$; $d= 2.28$]. The same was also true for the neutral/arousing condition, performance for the Rep5x (M=3.00) was significantly better than performance for the Fan5-5 (M=.61), [$t(42)= 17.33$, $p<.001$; $d=2.67$]. Finally, the same pattern was also upheld in the arousing/arousing condition, performance for the Rep5x (M=1.92) was significantly better than performance for the Fan5-5 (M=.27), [$t(38)= 9.37$, $p<.001$; $d=1.65$]. Thus, for all three conditions associative memory performance was significantly better for pairs that were seen together five times (Rep5x) than those that were not (Fan5-5). However, the results also show that the size of the effect is much larger for the neutral/neutral and the neutral/arousing conditions. Hence, the follow-up analyses also demonstrate that the arousing/arousing condition did not benefit from arousal to the same degree as the other two conditions. However, one potential issue is that performance is near floor in the Fan 5-5 condition of the arousing/arousing condition.

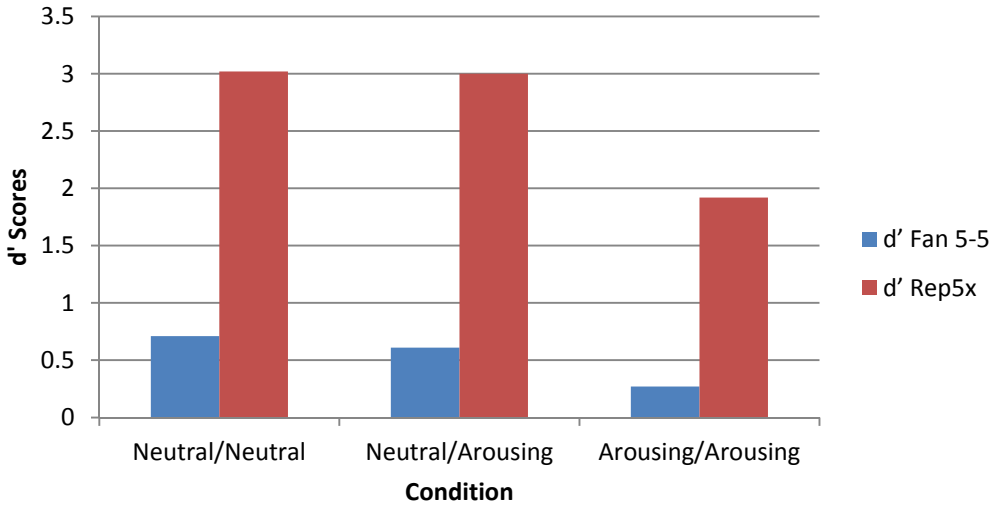

Figure 5. The effects of repetition on associative memory performance

Discussion

The finding that emotional arousal did not enhance associative memory in the current study does not appear to support a prediction of the arousal-biased competition theory (Mather & Sutherland, 2011). Associative memory performance in the neutral/arousing condition was not significantly better than performance in the neutral/neutral condition. In other words, the presence of an arousing item did not enhance associative memory even when it was explicitly stated that participants should remember the pictures together and therefore, the association between the pictures should have been high priority. This result is more consistent with Mather's (2007) object-based framework, which predicts that arousal will either impair or have no effect on associations between items (i.e., arousal only enhances within-object binding).

A second finding was that interference appears to have similar effects on associative memory regardless of the emotional arousal of the constituent stimuli. Instead, the results of the current study found that associative memory performance (as assessed by d' scores) declined steadily as a result of the interference effects created by Fan levels. Thus, impact of arousal on memory performance was similar across levels of interference. Of course, it is possible that the general interference created by the fan manipulation may be affected differently by arousal than proactive interference effects discussed by Mather (2009). Furthermore, one difference between the current experiment and studies such as Novak and Mather (2009) is that the latter focused on how well participants could recall picture-location conjunctions, which measures the ability to bind within-object features. Therefore, it is possible that the findings from their study do not translate into how arousal would affect interference for associative memory, which measures between-object binding.

It was also found that item memory performance for the arousing pictures was better than item memory performance for the neutral pictures, indicating that the arousing pictures were better remembered. This result was expected given that previous research has shown that item memory is generally better for emotional than neutral stimuli (e.g., Levine & Pizarro, 2004; Kensinger, 2004). However, this advantage was seen only when an arousing picture was presented in the context of a neutral picture. Arousing pictures that appeared in the arousing/arousing condition did not receive the same memory benefit as the arousing pictures that were presented in the arousing/neutral condition. This is consistent with the notion that having multiple high priority stimuli present causes them to compete with each other and thus may not be enhanced (Mather and Sutherland, 2011).

Item memory for neutral pictures that were presented in the arousing/neutral condition was significantly better than memory performance for the neutral pictures that were presented in the neutral/neutral condition. This result might seem to contradict what was put forth in the arousal-biased competition theory regarding the effects of arousal on item memory (Mather & Sutherland, 2011). According to this theory, arousal-eliciting items are always considered to be high priority and when presented in the context of a non-arousing item, the arousing items will receive more attentional resources and therefore enhanced processing, and this comes at the expense of the non-arousing items which receive low priority status and less processing. However, arousal-biased competition theory also suggests that arousal will increase priority of goal-relevant stimuli. The use of intentional encoding instructions for the picture pairs in this study may have created a top-down goal for participants that made both pictures goal-relevant. Hence, item memory performance for the neutral pictures in this study did not suffer when they were presented alongside an arousing picture. Interestingly, this particular finding does

contradict the prediction of Mather's (2007) object-based framework that arousal should only enhance within-object binding and thus the finding that neutral item memory was enhanced in the context of an arousing item should not have been obtained.

Another interesting finding from this study involves the effect of repetition on memory performance. The results showed that repetition (items that were presented 5 times) provided greater enhancement to memory for the neutral pictures as compared to memory for the arousing/arousing picture pairs. More specifically, while performance for all conditions improved with repetition, the increase in associative memory was much greater for neutral pictures. Thus, arousing pictures did not appear to benefit as much from repetition.

This finding with respect to repetition is consistent with other research from our laboratory examining the testing effect with (single) emotional and neutral stimuli (Karam & Lane, 2011). In this study, it was found that when pictures were presented more than once either through initial testing or repeated studying, performance on a subsequent recognition test showed that neutral pictures benefitted more from the repetition than the arousing pictures. So once again memory performance was enhanced for both items when they were repeated, but the arousing pictures did not benefit to the same degree. However, Karam and Lane's (2011) research assessed item memory while Experiment 1 described above found the same result for associative memory as well. Related to this are results that have been found in the work of Mather and Knight (2008). For this experiment, participants were asked to learn which sounds preceded either an emotional picture or a neutral picture (a harbinger). Those same sounds were then paired with digits during the second phase of the experiment. Participants were then tested on their memory for the tone-digit pairings. The results indicated that memory for the digit-tone pairings was worse when the tone was previously associated with an emotional picture than a

neutral picture, suggesting that learning initial associations for emotional items interferes with learning subsequent associations. Nevertheless, although this issue was examined in Experiment 1, it is it is more of a primary focus in Experiment 2.

