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Anne Hermes March 28, 2013

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An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
of the requirements of the degree of
Bachelor of Sciences with Honors

Department of Psychology

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Abstract

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Enhanced memory for emotional information is a widely studied phenomenon that pervades our lives and experiences. One mechanism that may enhance memory for emotional stimuli is the increased processing of and attention to emotionally salient information. Focusing attention on salient negative aspects of a stimulus has been related to subsequent memory performance, but this effect has not been widely studied in positive stimuli. The anticipation of emotion is another mechanism that may enhance memory for emotional stimuli. Research has shown that anticipatory neural activity predicts subsequent memory, but the effects of anticipation on memory-related encoding behaviors have not yet been investigated.

The current study used eye-tracking as a metric for attention during encoding in order to investigate the contribution of attention and anticipation to adults' memory for emotional images. Eye movements were recorded during the encoding of negative, positive, and neutral scenes. To manipulate emotion anticipation, half of the participants were presented with a cue indicating the emotional valence of the upcoming stimulus during encoding. Patterns of eye movement and attention were related to subsequent memory for the stimuli during a recognition task one week after encoding. The current study demonstrated that memory for negative and neutral scenes was related to the visual search of salient details. These results suggest that sustained processing of central details is an effective encoding mechanism for negative and neutral but not positive stimuli. The anticipation of negative stimuli was related to differences in the orienting of attention during encoding. Inconsistent with hypotheses, anticipation-related changes in encoding behavior were not related to memory. Future research should investigate relations between emotion anticipation and individual differences in affect and emotion regulation to evaluate how emotion anticipation affects memory through encoding processes such as attention.

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Acknowledgements

I would like to give special thanks to my advisor, Patricia Bauer, for all of her guidance and support on this project and throughout my undergraduate career, and to my committee members, James Rilling and Stephan Hamann. I would also like to thank Aoxiang Xu for help with running participants and various other aspects of this project, Shala Blue for assistance in using the eye-tracking system, and Cory Inman for providing valuable input and a subset of the stimuli used in this project. Additional thanks go to all the members of the Memory at Emory lab for their continued help and support throughout this project and the past three years.

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Emotional Memory: Mechanisms of Anticipation and Attention

Our daily lives are so rich in experience that we cannot remember every specific event that occurs or every scene that we encounter. Much of our life is shaped by what events and information we do or do not remember, and certain qualities of an event make us more likely to remember them. One such quality is emotion, which can vary based on valence (positive and negative) and arousal. Emotion pervades every aspect of our daily lives and experiences through its effects on our behaviors and cognitive processes such as memory. If you think about some of the most salient or memorable events of your life, they are probably events that were emotionally charged. For example, you might vividly remember negative events such as hearing about the death of a loved one or positive events like your wedding day. However, less emotionally arousing occurrences like last night's meal can be difficult to remember, even though it occurred very recently. Through its effects on memory, emotion shapes our experience of day-to-day events as well as how we react to future events and situations. In other words, emotion is a vital part of human experience. It is important to study the effects that emotion has on behavior to shed light on the mechanisms through which emotion affects both perceptual processing and memory. By studying these mechanisms, we have the potential to further understand the interactions between emotion and memory as well as mood disorders in which these mechanisms may not be functioning optimally such as depression (Beck, 1967).

Many studies have shown that emotional arousal can enhance the strength and accuracy of episodic memory, or memory for events (e.g. Hamann, 2001; LaBar & Cabeza, 2006; Phelps, 2004). However, negative and positive emotional information differentially affect memory performance. Negative stimuli are more often remembered, indicating a memory for specific details of the stimulus, and in a study of memory for emotional pictures, Kensinger, Garoff-Eaton and Schacter (2007) found that memory was enhanced for specific details of negative stimuli. For negative stimuli, memory for central and salient negative information is improved, but the peripheral details and context of a visual scene are not remembered with higher accuracy, indicating that central negative details may be remembered at the cost of peripheral information (Kensinger, 2009). Positive stimuli are more often identified as familiar, suggesting memory for information contained in the stimulus without specific memory for details of that stimulus (Ochsner, 2000). There has been little investigation of mechanisms involved in enhanced memory for positive stimuli.

The emotion related memory trade-off suggests that negative emotional content interacts with memory by recruiting different encoding mechanisms (Ochsner, 2000) and more sensory processing resources (Mickley & Kensinger, 2008) to emotionally salient information. Easterbrook's cue-utilization hypothesis (1959) proposes that emotional information prompts the narrowing of attention to fewer cues or details within a stimulus. The focusing of attention is one potential mechanism through which emotion enhances episodic memory (Inman, 2010; Sharot, Davidson, Carson, & Phelps, 2008). In addition to the effects of attentional mechanisms on memory, research has demonstrated that the anticipation of emotional information is related to memory performance. Studies using functional neuroimaging (Mackiewicz, Sarinopoulos, Cleven, & Nitschke, 2006) and event-related potentials (Galli, Wolpe, & Otten, 2011) have shown that anticipatory neural activity predicts memory for emotional stimuli. Galli et al., (2011) hypothesize that the anticipation of an emotional stimulus affects neural activity in such a way that prepares individuals for emotional information, leading to differences in encoding behaviors such as attention during that stimulus. However, no research has investigated this hypothesis by looking at the effects of anticipation on the allocation of attention to emotional stimuli. The present research uses eye-tracking as a measure of visual attention to evaluate the relations between the anticipation of emotion, allocation of attention during encoding, and enhanced memory for negative and positive emotional scenes.

Attention as an Encoding Mechanism

Previous research has identified attention as a key factor in the encoding and perceptual processing of emotional and non-emotional information (Gardiner, Gregg, & Karayianni, 2006; Ochsner, 2000). The relation between attention and the successful encoding of negative information has been widely studied (e.g. Sharot et al., 2008), but the effects that visual attention may have on subsequent memory for positive stimuli are not as well established (e.g. Gable & Harmon-Jones, 2008). In order to investigate the allocation of attention to a visual stimulus, eye gaze and eye movements are a sensitive and widely used metric (Rizzolatti, Riggio, Dascola, & Umilta, 1987). Eye-tracking technology allows for the fine-grain measurement of various aspects of visual attention including the location and duration of fixations or gaze points.

Strong memory for a stimulus is related to the amount of attention and processing resources devoted to that stimulus during encoding (Ochsner, 2000), and dividing attention can lead to deficits in episodic memory (Jacoby, 1991). In particular, where attention is allocated during encoding has an impact on what details are remembered about a stimulus (Gardiner et al., 2006). Not only does increased attention to a stimulus improve memory accuracy (Rajaram, 1993, as cited in Inman, 2010), but attention to salient features of a stimulus enhances memory for the entire stimulus (Kensinger, 2009). One hypothesis is that dispersed attention could improve memory due to the widespread processing of contextual details (Sharot et al., 2008). Evidence suggests that this hypothesis is inaccurate and that increased attention to the central details of a stimulus is related to successful encoding because allocating attention to particular information reflects deeper processing of perceptual details and potentially the recruitment of additional encoding processes (Amaral, Price, Pitkanen, & Carmichael, 1992; Kensinger, 2009; Ochsner, 2000; Sabatinelli, Bradley, Fitzsimmons, & Lang, 2005).

Because attention is related to improved memory (Gardiner et al., 2006), the effects of emotion on attention are a likely mechanism for the memory-enhancing qualities of emotional stimuli. Although bottom-up features such as visual salience determined by low-level information (e.g. color, intensity, contrast, and edges) can draw attention via saccadic eye movements (Itti & Koch, 2000), eye-tracking research has shown that emotionally salient features of complex scenes are more likely to attract attention (Niu, Todd, Kyan, & Anderson, 2012). In particular, attention is drawn to highly arousing and negative emotional stimuli (Niu, Todd, & Anderson, 2012). Because emotional arousal is an important factor in improving memory performance (Hamann, 2001), these results suggest that visual attention is an important measure of the encoding processes that may be enhanced for emotional information. Therefore, visual attention is an ideal metric for both the processing of emotional information and the successful encoding of a visual stimulus.

Effects of Attention on Emotional Memory

For negative stimuli, the effects of emotion on attention and the relation between attention and subsequent memory are consistent throughout the literature. The narrowing of attention in response to negative stimuli is related to enhanced memory (Inman, 2010; Sharot et al., 2008). Consistent with Easterbrook’s cue-utilization hypothesis (1959), the encoding of emotionally arousing negative scenes involves attending to fewer cues or details in a stimulus. This phenomenon can be seen in the focusing of attention and fixations when viewing complex negative scenes (Inman & Hamann, 2012; Sharot et al., 2008). In a study using eye-tracking to investigate the allocation of attention to complex scenes, the encoding of negative scenes was also related to an increased number of fixations, indicating that there was increased visual search and sampling of details in the negative stimuli (Bradley, Houbova, Miccoli, Costa, & Lang, 2011). By evaluating the distance between fixations, Sharot et al. (2008) found that although negative stimuli prompted an increased number of fixations, these fixations were clustered in particular areas of negative scenes, demonstrating that negative emotional information prompts the narrowing of attention while increasing visual search within the areas receiving attention. Further, Inman and Hamann (2012) demonstrated that the areas to which attention was focused were the most salient negative portions of complex visual scenes. Therefore, the salient negative aspects of stimuli capture attention during encoding, decreasing the extent to which individuals allocate attention to dispersed visual cues and peripheral information (Inman & Hamann 2012; Sharot et al., 2008).

The allocation of attention to central details instead of distributing attention across an image is related to enhanced memory for negative stimuli (Inman, 2010; Sharot et al., 2008) and may explain the trade-off seen in emotional memory in which central details are remembered at the cost of peripheral information (Kensinger, 2009). The clustering of fixations and narrowing of attention during the encoding of highly arousing negative stimuli was predictive of successful encoding and subsequent memory (Inman, 2010; Sharot et al., 2008). Using eye-tracking, Inman and Hamann (2012) identified that narrowed attention was focused on salient aspects of negative scenes. It was not just the narrowing of attention, but the focusing of attention on particularly emotional aspects of a scene that was related subsequent memory of negative stimuli (Inman & Hamann, 2012). These results are consistent with Easterbrook’s cue-utilization hypothesis (1959), and they also suggest that the narrowing of visual attention, as measured by the clustering of fixations (Sharot et al., 2008) and time spent fixating on salient information (Inman

& Hamann, 2012), may be the encoding mechanism that results in enhanced memory for negative information.