Experiment 2

Although Experiment 1 did not find any evidence that emotional arousal enhanced associative memory, it is possible that this result was obtained because of the short retention interval that was employed (a necessity because of the fan manipulation). Research on the impact of emotional arousal on memory has found that effects are generally greater over a delay, with lower levels of forgetting for emotional than neutral materials (e.g., Dolcos, LaBar, & Cabeza, 2005; La Bar & Phelps, 1998). Research on the neural mechanisms of memory for arousing events indicates that arousal enhances long-term retention of emotional stimuli by altering hippocampal-dependent consolidation of arousing memories (e.g., LaBar, 2007; LaBar & Phelps, 1998; McGaugh & Roozendaal, 2002; Phelps & Sharot, 2008). The memory modulation hypothesis proposed by McGaugh (2004) postulates that the amygdala is responsible for enlisting stress hormones that interact to promote memory storage for arousing events, leading to slower forgetting over time.

Support for this hypothesis can be found in one study by Sharot and Phelps (2004). In this experiment participants were asked to fixate on a central word while an arousing or neutral word was shown in their periphery. Participants then completed a recognition test of the peripheral words either immediately or after a 24 hour delay. Performance on the recognition test showed that recognition of neutral words declined over time, but recognition of the arousing words remained stable indicating less forgetting of the arousing words over time.

Similar effects have been found over longer delays as well. In one study by Dolcos, LaBar, and Cabeza (2005), the memory-enhancing effect of emotion was found to be present even after a one year delay. During this study participants were asked to rate both emotional and neutral pictures on pleasantness and were not warned that they would tested on their memory for

the pictures. One year later, participants returned and were asked to complete a recognition test where they were shown previously seen pictures and new pictures. It was found that recognition performance was better for the emotional pictures than the neutral pictures demonstrating that the enhancing effect of arousal is present even after lengthy retention intervals.

However, all of the aforementioned studies that investigated the enhancing effect of emotion after a delay only assessed item memory. Much less is known about how associative memory would be affected. A recent study by Pierce and Kensinger (2011) investigated this issue and proves to be more relevant to Experiment 2. Across two experiments, participants were asked to study negative, neutral, and positive word pairs and told that they should link the two words together because they would later be tested on them. To facilitate how well participants linked the words, they were told to construct a sentence in their head using both words. During the test portion of the experiment, participants were asked to discriminate between intact, rearranged, and new versions of the word pairs (a task that is similar to what is performed during the Fan 5 paradigm). In the first experiment, the associative recognition test was completed only after a short delay. These results showed that accuracy for intact pairs was equivalent across word pair types (negative, positive, and neutral), whereas accuracy for rearranged pairs was lower for negative word pairs than for positive or neutral word pairs. This finding would be consistent with what was found in our previous experiment in that once again it appears that arousal failed to enhance associative recognition performance. However, in the second experiment, the associative recognition task was administered after a one-week delay. This time it was found that accuracy was greater for intact negative word pairs and accuracy was equivalent across the word pair types for rearranged pairs[1]. Thus, the beneficial effects of arousal on associative memory were only apparent after a delay. From this, the authors concluded that

arousal from negative stimuli may impair associative binding after a short delay, but it improves associative binding after a long delay. Experiment 2 sought to further investigate this claim.

The procedure for Experiment 2 was identical to that used in Experiment 1, except for four differences. Most importantly, participants returned 48 hours after the study phase to take the recognition memory test. Second, the interference manipulation (Fan) was not used, as performance in many conditions (e.g., Fan 5-5) would likely be at or near floor after such a delay. Third, the pictures were repeated once, three times, or five times. Finally, during the study phase, picture pairs appeared on the screen at a rate of five seconds each, instead of six. This allowed the study phase to be completed within a single session (1/2 hour).

Predictions

The effects of arousal on associative memory performance were analyzed using d' measures where correctly calling an intact pair Old/Old Same counted as a hit and incorrectly calling a rearranged pair Old/Old Same served as a false alarm. If the hypothesis that the beneficial effects of emotion are more apparent after a delay is true, then the results should reveal better associative memory (higher d' scores) for arousing/neutral picture pairs as compared to memory for neutral/neutral and arousing/arousing picture pairs. This result would be consistent with the predictions of arousal biased competition theory (Mather & Sutherland, 2011), as well as recent research by Pierce and Kensinger (2011).

Similarly, the effects of arousal on item memory was also assessed using d' scores. In this case, a hit was defined as correctly labeling a previously seen picture as "old" by selecting the appropriate response option, Old/New or New/Old, and a false alarm was defined as labeling a previously seen picture as "new" labeling a novel pair either "Old/New" or "New/Old." Once again, consistent with the literature showing that forgetting of arousing stimuli is slower than for

neutral stimuli, it is expected that item memory will be better overall for arousing pictures than neutral pictures after a delay (Dolcos, et al., 2005; LaBar & Phelps, 1998; Sharot & Phelps, 2004). This advantage may only be seen when arousing pictures are paired with neutral pictures, an effect that was demonstrated in the previous study, because presenting two arousing pictures together causes them to compete for attention and leads to a decrement in memory. Furthermore, if arousal-biased competition theory is correct then neutral pictures that are paired with arousing pictures should also be better remembered over a delay because the neutral picture will become a goal-relevant stimulus when participants are instructed to remember the association between the pictures (Mather & Sutherland, 2011).

With respect to the repetition manipulation, if the results of the proposed study are consistent with what was found in Experiment 1, then associative memory should be enhanced to a greater degree for neutral pictures than arousing pictures. If it is, then it's expected that we will see lower item memory performance due to the longer delay in this study; however, the decline we see should be similar in proportion for items seen once and those seen five times. Hence, we expect to see the same pattern of results for item memory that was found in Experiment 1.

Endnote

[1] It was also the case that false alarms (saying rearranged or new items had been seen "intact" at encoding) were made at a higher rate to negative arousing pairs than neutral arousing pairs. However, using corrected recognition scores, the authors argued that the increase in accuracy to negative arousing pairs exceeded the general tendency to respond "intact" to rearranged pairs.