Evidence for the relations between positive information, attention, and subsequent memory is significantly less consistent. Some studies suggest that attention is broader for positive stimuli (Wadlinger & Isaacowtiz, 2006), and others demonstrate that attention is focused for both positive and negative emotional stimuli (Inman, 2010). Due to an emphasis on negative stimuli throughout the literature, there is little evidence linking patterns of attention during encoding to memory performance for positive stimuli. Positive mood and the presentation of positive stimuli have been shown to increase the frequency of shifts in attention and number of fixations on peripheral information, resulting in a broadening of attention and increased visual search (Rowe, Hirsch, & Anderson, 2007; Wadlinger & Isaacowitz, 2006). Bradley et al. (2011) also demonstrated that visual search and sampling of information, as measured by the number of fixations on an image, was increased during the viewing of positive stimuli. Although these results suggest that positive stimuli prompt the broadening of attention to sample many cues throughout the image, other research suggests the opposite. Inman (2010) demonstrated a narrowing of attention to positive information, consistent with the Easterbrook hypothesis (1959). When evaluating the clustering of fixations, Inman (2010) found that individuals focused attention in response to positive stimuli, clustering fixations for positive scenes just as they did for negative scenes. For positive stimuli, however, focused attention was not related to enhanced memory, suggesting that the narrowing of attention may be a successful mechanism for the encoding of negative but not positive scenes (Inman, 2010).

Most research investigating attention and emotional memory has evaluated gaze patterns in terms of the focusing or broadening attention, but emotional content affects other aspects of attention allocation whose relations with memory have not yet been considered. Some theories of emotion processing posit that the early capture of attention, not necessarily the narrowing of attention, is the primary mechanism by which emotional information is preferentially processed. Calvo and Lang (2004) found that preferential attention to both positive and negative images when presented simultaneously with neutral images occurs most during the initial stages of viewing. Emotional pictures were more likely to draw eye gaze during the first 500 milliseconds of a stimulus, but sustained allocation of attention was not affected by emotional content (Calvo & Lang, 2004). It is possible that the immediate orienting of attention to emotional information leads to the preferential processing of that information, but no previous research has investigated if this particular effect of emotion on attention is related to enhancements in encoding and subsequent memory for emotional stimuli.

Anticipatory Effects on Stimulus Processing and Memory

Just as emotional valence affects the processing and subsequent memory of stimuli, the anticipation of emotional information can predict subsequent memory (Galli et al., 2011; Mackiewicz et al., 2006). Despite the prevalence of hypotheses about the effects of anticipation on attention and perceptual processes (e.g. Simmons, Matthews, Stein, & Paulus, 2004), research has focused on anticipatory neural activity rather than evaluating the effects of anticipation on behaviors during encoding. The anticipation of emotional events may be particularly useful because knowledge of an upcoming event or stimulus may help individuals prepare and adjust neural activity or behavior to better suit the situation, whether it is appetitive or aversive (Bradley, 2008). Functional neuroimaging studies have identified characteristic patterns of anticipatory neural activity prior to the presentation of an expected aversive stimulus (Simmons et al., 2004; Mackiewicz et al., 2006; Nitschke, Sarinopoulos, Mackiewicz, Schaefer, &

Davidson, 2006). When individuals were given cues signaling the upcoming presentation of an aversive stimulus, patterns of neural activation prior to stimulus presentation were similar to patterns seen during the aversive stimulus and included insula and amygdala activation (Simmons et al., 2004; Mackiewicz et al., 2006; Nitschke et al., 2006). This overlap in neural activity may be related to preparation for a stimulus, allowing individuals to more effectively attend to relevant aversive information if they are expecting it. Hypotheses also suggest that anticipation may heighten attention to aversive information and therefore improve perceptual processing of that information (Simmons et al., 2004; Nitsche et al., 2006; Herwig, Abler, Walter, & Erk, 2007).

Neural activity during the anticipation of a particular type of stimulus, which has hypothesized links with enhanced perceptual processing (e.g. Simmons et al., 2004), is also related to enhanced recognition memory. During the anticipation of upcoming aversive stimuli, amygdala and hippocampus activity correlated with subsequent recognition memory for those stimuli (Mackiewicz et al., 2006). These results suggest that cuing individuals about an upcoming stimulus primes a neural circuitry necessary for the successful encoding of aversive or emotional information, leading to more successful encoding processes. Similar processes can be seen in reward based cues. When individuals are cued to the reward they will receive for remembering an upcoming stimulus, neural activity in the ventral tegemental area, an area in the mesolimbic dopamine reward system, and the hippocampus is related to subsequent memory (Adcock, Thangavel, Whitfield-Gabrieli, Knutson, & Gabrieli, 2006). Cue effects on neural activity and memory are more widespread than just the emotion and motivation literature. Hippocampal and medial temporal lobe activity following semantic cuing, modality-related cuing, emotion cuing, and reward cuing is related to memory for the cued stimuli (Bollinger, Rubens, Zanto, & Gazzaley, 2010; Park & Rugg, 2010; Adcock et al., 2006; Mackiewicz et al., 2006). Therefore, hypotheses suggest that pre-stimulus cues can lead to anticipatory neural activity in brain areas related to memory, emotion, and reward in order to improve encoding and enhance subsequent memory for particular items (Bollinger et al., 2010; Park & Rugg, 2010; Adcock et al., 2006; Mackiewicz et al., 2006).

Anticipatory neural activity seen in event-related potentials (ERPs) is also related to memory for stimuli (Otten, Quayle, Akram, Ditewig, & Rugg, 2006; Gruber & Otten, 2010). Galli et al. (2011) investigated the effects of emotion cuing on pre-stimulus ERPs and subsequent memory for emotional scenes. Prior to stimulus presentation, schematic faces indicating the emotional valence (positive, negative, or neutral) of the upcoming image were presented for 1500 milliseconds while neural activity was recorded. For negative stimuli that were later remembered, ERP waveforms in response to the emotion cue showed increased positivity. However, more sustained positivity in ERP waveforms during the stimulus was predictive of memory for all emotional valences (Galli et al., 2011). Therefore, the enhanced memory seen for negative stimuli can be related to pre-stimulus anticipatory activity as opposed to differential processing of the stimulus itself. These results suggest that anticipation of a negative stimulus leads to a particular brain state that aids individuals in encoding the qualities of a visual stimulus. These anticipatory effects may be due to an attentional bias (Mogg, Bradley, Dixon, Fisher, Twelftree, & McWilliams, 2000, as cited in Galli et al., 2011), which heightens and focuses individuals' attention to salient negative aspects of the stimuli. An alternative explanation suggests that knowledge about the aversive properties of an upcoming stimulus may allow individuals to more "objectively" encode and process the information in the stimulus by allocating attention to more widespread cues in the stimulus instead of focusing only on salient details, thereby enhancing memory (Galli et al., 2011). Galli et al. (2011) identified the neural patterns associated with anticipation, but an evaluation of behavior during encoding may shed light on the mechanisms through which anticipation interacts with encoding and memory for negative stimuli. By looking at eye movement behaviors, the current study will investigate the hypothesis put forth by numerous studies of anticipatory neural activity that the cuing and anticipation of negative stimuli alters the allocation of attention during encoding leading to effects of anticipation on subsequent memory.

Aims and Hypotheses

In the current study, we use eye-tracking as a measure of attention in order to investigate the contributions of attention and emotion anticipation to the enhancement of memory for emotional stimuli (see LaBar & Cabeza, 2006 for review). Previous research has shown that pre-stimulus anticipatory neural activity is related to subsequent memory but has not examined potential adaptations in attention and encoding behavior that may result from the anticipation of an emotional stimulus (e.g. Mackiewicz et al., 2006; Otten et al., 2006). Therefore, in the current study, we will attempt to identify if anticipation of emotional information is altering visual search patterns during encoding and how these changes in behavior relate to subsequent memory for emotional stimuli. Studies have identified a wide variety of effects of emotion on attention including the narrowing of attentional focus in response to negative and positive emotional stimuli (Inman, 2010), attention to a wider range of cues within a positive emotional stimulus (Wadlinger & Isaacowitz, 2006), and the immediate, but not sustained, capture of attention by emotional information (Calvo & Lang, 2004). Because literature on the effects of positive emotion on attention is sparse and inconsistent, we will attempt to further elucidate the effects of emotion on the allocation of attention and visual processing. The relation between patterns of attention and subsequent memory will also be evaluated in order to further explore the effects of encoding behaviors, including those resulting from anticipation of an emotional stimulus, on memory in both the positive and negative valences. It is important to ask these questions in order to gain insight into how anticipation, emotion, and attention serve as mechanisms to enhance our memory for important emotional stimuli.

Visual Processing of Emotional Stimuli. Based on previous studies of attention allocation to emotional scenes (Inman 2011; Sharot et al., 2008), we expect that negative stimuli will lead to a narrowing of attention which will be seen in increased time spent looking at salient areas of each image and increased visual search within those salient areas. However, it is hypothesized that positive stimuli will show increased visual search behavior throughout the image as a result of broader and less focused attention (Rowe et al., 2007; Wadlinger & Isaacowitz, 2006). Additionally, we hypothesize that emotionally salient information will draw attention earlier during picture viewing based on theories of attention orienting (Calvo & Lang, 2004). Cues indicating the emotional valence of the upcoming stimulus will lead to anticipatory effects on attention to emotional information. In particular, we expect that emotion cues will lead to faster orienting of attention to emotional information (Calvo & Lang, 2004). We also predict that the anticipation of an emotional stimulus will result in more "objective" encoding of emotional stimuli (Galli et al., 2011) and alter encoding patterns by causing individuals to treat negative stimuli more like neutral stimuli. We expect that this phenomenon will result in a decreased attentional bias for salient negative information and therefore less attention to negative details when negativity is expected.

Subsequent Memory. It is expected that the results of this study will replicate previous findings regarding the effects of emotion on memory (Hamann, 2001; LaBar & Cabeza, 2006;

Phelps, 2004). We hypothesize that emotional stimuli, both negative and positive, will have higher rates of recognition compared to neutral images, and that negative stimuli will be more accurately and more confidently remembered than positive stimuli.

Encoding and Subsequent Memory. We expect that the relation between attention patterns at encoding and subsequent memory will be consistent with previous research. Therefore, subsequently remembered negative items will have more focused attention during encoding (Inman, 2010; Inman & Hamann, 2012; Sharot et al., 2008). We also predict that memory for positive stimuli will be enhanced by patterns of attention that are specific to positive stimuli due to the likely relation between the recruitment of specific encoding processes and the success of those processes. Therefore, widespread visual search will be related to memory for positive stimuli. It is also expected that the changes seen in emotion processing as a result of emotion cuing and anticipation will be related to enhanced memory. Based on the hypothesis that emotion anticipation may allow individuals to more "objectively" encode and process the information in the stimulus (Galli et al., 2011), we predict that, for anticipated negative stimuli, distributed attention and visual search will be related to enhanced memory performance. However, negative stimuli not preceded by an emotion cue will show the opposite pattern because focused attention is related to deep processing of the central details of a stimulus which can enhance memory (Sharot et al., 2008).