Method

Participants

One-hundred and eight undergraduate students from Louisiana State University participated in this study in exchange for fulfillment of a course requirement or for extra credit. The data from two students were removed from the study because their accuracy levels at test were more than two standard deviations away from the group mean.

Design

A 3 x 3 mixed design was used for this study, where picture pair condition served as a between subjects variable (neutral/neutral vs. neutral/arousing vs. arousing/arousing) and repetition (once vs. thrice vs. five times) served as a within-subjects variable. Participants were randomly assigned to the picture pair conditions so that 37 students participated in the neutral/neutral picture condition, 39 students participated in the neutral/arousing picture condition and 32 participated in the arousing/arousing picture condition.

Stimuli

One hundred and fifty-six IAPS pictures were taken from both groups in Experiment 1 (neutral and negative arousing) and were used in Experiment 2. The subset of the pictures were selected such that of the arousing pictures originally used, the ones that were higher in arousal and lower in valence will be selected and of the neutral pictures originally used, the ones that were lower in arousal and more neutral in valence will be selected. Therefore, in Experiment 2, the arousing pictures had a mean arousal rating of 6.15 and a mean valence rating of 2.28 and the neutral pictures had a mean arousal rating of 3.6 and a mean valence rating of 5.58.

From each set of 156 pictures, 48 were randomly chosen to serve as novel pictures during the test phase. The other 108 pictures were randomly paired and randomly assigned to each repetition condition and were seen one, three, or five times during the study phase. In all, this produced 162 picture pairs that were seen during the study phase.

Test items consisted of 78 picture pairs and were constructed in the same fashion as Experiment 1, meaning at test each picture pair was either the same as a picture pair seen during study, or one of three different types of foils: rearranged pairs, item pairs, or novel pairs. Rearranged pairs consisted of two pictures previously seen during the study phase, but these two pictures were not paired together. Item pairs consisted of one previously seen picture paired with one novel picture. And novel pairs consisted of two never-seen pictures paired together. Study and test pairs were randomly generated for each participant.

Procedure

The procedure for Experiment 2 was identical to that used in the Experiment 1, except for the delay. All instructions were otherwise the same.

Results

Effects of Arousal and Repetition on Associative Memory

In order to evaluate the effects of arousal and repetition on associative memory, performance was assessed using d' scores for each condition. Hits were defined as "Old/Old Same" responses to intact picture pairs and false alarms were defined as "Old/Old Same" responses to rearranged picture pairs (see Appendix B for descriptive data for all response categories). A 3 x 3 mixed model ANOVA was conducted where repetition served as the within subjects factor (once vs. thrice vs. five times) and picture pair condition served as a between-subjects factor (neutral/neutral vs. neutral/arousing vs. arousing/arousing). The results of this ANOVA revealed a significant main effect of condition $F(2, 105) = 13.97$, $p < .001$. Tukey post hoc comparisons demonstrated that performance in the neutral/neutral condition ($M = 1.77$) was significantly better than performance in the neutral/arousing condition ($M = 1.03$), ($p<.001$) and performance in the arousing/arousing condition ($M = .95$), ($p<.001$). However, performance in the neutral/arousing condition and arousing/arousing condition did not statistically differ, $p>.05$. Once again, this demonstrates that associative memory performance was not enhanced when an arousing picture was present. In contrast to Experiment 1, arousal appeared to impair associative memory in the arousing/neutral condition. There was also a significant main effect of repetition $F(2, 210) = 52.69$, $p < .001$. A post hoc Tukey test revealed that associative memory was significantly higher for pairs that were repeated five times ($M= 1.82$) than by pairs that were repeated three times ($M = 1.34$), ($p<.001$) and pairs that were only seen once ($M = .55$), ($p<.001$). Associative memory performance was also significantly higher for pairs that were repeated three times than pairs that were only seen once ($p<.001$) during the study phase. Finally, there was also a significant interaction $F (4, 210) = 4.31$, $p< .01$. Post Hoc analyses were

performed and revealed that performance for pictures that were only seen once did not statistically differ by condition (neutral/neutral *M*= .70, neutral/arousing *M*= .43, arousing/arousing *M*= .51). However, performance did significantly differ for pictures that appeared three times during encoding. In this case, performance in the neutral/neutral condition (*M*= 2.18) was significantly higher than performance in the neutral/arousing condition (*M*= 1.08), (*p*<.001) and the arousing/arousing condition (*M*=.75), (*p*<.001). The same was true for pictures that were repeated five times during encoding. Performance in the neutral/neutral condition (*M*=2.44) was significantly higher than performance in the neutral/arousing condition (*M*=1.56), (*p*<.001) and the arousing/arousing condition (*M*=1.43), (*p*<.001). No other differences were significant. Associative memory performance in the neutral/neutral condition after three and five repetitions was significantly better than associative memory performance for the other two conditions at the same repetition levels, thus replicating our finding from Experiment 1 that pictures in the neutral/neutral condition receive a greater enhancement from repetition (see Figure 6).

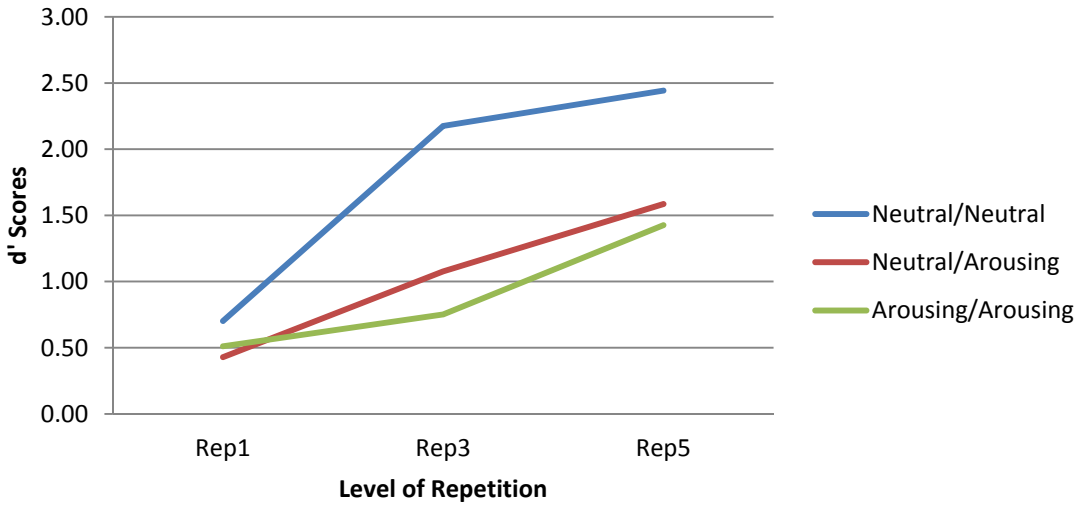

Figure 6. Associative memory performance as assessed by d' scores across repetition levels for each condition.

In order to further investigate whether these differences in associative memory are driven by differences in the hit rates or the false alarm rates, analyses were run separately on both aspects of performance (see descriptive statistics in Table 1). To begin, a one-way ANOVA performed on the average hit rates revealed a significant difference in how well participants correctly remembered intact test pairs for each condition, $F(2, 107) = 3.16$, $p=.046$. However, Tukey post hoc tests revealed that none of the comparisons between average hit rates for each condition reached conventional significance. Instead, it was found that the hit rates for the neutral/neutral condition ($M=.68$) and the neutral/arousing condition ($M=.69$) were higher than the hit rate for the arousing/arousing condition ($M=.59$), but these differences only approached significance ($p=.09$ and $p=.06$, respectively). Hence, there were only minor differences in the hit rates for each picture pair condition.

Next, a one-way ANOVA was performed on the average false alarm rate for each condition. Again, false alarms were defined as incorrect "Old/Old Same" responses to rearranged picture pairs. A significant effect was found indicating that false alarm rates did statistically differ for each condition, $F(2, 107) = 16.45$, $p<.001$. Tukey post hocs test revealed that the false alarm rates for the arousing/arousing condition ($M= .32$) and the neutral/arousing condition ($M= .37$) were significantly higher than the false alarm rate for the neutral/neutral condition ($M= .16$), $p<.001$; however, the first two conditions did not significantly differ from each other. Thus, it appears that the lower d' scores for the arousing/arousing and arousing/neutral picture pair conditions were driven mainly by increased false alarm rates. This indicates that participants in these conditions had greater difficulty rejecting distractors that appeared at test.

Table 1.

Hit and false alarm rates by picture pair type.

	Neutral/Neutral	Neutral/Arousing	Arousing/Arousing
Average Hit Rate	0.68	0.69	0.59
Average False Alarm Rate	0.16	0.37	0.32

Effects of Arousal and Repetition on Item Memory

In order to assess the effects of arousal and repetition on item memory, d' scores were calculated for all test pairs that contained one old picture paired with one new picture for each condition (item pairs). Hits were defined as correctly labeling an item test pair as "Old/New" or "New/Old" and false alarms were defined as calling a novel test pair (two novel pictures paired together) as either "Old/New" or "New/Old." The item test pairs that corresponded to the response options "Old/New" and "New/Old" were composed of one picture that was seen during the study phase and one novel picture; hence, no association was formed between the pictures in these pairs. Therefore, correct memory performance for these test pairs was based on item memory alone.

To assess the effects of arousal and repetition on item memory a 3 x 3 repeated measures ANOVA was performed. Repetition level (once vs. thrice vs. five times) served as a within-subjects factor and picture pair condition (neutral/neutral vs. neutral/arousing vs. arousing/arousing) served as a between-subjects variable. This repeated measures ANOVA revealed a significant main effect of repetition $F(2, 210) = 229.69$, $p < .001$, demonstrating that item memory performance significantly differed at each level of repetition. Post hoc tests using the Bonferroni correction showed that item memory for pictures that were seen five times during

encoding (M = 2.60) were remembered significantly better than pictures that were seen three times (M = 2.40), p<.001 and pictures that were seen three times were remembered significantly better than pictures that were only seen once (M = 1.44) , p<.001. There was also a significant main effect of condition $F(2, 105) = 7.16$, $p < .001$, demonstrating that arousal also had a significant effect on item memory performance. Tukey post hoc tests indicated that item memory performance in both the neutral/neutral (M = 2.43) and the neutral/arousing conditions (M = 2.19) were significantly better than performance in the arousing/arousing condition (M = 1.78), p<.05. However, item memory performance in the neutral/neutral condition and the neutral/arousing condition did not significantly differ. Lastly, the interaction between the effects of repetition and arousal on item memory performance was not significant, $F(4, 210) = 2.02$, p = .09 (see Figure 7).

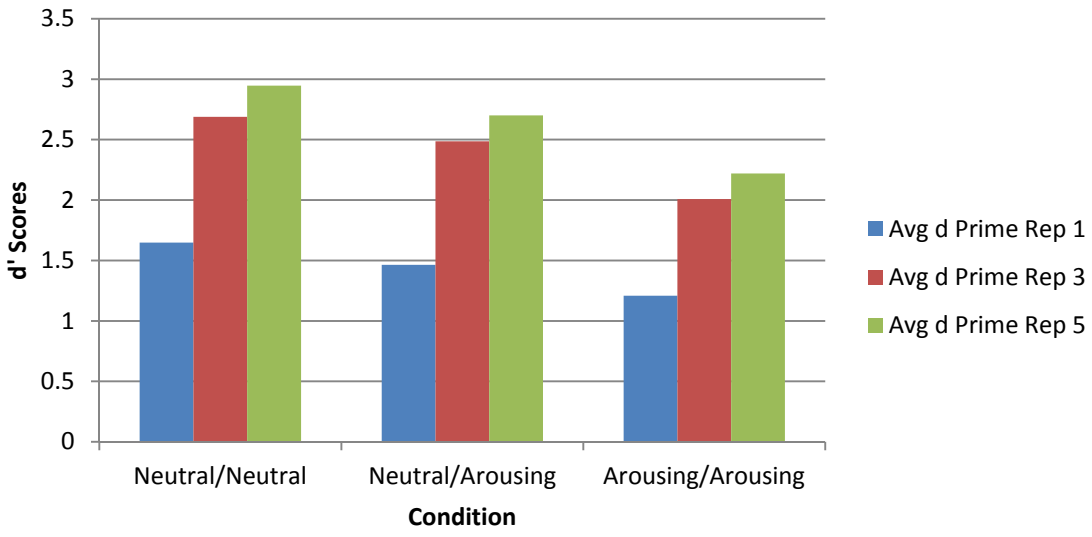

Figure 7. Item memory performance as assessed by d' scores for each condition at each level of repetition.