Method

Participants

Fifty-six adult participants (29 female; ages 18-22, M = 19.52 years, SD = 0.98) were recruited from the Emory University Psychology department participant pool. Participants took part in two experimental sessions, both approximately 45 minutes in length, during which eye-movement data were continuously recorded. Five participants were involved in pilot testing, four participants were not included in analyses due to failure to attend both experimental sessions, and seven participants' data were not included in analyses due to insufficient eye-fixation data acquisition. Specifically, data was considered insufficient if less than 80 percent of eye-gaze measurements during all 3000ms stimulus presentations were valid (see below for details). The data of the remaining 40 participants (21 female) were used in analyses. Participants were compensated for their time with course credit. This study's procedures were approved by Emory's Institutional Review Board. All participants gave written informed consent prior to participation in the study.

Materials

Stimuli. One-hundred and ninety pictures were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) and an additional set of emotional pictures (Inman, 2010). Within the set, 180 images were used as the experimental stimuli with 60 images of each emotional valence (positive and negative) as well as 60 neutral images as identified by use in previous research (Inman, 2010; Lang et al., 2008). Based on data obtained from a set of independent raters (N = 5), visual complexity did not differ significantly between emotional valence sets. Additionally, each emotional valence set consisted of an approximately equal number of pictures containing humans (30 images), animals (12 to 14 images), and non-living objects or scenes (16 to 18 images). All images, including fixation and rating screens (see below for description), were presented in 16-bit grayscale and were matched for average luminance (M = 107.13, SD = 2.68 lumens) across the image in order to ensure the optimal recording of pupil dilation data, which are beyond the scope of the current paper. An additional five neutral images were included in the set for practice at various points in the experimental sessions, and five additional highly positive images were presented at the end of the second session to ensure that the study ended on a positive note.

The 180 experimental images were arranged in pseudorandom order and separated into three sets of 60 images each (20 neutral, 20 negative, 20 positive). Each set of 60 images consisted of approximately equal numbers of images containing humans, animals, and non-living things. Two sets of 60 were viewed by each participant during the first experimental session for a total of 120 images. To control for order effects, each group of 120 images was arranged in two pseudorandom orders, for a total of six experimental orders in the first session. The orders were arranged such that no more than two images of each emotion category were presented in a row to prevent carryover effects, and each order was seen by an approximately equal number of participants. Participants were randomly assigned to one of the six session-one orders. During the second experimental session, all 180 experimental stimuli were presented in one of six pseudorandom orders. Orders were arranged such that no more than two images of each emotional valence were presented in a row and no more than five images of each recognition category (old or new, based on which images were seen by the participant during the first session) were presented in a row to prevent carryover effects. Each of the six session-two orders was seen by an approximately equal number of participants, and these orders were randomly assigned to participants based on their order in the first experimental session.

Apparatus. A Tobii T120 eye-tracker system was used to present stimuli and record eye fixation data. This system tracks the location of the pupil by looking at the location of the darkness of the pupil and the reflection of an infrared light off the retina. Utilizing two types of pupil tracking allows for the acquisition of optimal eye-fixation data. Images were presented in a landscape orientation to ensure that they filled the entire screen of the eye-tracker (12 x12 inches; 1024 x 760 pixels). Eye movement data was measured in pixels and recorded continuously throughout both experimental sessions at a rate of 120 Hz. Ambient light conditions in the testing room were controlled throughout all sessions.

Self-Assessment Manakin. At the end of the second experimental session, participants rated their subjective experience of emotional valence and arousal in response to images used during the study using a version of the Self-Assessment Manakin (SAM) procedures developed by Bradley and Lang (1994). The SAM rating scales were adapted for use with child participants whose data are beyond the scope of this paper. The adapted version of the SAM consists of pictorial representation of a five-point scale showing schematic human-like drawings displaying different levels of emotional valence and arousal (see Figure 1). The valence rating scale ranged from very unpleasant (1) to very pleasant (5) with a rating of 3 indicating a neutral emotional valence. The arousal scale ranged from not at all emotionally arousing (1; described as feeling calm, bored, or sleepy) to very emotionally aroused (5; which was described at feeling jittery, anxious, or excited). An arousal rating of 3 was described as an average amount of arousal, meaning neither arousing nor calm.

Participants completed SAM ratings of valence and arousal for 60 of the experimental images. Ratings were only completed on a subset of the experimental images to reduce the demands of participation in the study in order to accommodate future use of this paradigm with child participants. Three subsets of pictures were formed by arranging all images in a random order and ensuring that each set had equal numbers of pictures in each emotional valence (20 positive, 20 negative, 20 neutral). Once subsets of 60 pictures were created, they were arranged in two pseudorandom orders, with no more than two images of the same emotional valence appearing in a row. This process created six orders of images for rating, which were assigned randomly to participants. All pictures were rated by an approximately equal number of participants.

Questionnaires. Participants completed mood questionnaires at the beginning of the first experimental session. Data from these questionnaires are beyond the scope of the current study and will be used in future analyses to determine the relationship between mood and performance on the experimental task.

Depression Anxiety and Stress Scale. As a subclinical measure of depression, stress, and anxiety, adult participants completed the Depression, Anxiety, and Stress Scale (DASS; Lovibond & Lovibond, 1995). This questionnaire consists of 42 statements relating to three subscales: depression, stress, and anxiety. Participants rated, on a five-point likert scale (0-4), the extent to which they felt the way described by each statement over the past week.