To follow up on a finding from Experiment 1, item memory performance for the two types of items in the neutral/arousing condition was investigated. During the test phase, picture pairs in this condition consist of either an old neutral picture presented in the context of a new

arousing picture, or an old arousing picture presented in the context of a new neutral picture. In Experiment 1 we found that item memory performance for arousing pictures that were presented in the context of a neutral picture was significantly better. To investigate whether or not this result also held up in Experiment 2, additional analyses were conducted to compare item memory performance for these two item types. In order to do this, test pairs in the neutral/arousing condition were again separated based on whether the arousing picture appeared served as the old or new item in each test pair. This divided the neutral/arousing condition into two picture pair types – (old) arousing with (new) neutral and (old) neutral with (new) arousing. A 2x3 within-subjects ANOVA was conducted where item type (neutral vs. arousing) and repetition level (one vs. three vs. five) served as the variables. There was significant main effect of repetition $F(2, 76) = 97.05$, $p<.001$. Tukey post hoc tests showed that item memory for pictures that were seen five times ($M=2.70$) was significantly higher than pictures that were seen three times ($M=2.48$) and those that were seen once ($M=1.46$), $p<.05$. And item memory for pictures that were seen three times was significantly better than those that were seen once, $p<.05$. There was not a significant main effect of item type, $p>.05$, and the interaction between item type and repetition was also not significant, $p>.05$ (see Figure 8).

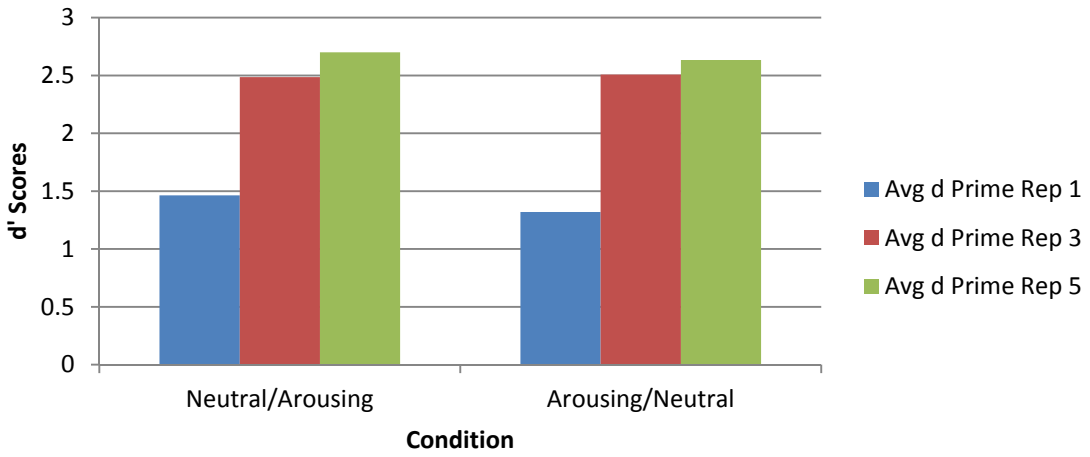

Figure 8. Item memory performance as assessed by d' scores at each repetition level for old neutral pictures presented in the context of an arousing picture and old arousing pictures presented in the context of a neutral picture.

Discussion

Experiment 2 was designed to test the hypothesis that the beneficial effects of arousal on associative memory may be more apparent after a delay. However, the results showed that the presence of an arousing item did not enhance associative memory even when the associative recognition test was administered to participants 48 hours after the encoding task. Associative memory performance for the neutral/neutral condition was significantly better than the neutral/arousing and the arousing/arousing conditions. Furthermore, item memory performance revealed no advantages for arousing pictures. Item memory for the arousing/arousing condition was significantly lower than performance for the neutral/arousing condition and the neutral/neutral condition.

Another purpose of Experiment 2 was to further test the effects of repetition on memory. As expected, pictures that were repeated five times were remembered the best, followed by those that were repeated three times, and then those that were seen only once. However, an analysis of associative memory performance also revealed an interaction between the effects of arousal and repetition such that pictures in the neutral/neutral condition benefitted from repetition to a greater degree than did conditions with arousing pictures. More specifically, after only one repetition, associative memory performance was similar across each condition. However, after three and five repetitions, associative memory performance for the neutral/neutral condition was significantly higher than performance for the neutral/arousing and arousing/arousing conditions. This result is consistent with what was found during Experiment 1.

General Discussion

Summary of Pattern of Results

Across two experiments the overall pattern of results for associative memory revealed several important findings. First, arousal did not enhance associative memory performance, even with the inclusion of intentional encoding instructions and a 48-hour delay between encoding and assessment. Memory performance for the neutral/arousing condition was not significantly better than performance for the neutral/neutral condition (and was significantly worse in Experiment 2) and participants in the arousing/arousing condition consistently showed the worst memory performance overall. Second, the hypothesis that arousal may increase interference in memory was not supported (e.g., Mather, 2009). Instead, Experiment 1 found that the impact of arousal on memory performance was similar across levels of interference. Finally, both studies found evidence consistent with the notion that repetition enhances associative memory more for neutral picture pairs than it does for arousing picture pairs.

The effect of arousal on item memory varied by experiment. Using an immediate test in Experiment 1, item memory was improved by arousal when it was elicited by a single picture (the neutral/arousing condition). In this situation, item memory performance for arousing pictures presented in the context of a neutral picture was the best overall. Furthermore, the neutral member of these pairs also benefitted. Item memory performance for neutral pictures in the neutral/arousing condition was significantly better than performance for the neutral pictures in the neutral/neutral condition. Finally, there was no benefit to item memory when two arousing pictures were paired. This pattern changed after the 48-hour delay of Experiment 2. Item memory was similar in the neutral/neutral and arousing/neutral conditions. Furthermore,

item memory in the arousing/arousing condition was significantly worse than the other two conditions. Finally, it was generally the case that arousal and repetition did not interact to influence item memory. The only exception was Experiment 1, where there were differences within the neutral/arousing condition such the repetition enhanced memory for neutral pictures paired at encoding with arousing pictures than it did for arousing pictures paired at encoding with neutral pictures.

Implications

The associative memory results of both studies appear to conflict with one prediction of arousal-biased competition theory (Mather & Sutherland, 2011). Specifically, this theory states that if the association between two items is considered high priority (e.g., through intentional encoding), then arousal will enhance this association in memory. This result was not obtained. In Experiment 1, there were no significant differences in associative memory performance for the neutral/neutral and the neutral/arousing conditions. In Experiment 2, performance was significantly *better* for the neutral/neutral condition than the neutral/arousing condition. Thus, the presence of an arousing item did not enhance associative memory performance even when participants were explicitly told they should remember each pair of pictures together. Furthermore, participants in the arousing/arousing condition displayed the worst memory performance overall in both experiments. This finding could be considered consistent with arousal-biased competition theory, as having multiple high priority stimuli present (i.e., two highly arousing pictures) may lead to competition between them and thus disrupt working memory processes at encoding, resulting in an overall decrement rather than enhancement in memory (Mather et al., 2006; Mather & Sutherland, 2011).