Positive and Negative Affect Scale. As a measure of mood, the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988) was administered to adult participants prior to the first session of the study. This questionnaire consists of 20 adjectives that can be used to describe mood or affect. Participants rated, on a five-point likert scale (1-5), the extent to which they felt a certain way at the time of the experiment.

Procedure

Participants completed the study in two experimental sessions: encoding and retrieval. During both sessions, participants were seated approximately 500 to 700 mm (M = 623.15 SD = 35.83) from the Tobii eye-tracker screen, and eye fixation data was recorded continuously throughout the encoding and retrieval stimulus presentations.

Encoding. At the beginning of the encoding session, adult participants completed mood questionnaires, the Depression Anxiety and Stress Scale and the Positive and Negative Affect

Scale (Lovibond & Lovibond 1995; Watson et al., 1988), to gain a measure of their affect and emotional state prior to the experiment. Data from these questionnaires are beyond the scope of this paper.

After completing two practice trials, participants viewed the assigned order (see above for details) of 120 images separated into four blocks of 30 pictures each. Before each block, the apparatus was calibrated to each participant's eye position by asking participants to fixate upon a moving red dot on the screen. At the beginning of each trial (see Figure 2a), a small square was presented in the center of the screen for 1500ms as a fixation. Half of participants were randomly assigned to the emotion cued group (N = 20; 10 female). For this group of participants, the fixation square contained a schematic face indicating the emotional valence (positive, negative, or neutral) of the subsequent stimulus. The rest of the participants were assigned to the non-cued group (N = 20; 11 female). They saw a blank fixation square. Stimuli were presented for 3000ms following the fixation square, and participants were instructed to freely view stimuli. Each stimulus was followed by a blank grayscale screen for 4000ms to allow for the pupil's response to each picture to return to baseline before the next stimulus. Following the blank screen, a rating screen was displayed for 2500ms during which participants used a button press to rate the aesthetic quality of each stimulus on a scale of one to three. Participants were instructed to complete this rating regardless of the content of the picture on a scale from one to three (1- poor quality picture; 3- high quality picture, could have been taken by a professional photographer). This rating was used to maintain participants' focus and involvement throughout the session without drawing their attention to any particular aspects of the stimuli. These four screens composed one 11000ms trial (see Figure 2a). All participants were told that they would be viewing more pictures during the second session and were not aware that they would be tested on their memory.

Retrieval. Participants returned for their second experimental session approximately one week after their encoding session (6-8 days; *M* = 6.90 days, *SD* = 0.74). They were then informed that they would be seeing some images that they had seen before and some new images, and that their task would be to identify which images they had seen previously. After receiving instructions about the task and completing two practice trials, participants were presented with the assigned order (see above) of 180 experimental images arranged into six sets of 30 images each. The apparatus was calibrated before each set of images, just as during the encoding session. In each trial (see Figure 2b), a square was presented as fixation for 1500ms followed by 2000ms of image presentation. Following each image, a rating screen appeared for 2000ms during which participants responded with a button press to indicate if they were confident that had seen the previous image in the first experimental session (indicated by a check mark), if they thought they had seen image previously but were unsure (indicated by a question mark), or if they had not seen the image in the previous session (indicated by an X). The direction (left to right or right to left) of the check, question mark, and X was counterbalanced across participants to account for any order bias which might lead to the selection of a particular response. Therefore, each trial consisted of three screens and lasted 55000ms (see Figure 2b).

Ratings. After completing the recognition task, participants were instructed to use the SAM to report their subjective experience of each of the 60 images in the assigned order (see above). The experimenter explained to participants the meaning of each scale using procedures modified from Bradley and Lang (1994). Participants completed one practice rating to ensure that they understood the instructions and pictorial representations for both the valence and arousal rating scales. Participants completed the ratings by circling one of five figures on the SAM rating scale to indicate their subjective experience of the picture and advanced through the 60 images at their own pace.

Data Reduction

Eye fixations were determined using the Tobii Fixation Filter. This filter uses the gaze position at each measurement time point (every 8.3ms; 120 Hz) and the velocity of each eye movement to classify each gaze point as a fixation or a saccade. If the gaze position at a particular time point is within a default spatial threshold (35 pixels) of the previous gaze position and if the velocity of the change in gaze position is below a certain threshold, this eye movement event is considered a fixation. Saccades are classified as abrupt and rapid changes in gaze position and are identified by calculating the difference in gaze position between measurement time points.

Areas of Interest. Areas of interest were defined as the most salient areas of each image and were identified using a combination of manual selection and eye-movement data (see Bebko, Franconeri, Ochsner, & Chiao, 2011). An independent sample of participants ($N = 5$) were instructed to view each of the 180 experimental images and manually select the most salient or attention-grabbing aspects of each picture using shapes in Microsoft PowerPoint. Pictures were presented in a random order and participants were instructed to select the areas of interest at their own pace and advance to the next slide. All participants completed the task in 45 minutes or less. An additional sample of participants ($N = 5$) viewed all 180 images in a random order for ten seconds each, with a two second fixation between each image. Participants were instructed to view the images freely, with no additional task occurring during the session. Using Tobii Studio's cluster analysis, salient portions of each picture were identified using a spatial threshold to select areas with the modal number of fixations in each image. Fixations within a certain distance of this modal area were assigned to the cluster, and the percentage of participants who fixated within the defined cluster was reported by Tobii studio. Clusters were determined using data from the first three seconds of participants' viewing of each stimulus. This time interval was selected because each image was viewed for three seconds in the experimental portion of the study.

The overlap between the areas selected using these two methods was identified by overlaying a visual representation of the cluster analysis and the shapes drawn by participants. Areas of interest (AOIs) were chosen if any number of participants manually selected the area in addition to 80 to 100 percent participants fixating in that area during free viewing (see Figure 3). Participants' manual selections were used to verify that areas identified by cluster analysis, which was the primary AOI selection tool, were in fact salient. Because there are many factors playing into participants' decision to manually select areas, such as additional time, effort, and processing resources, free viewing procedures can more accurately identify salient areas by using eye-gaze as a measure of attentional capture. It is important to utilize manual selection data, however, to ensure that areas identified by cluster analysis were salient objects as opposed to areas that were more likely to be fixated upon despite their lack of salience (e.g. the middle portions of each picture). The average surface area, in pixels, occupied by the areas of interest did not differ significantly between the three emotional valence sets (positive, negative, and neutral), nor did the number of areas of interest per image.

Statistical Analysis

Eye-fixation data from the encoding session were grouped for analysis based on emotional valence (negative, positive, and neutral) and subsequent memory (hits and misses). Images for which data were categorized as hits were correctly and confidently remembered by participants during the retrieval session. Misses included images that were both incorrectly identified as new and those images that were correctly remembered with low confidence during the retrieval session. Images remembered with low confidence were classified as misses because they were considered guesses. It is likely that participants were reporting memory with low confidence to signal a guess because the proportions of correctly remembered items and false alarms were near chance for unsure responses. Statistical analyses on each of several variables were conducted using each participant's average for that variable across each 3000ms stimulus presentation. Analyses based on valence were conducted using averages between hits and misses within that valence for each variable. Variables for which analyses were conducted include: average number of fixations on each picture, average time to first fixation on any of the identified areas of interest, average number of fixations across areas of interest, and average total time spent fixating within the areas of interest. The number of fixations on images was used to assess visual search across the image, including search for peripheral details. Time to first fixation on areas of interest was used to evaluate initial capture of attention by the salient aspects of each image. Number of fixations on areas of interest and time spent looking in areas of interest were used to measure the amount of visual search within salient portions of images and the focusing of attention to those salient areas. Mixed model ANOVAs with Greenhouse Geisser corrections were conducted to evaluate the effects of emotion cuing, emotional valence, and subsequent memory on each of the above variables. All reported post-hoc tests were Bonferroni corrected for multiple comparisons.

Results

Valence and Arousal Ratings

Self-Assessment Manakin ratings in the current study suggested a successful manipulation of emotional valence between the three categories of stimuli (positive, negative, and neutral). In one-way repeated measures ANOVAs with Greenhouse Geisser corrections, significant main effects of emotion category were seen in both valence ratings ($F(1.302, 50.782) = 244.537$, $p < 0.001$, $\eta_G^2 = 0.862$) and arousal ratings($F(1.740, 67.878) = 56.918$, $p < 0.001$, $\eta_G^2 = 0.593$). Stimuli in the negative category were rated negatively on the valence scale (*M* = 1.975 *SD* = 0.515) and differed from both neutral ($p < 0.001$) and positive stimuli ($p < 0.001$) in Bonferroni corrected post-hoc comparisons. Participants' ratings of stimuli in the positive category (*M* = 3.921, *SD* = 0.332) were indicative of the pictures' emotional valence and were significantly more positive than stimuli in the neutral category ($p < 0.001$) which were rated as neither positive nor negative on the one to five rating scale (*M* = 2.973, *SD* = 0.223) (see Figure 4). Negative (*M* = 3.276, *SD* = 0.755) and positive stimuli (*M* = 3.108, *SD* = 0.636) were rated significantly higher than neutral pictures (*M* = 2.180, *SD* = 0.614) for arousal as indicated by Bonferroni corrected post-hoc comparisons ($p < 0.001$ for both comparisons). Additionally, positive and negative pictures did not differ significantly in participants' ratings of their emotional arousal ($p = 0.500$), suggesting that images in these two categories differed in emotional valence but not arousal (see Figure 4).

Visual Processing of Emotional Stimuli

To test for the effects of emotional valence and emotion cuing on allocation of attention and visual processing during encoding, 2 (emotion cued and non-cued groups) x 3 (positive, negative, and neutral valence) mixed model ANOVAs with were conducted for a number of eye-gaze variables on encoding fixation data only.

Image-Wide Visual Search. A 2 (cue group) x 3 (valence) mixed model ANOVA on the average number of fixations on the whole image across hits and misses was conducted to investigate visual search behavior. There was a trend towards a significant interaction between emotional valence and emotion cuing ($F(1.967, 74.740) = 2.505$, $p = 0.089$, $\eta_G^2 = 0.062$; see Figure 5). There was no significant main effect of emotional valence or emotion cuing. Based on this trend to significance, valence and emotion cuing have a tendency to affect visual search in complex scenes, with a tendency for emotion cuing to increase visual search in negative stimuli (see Figure 5). The anticipation of emotion and emotional valence do not have any significant relations to image-wide visual search.