However, an earlier theory proposed by Mather seems more consistent with the associative recognition results from these studies. In contrast to arousal-biased competition theory, the object-based framework asserts that arousal will either impair or have no effect on the association between two objects (Mather, 2007). The reason is that in this theory the beneficial effects of arousal on attention for memory binding only accrue for the object being attended to and do not carry over for other objects present at the same time. However, it is important to point out that this prediction of the theory does conflict with the item memory results from Experiment 1, where we found enhancement for neutral pictures when they were presented in the context of an arousing picture. Hence, only our associative memory results are more aligned with this notion because across two experiments that made use of intentional encoding instructions we were unable to find any enhancement in associative memory when arousal was present.

In contrast to previous research, we also did not find any enhancement in the effects of interference from arousal. In Experiment 1, all three conditions saw a comparable decline in performance as interference increased. Research reviewed by Mather (2009) indicated that emotional items tend to be more subject to interference effects in memory under a variety of circumstances. This tendency has been attributed to some of the characteristics that make emotional items more memorable to begin with (e.g., emotional memories are usually categorized together; initial memory bindings are stronger for emotional items, etc.). Although the results do not support this hypothesis, the reason may have to do with differences in the type of interference under study. For example, research findings on the effects of arousal on memory updating have been attributed to proactive interference (e.g., Novak & Mather, 2009). In contrast, the fan manipulation in Experiment 1 likely created strong general interference. Furthermore, the interference in this experiment was directed at the association between two

objects (pictures) rather than within-object interference (object – location), which has been the focus of memory updating research. The results suggest potential boundary conditions on whether arousal interacts with interference, but more research on the topic is necessary.

With respect to repetition, associative memory performance for neutral items increased to a much greater extent than performance for arousing items. This finding is similar to what has been found for recognition memory in previous work by Karam and Lane (2011). Their results showed that multiple presentations of an item, either through repeated study or an initial test phase, benefitted memory for neutral items more than arousing items. They relate their finding to research on memory updating (e.g., Novak & Mather, 2009), which found that initial errors in location memory for arousing pictures were less likely to be corrected on subsequent trials than neutral pictures. Both kinds of findings suggest that, if study repetition or initial retrieval improves retention by increasing contextual variability relative to the initial encoding (e.g., Bower, 1972), this variability may be less for emotional than neutral items. The current findings would be consistent with this view.

Another important aspect of arousal-biased competition theory concerns the effect of arousal on *item memory* performance. In general, arousing items are considered to be high priority and garner more attentional resources. This leads to enhanced processing of those items and this often comes at the expense of any non-arousing items that are present in the same context (Mather & Sutherland, 2011). However, arousal-biased competition theory also says that through the use of intentional encoding instructions, arousal will also enhance the processing of goal-relevant stimuli that, in this case, includes both pictures in each pair (in addition to the association). Thus, neutral pictures may not suffer a deficit in processing when they are paired

with an arousing picture because they are considered to be goal-relevant stimuli (and may even be enhanced).

Interestingly, these predictions were found in Experiment 1, but not in Experiment 2. Item memory performance for Experiment 1 was best for arousing pictures, but only when they were presented in the context of a neutral picture (presenting two arousing pictures together only led to competition between them; Mather, et al., 2006). Neutral pictures that were presented with an arousing picture were better remembered than neutral pictures that were presented with other neutral pictures. In Experiment 2, this enhancement was not obtained. The only consistent result for item memory performance was that performance was once again lowest for pictures in the arousing/arousing condition. However, the two experiments do differ in terms of both the delay between encoding and test, and the presence of competing associations. The notion that delay might play a role in the (lack of an) effect is surprising, given that the memorial advantage for emotionally arousing information is often greater over a delay (e.g., Sharot & Phelps, 2004). However, the procedure in this study for examining item memory is different than previous studies, which often use recognition tests rather than an associative recognition test requiring fine-grained distinctions between item pairs (see continued discussion below). Resolving the discrepancy between experiments may require additional research.

The associative memory results from Experiment 2 also differ from those of Pierce and Kensinger (2011). They presented positive, negative, and neutral word pairs to participants and instructed them to remember each pair. Associative memory performance was assessed both immediately (Experiment 1) and after a one-week delay (Experiment 2) by presenting participants with intact, rearranged, and novel word pairs. Their work suggested that arousal from negative stimuli may impair associative binding after a short delay, but improves

associative binding after a long delay. This is also consistent with previous work demonstrating that the effects of emotion are usually more apparent after a delay (e.g., Sharot & Phelps, 2004). Hence, a main purpose of Experiment 2 was to test this notion. However, as previously stated, even with a 48-hour delay between encoding and test, we were unable to find any improvement in associative memory performance from arousal. In fact, performance for the neutral/arousing condition was significantly lower after the longer delay.

However, there were several methodological differences between the current work and that of Pierce and Kensinger (2011) that may account for some of the differences in the results. First, they made use of word pairs while the current study used picture pairs. It is possible that some of the differences in memory accuracy may be due to the nature of the stimuli. Furthermore, Pierce and Kensinger instructed their participants to form sentences with each word pair during the encoding phase. Relative to the instructions used in the current experiments, such an encoding task might have led to stronger associations between the items. If this is the case, this might explain why arousal did not enhance associative memory. A second difference concerns the type of test they used. In their associative recognition test, participants had three options: Intact, Rearranged or New. In contrast, the current experiments required participants to make more fine-grained judgments about both items, as some test pairs included one item that was previously seen and another that was not. In their results, Pierce and Kensinger focused their analyses on accuracy for each item type, but false alarm rates were also higher for emotional items. For example, the false alarm rates (claiming that rearranged pairs were intact) for the positive and negative word pairs increased more than the false alarm rate for neutral word pairs after the one-week delay in Experiment 2 (~.38, .38, .27, respectively). Although the authors used corrected recognition to argue that accuracy to intact negative word pairs

outstripped increased response bias, the general pattern of errors in that experiment suggests greater forgetting for neutral word pairs and relatively imprecise representations for negative word pairs. Thus, it is possible that the test format used in the current experiments was more sensitive to the forgetting of memorial features associated with negative pairs than was the case in Pierce and Kensinger.

Conclusion

Emotional arousal is known to enhance some, but not all, aspects of memory (e.g., Mather, 2007). In contrast to arousal-biased competition theory (Mather & Sutherland, 2011), but not the object-based framework (e.g., Mather, 2007), these studies found no evidence that associative recognition is enhanced by emotional arousal, even after intentional encoding instructions. Furthermore, emotional arousal did not moderate the impairing effects of associative interference (cf., Mather, 2009). However, under immediate test conditions, emotional arousal enhanced item memory when one member of a pair was arousing, but not when both items were arousing. Finally, there was consistent evidence that repetition had weaker effects on associative memory for emotionally arousing pairs than for neutral pairs.

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Appendix A: Experiment 1 Response Proportions

Mean proportion of responses to each of the picture pair types presented during the recognition test. Correct responses are shown in bold.

Neutral/Neutral						
	Word Pair	Responses				
		Old-Old (same)	Old-Old rearranged	Old-New	New-Old	New-New
Intact Pairs	Fan 1-1	**0.60**	0.13	0.08	0.08	0.11
	Fan 1-5	**0.49**	0.32	0.01	0.16	0.01
	Fan 5-1	**0.49**	0.31	0.19	0.01	0.01
	Fan 5-5	**0.50**	0.50	0.00	0.00	0.00
	Rep 5x	**0.96**	0.03	0.00	0.00	0.01
Rearranged Pairs	Fan 1-1	0.14	**0.48**	0.14	0.15	0.09
	Fan 1-5	0.19	**0.59**	0.01	0.21	0.00
	Fan 5-1	0.15	**0.60**	0.24	0.01	0.00
	Fan 5-5	0.28	**0.71**	0.00	0.00	0.00
	Rep 5x	0.11	**0.87**	0.01	0.01	0.00
Item Pair	Fan1-New	0.06	0.11	**0.57**	0.03	0.23
	New-Fan1	0.04	0.07	0.03	**0.60**	0.25
	Fan5-New	0.01	0.04	**0.92**	0.03	0.00
	New-Fan5	0.01	0.05	0.02	**0.91**	0.01
Novel Pair	New-New	0.01	0.02	0.11	0.08	**0.78**

Neutral/Arousing						
	Word Pair	Responses				
		Old-Old (same)	Old-Old rearranged	Old-New	New-Old	New-New
Intact Pairs	Fan 1-1	**0.67**	0.08	0.07	0.08	0.09
	Fan 1-5	**0.58**	0.25	0.00	0.16	0.00
	Fan 5-1	**0.46**	0.37	0.16	0.01	0.00
	Fan 5-5	**0.61**	0.38	0.00	0.00	0.00
	Rep 5x	**0.95**	0.04	0.00	0.00	0.00
Rearranged Pairs	Fan 1-1	0.21	**0.43**	0.11	0.19	0.06
	Fan 1-5	0.25	**0.56**	0.00	0.19	0.00
	Fan 5-1	0.18	**0.64**	0.17	0.00	0.00
	Fan 5-5	0.41	**0.59**	0.00	0.00	0.00
	Rep 5x	0.11	**0.87**	0.01	0.00	0.00
Item Pair	Fan1-New	0.04	0.12	**0.55**	0.03	0.26
	New-Fan1	0.06	0.05	0.01	**0.68**	0.20
	Fan5-New	0.01	0.04	**0.93**	0.01	0.00
	New-Fan5	0.00	0.01	0.02	**0.95**	0.00
Novel Pair	New-New	0.01	0.02	0.08	0.12	**0.78**

Arousing/Neutral						
	Word Pair	Responses				
		Old-Old (same)	Old-Old rearranged	Old-New	New-Old	New-New
Intact Pairs	Fan 1-1	**0.64**	0.11	0.12	0.04	0.09
	Fan 1-5	**0.49**	0.40	0.00	0.12	0.00
	Fan 5-1	**0.53**	0.27	0.20	0.00	0.00
	Fan 5-5	**0.58**	0.42	0.00	0.00	0.00
	Rep 5x	**0.98**	0.01	0.00	0.00	0.00
Rearranged Pairs	Fan 1-1	0.21	**0.44**	0.20	0.07	0.08
	Fan 1-5	0.27	**0.58**	0.01	0.14	0.00
	Fan 5-1	0.20	**0.57**	0.21	0.00	0.00
	Fan 5-5	0.40	**0.59**	0.00	0.00	0.00
	Rep 5x	0.11	**0.87**	0.02	0.00	0.00
Item Pair	Fan1-New	0.07	0.05	**0.70**	0.02	0.16
	New-Fan1	0.04	0.07	0.03	**0.59**	0.27
	Fan5-New	0.00	0.05	**0.92**	0.02	0.00
	New-Fan5	0.01	0.03	0.03	**0.93**	0.00
Novel Pair	New-New	0.01	0.03	0.07	0.09	**0.80**

Arousing/Arousing						
	Word Pair	Responses				
		Old-Old (same)	Old-Old rearranged	Old-New	New-Old	New-New
Intact Pairs	Fan 1-1	**0.50**	0.18	0.10	0.12	0.10
	Fan 1-5	**0.39**	0.38	0.02	0.20	0.00
	Fan 5-1	**0.40**	0.38	0.21	0.01	0.01
	Fan 5-5	**0.51**	0.47	0.01	0.02	0.00
	Rep 5x	**0.87**	0.10	0.01	0.01	0.00
Rearranged Pairs	Fan 1-1	0.27	**0.27**	0.19	0.13	0.12
	Fan 1-5	0.26	**0.53**	0.01	0.19	0.01
	Fan 5-1	0.22	**0.52**	0.25	0.01	0.00
	Fan 5-5	0.42	**0.56**	0.01	0.01	0.00
	Rep 5x	0.30	**0.65**	0.02	0.02	0.00
Item Pair	Fan1-New	0.08	0.04	**0.59**	0.05	0.24
	New-Fan1	0.06	0.09	0.04	**0.53**	0.28
	Fan5-New	0.01	0.07	**0.87**	0.03	0.03
	New-Fan5	0.01	0.05	0.02	**0.91**	0.02
Novel Pair	New-New	0.02	0.02	0.11	0.07	**0.78**

Appendix B: Experiment 2 Response Proportions

Mean proportion of responses to each of the picture pair types presented during the recognition test. Correct responses are shown in bold.

Neutral/Neutral						
	Word Pair	Responses				
		Old-Old (same)	Old-Old rearranged	Old-New	New-Old	New-New
Intact Pairs	Rep 1x	**.34**	.17	.09	.18	.21
	Rep 3x	**.81**	.13	.04	.01	0
	Rep 5x	**.90**	.07	.02	.01	0
Rearranged Pairs	Rep 1x	.14	**.26**	.22	.22	.17
	Rep 3x	.16	**.66**	.09	.08	.01
	Rep 5x	.18	**.72**	.05	.04	.01
Item Pair	Rep1-New	.01	.04	**.54**	.01	.40
	New-Rep1	.02	.02	.02	**.51**	.43
	Rep3-New	.01	.02	**.84**	.02	.11
	New-Rep3	.01	.03	.02	**.85**	.10
	Rep5-New	0	.02	**.90**	0	.08
	New-Rep5	0	.05	.01	**.91**	.03
Novel Pair	New-New	0	0	.01	.03	**.94**

Neutral/Arousing						
	Word Pair	Responses				
		Old-Old (same)	Old-Old rearranged	Old-New	New-Old	New-New
Intact Pairs	Rep 1x	**.38**	.18	.10	.20	.15
	Rep 3x	**.78**	.12	.02	.05	.03
	Rep 5x	**.85**	.10	.01	.02	.02
Rearranged Pairs	Rep 1x	.30	**.30**	.04	.27	.09
	Rep 3x	.46	**.39**	.03	.09	.03
	Rep 5x	.36	**.53**	.03	.06	.02
Item Pair	Rep1-New	.03	.02	**.38**	.03	.55
	New-Rep1	.03	.09	.02	**.62**	.24
	Rep3-New	.06	.03	**.76**	.02	.13
	New-Rep3	.03	.09	.05	**.76**	.06
	Rep5-New	.04	.05	**.81**	.05	.04
	New-Rep5	.04	.03	.03	**.87**	.02
Novel Pair	New-New	.03	.01	.03	.04	**.89**

Arousing/Neutral						
	Word Pair	Responses				
		Old-Old (same)	Old-Old rearranged	Old-New	New-Old	New-New
Intact Pairs	Rep 1x	**.47**	.13	.19	.06	.15
	Rep 3x	**.75**	.15	.05	.03	.02
	Rep 5x	**.89**	.09	.01	.01	.01
Rearranged Pairs	Rep 1x	.25	**.19**	.30	.09	.17
	Rep 3x	.38	**.44**	.13	.03	.02
	Rep 5x	.45	**.49**	.04	0	.02
Item Pair	Rep1-New	.07	.07	**.59**	.03	.24
	New-Rep1	.06	.03	.05	**.34**	.51
	Rep3-New	.02	.03	**.85**	.02	.08
	New-Rep3	.05	.03	.03	**.75**	.15
	Rep5-New	.03	.03	**.87**	.01	.05
	New-Rep5	.04	.04	.04	**.82**	.05
Novel Pair	New-New	0	.02	.05	.03	**.91**

Arousing/Arousing						
	Word Pair	Responses				
		Old-Old (same)	Old-Old rearranged	Old-New	New-Old	New-New
Intact Pairs	Rep 1x	**.34**	.21	.16	.15	.15
	Rep 3x	**.63**	.24	.05	.06	.02
	Rep 5x	**.81**	.14	.02	.02	.01
Rearranged Pairs	Rep 1x	.19	**.24**	.22	.16	.18
	Rep 3x	.40	**.40**	.08	.10	.02
	Rep 5x	.38	**.52**	.05	.04	.01
Item Pair	Rep1-New	.05	.05	**.52**	.06	.33
	New-Rep1	.06	.05	.07	**.46**	.35
	Rep3-New	.03	.09	**.76**	.02	.10
	New-Rep3	.03	.08	.01	**.74**	.14
	Rep5-New	.04	.10	**.76**	.02	.08
	New-Rep5	.05	.04	.02	**.83**	.06
Novel Pair	New-New	.01	.01	.07	.05	**.87**

Appendix C: IRB Approval Form

Application for Exemption from Institutional Oversight

Institutional Review Board
Dr. Robert Mathews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.6792
irb@lsu.edu
lsu.edu/irb

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/ projects using living humans as subjects, or samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.

-- Applicant,Please fill out the application in its entirety and include the completed application as well as parts A-E, listed below, when submitting to the IRB. Once the application is completed, please submit two copies of the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at http://www.lsu.edu/screeningmembers.shtml

– A Complete Application Includes All of the Following:
(A) Two copies of this completed form and two copies of part B thru E.
(B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)
(C) Copies of all instruments to be used.
*If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
(D) The consent form that you will use in the study (see part 3 for more information.)
(E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (http://phrp.nihtaining.com/users/login.php.)
(F) IRB Security of Data Agreement: (http://www.lsu.edu/irb/IRB%20Security%20of%20Data.pdf)

1) Principal Investigator: Leslie Butler **Rank:** Graduate Student

Dept: Psychology **Ph:** (225) 394-0027 **E-mail:** lbutl12@tigers.lsu.edu

2) Co Investigator(s): please include department, rank, phone and e-mail for each

Sean Lane, Associate Professor, Dept. of Psychology; ext.4098, slane@lsu.edu

IRB# E5492 LSU Proposal #

Complete Application

Human Subjects Training

3) Project Title: Memory for Pictures

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 4-14-2014

4) Proposal? (yes or no) No **If Yes, LSU Proposal Number**

Also, if YES, either ◯ **This application completely matches the scope of work in the grant**

OR ◯ **More IRB Applications will be filed later**

5) Subject pool (e.g. Psychology students) Psychology Students

*Circle any **"vulnerable populations" to be used**: (children <18; the mentally impaired, pregnant women, the ages, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature Leslie Butler **Date** 4/14/11 (no per signatures)

** **I certify my responses are accurate and complete.** If the project scope or design is later changes, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted X Not Exempted ____ Category/Paragraph 2b

Reviewer ALEX S. COHEN, PH.D. **Signature** _____ **Date** 4-15-2011

Vita

Leslie A. Butler began studying psychology at the University of Central Florida where she received a Bachelor of Arts degree. Before attending graduate school she spent time working as a research associate at the Naval Air Warfare Center, Training Systems Division in Orlando, Florida. During her time there she was involved with a project aimed at developing a computer-based tutoring system to train navy personnel in basic electronics.

In 2007 she decided to pursue graduate studies and received a Master of Arts degree in Experimental Psychology from Florida Atlantic University in 2009. Her thesis was titled, "Memory for Emotional and Non-emotional Events" and studied the effects of negative emotion on memory. From there, she decided to continue her education at Louisiana State University. In the fall of 2009, she entered the Cognitive and Developmental Psychology program and began working in the Office of Applied Cognition where she took part in a variety of research projects. A majority of her research was still focused on how emotion affects memory, but she took part in a large NSF-funded research project aimed at improving secondary math and science education by increasing the expertise of teachers. She will be receiving a second Master of Arts degree in May 2013.