Initial Capture of Attention. In order to investigate the initial capture of attention by salient information, the average time until individuals' first fixation within areas of interest was evaluated using a 2 (cue group) x 3 (valence) mixed model ANOVA. There was a significant main effect of valence ($F(1.842, 69.993) = 13.856$, $p < 0.001$, $\eta_G^2 = 0.267$). Neutral images ($M = 0.332$, $SD = 0.108$) had a longer time to the first fixation within areas of interest than both negative ($M = 0.279$, $SD = 0.099$) and positive ($M = 0.281$, $SD = 0.074$) images (see Figure 6). Bonferroni corrected post-hoc comparisons indicated that the areas of interest in positive ($p = 0.001$) and negative ($p < 0.001$) images were fixated upon more quickly than neutral areas of interest, but that there was no significant difference between the time to first fixation for the two emotional valences ($p = 1.000$; see Figure 6). This analysis also indicated a significant interaction of valence and cue group ($F(1.842, 69.993) = 4.711$, $p = 0.014$, $\eta_G^2 = 0.110$). Further investigation of this interaction found no significant differences in time to first fixation for the cued and non-cued groups within the positive ($t(30.215) = 0.864$, $p = 0.394$, $d = 0.314$) or neutral ($t(33.798) = 0.617$, $p = 0.514$, $d = 0.212$) valences. A significant effect of cuing was found within the negative valence (*t*(25.771) = 2.117, *p* = 0.044, *d* = 0.834) such that participants who were given emotion cues had a shorter time to their first fixation within an area of interest (*M* = 0.250, *SD* = 0.062) than participants who did not receive an emotion cue (*M* = 0.307, *SD* = 0.120; see Figure 7). There was no significant main effect of emotion cuing. These results suggest that emotionally salient information draws attention more quickly than salient information in neutral images, and that this effect is enhanced for negative stimuli following the presentation of an emotion cue.

Processing of Salient Information. To test the effects of emotional valence and cuing on visual search within salient areas of stimuli a 2 (cue group) x 3 (valence) mixed model ANOVA was conducted on the average number of fixations within areas of interest. There were no significant main effects of valence or emotion cuing and no significant interaction between cuing and valence. A 2 (cue group) x 3 (valence) mixed model ANOVA was also conducted on total time spent looking within areas of interest to investigate the focusing of attention. There was a significant main effect of emotional valence (F(1.960, 74.481) = 4.668, p = 0.013, η_G^2= 0.109). Bonferroni corrected post-hoc comparisons indicated that participants spent less time looking within areas of interest for negative stimuli (*M* = 1.229, *SD* = 0.229) compared to both positive (*M* = 1.277, *SD* = 0.241; *p* = 0.020) and neutral (*M* = 1.271, *SD* = 0.241; *p* = 0.042) stimuli (see Figure 8). There was no significant main effect of emotion cuing as well as no interaction between cuing and emotional valence. These results suggest that emotional valence and emotion cuing had no detected effect on the visual processing of salient information, but negative emotional information results in decreased attention to salient portions of scenes.

Subsequent Memory

To evaluate the effects of emotion cuing and emotional valence on memory, a 2 (cued and non-cued group) x 3 (positive, negative, and neutral valence) mixed model ANOVA with Greenhouse-Geisser corrections was conducted on proportions of corrected recognition for each participant. As mentioned above, hits, or correctly remembered stimuli, were defined as those stimuli which were remembered with high confidence during the recognition task. Corrected recognition scores for each emotional valence were obtained by subtracting the proportion of false alarms, new items which were mistakenly remembered during the recognition task, from the proportion of hits for each participant. There was a significant main effect of emotional valence on recognition memory ($F(2,76) = 8.182$, $p = 0.001$, $\eta_G^2 = 0.177$) but no significant main effect of cuing or interaction between cuing and emotional valence. Negative stimuli had the highest recognition scores ($M = 0.563$, $SD = 0.198$) followed by positive stimuli ($M = 0.510$, $SD = 0.169$) and neutral stimuli with the lowest rates of recognition ($M = 0.459$, $SD = 0.179$). Bonferroni corrected post-hoc comparisons indicated that whereas negative images had higher recognition scores than neutral images ($p = 0.001$), memory for positive images did not differ significantly from negative ($p = 0.142$) or neutral stimuli ($p = 0.160$; see Figure 9). No main effect of cuing or interaction between cuing and valence was found. These results suggest that emotion cuing has no significant effects on recognition scores, but we can conclude that recognition memory was enhanced for negative emotional stimuli.

Encoding and Subsequent Memory

In order to investigate the effects of emotional valence and emotion cuing on the allocation of attention during encoding and how these factors relate to subsequent memory, 2 (cued group and non-cued group) x 2 (subsequently remembered and not remembered) x 3 (positive, negative, and neutral valence) mixed model ANOVAs with Greenhouse Geisser corrections were conducted on a number of eye-gaze variables for fixation data from the encoding session only.

Image-Wide Visual Search. Gaze patterns throughout entire images were analyzed with 2 (cue group) x 2 (subsequent memory) x 3 (valence) mixed model ANOVAs on the average number of fixations throughout each image. A significant main effect of subsequent memory was identified ($F(1, 38) = 7.588$, $p = 0.009$, $\eta_G^2 = 0.166$) such that subsequently remembered images ($M = 9.940$, $SD = 0.892$) had a higher number of fixations during encoding than images that were subsequently forgotten ($M = 9.736$, $SD = 0.949$). Replicating results from the 2 (cue group) x 3 (valence) ANOVA (see above), there were no significant main effects of emotional valence or emotion cuing, and there was a trend towards an interaction of group (cued and non-cued) and emotional valence (positive, negative, and neutral). These results suggest that increased image-wide visual search, as indicated by a higher number of fixations throughout scenes, is related to enhanced memory.

Initial Capture of Attention. A 2 (group) x 2 (subsequent memory) x 3 (valence) mixed model ANOVA was conducted on the average time to first fixation. This analysis replicated the results of the 2 (cue group) x 3 (valence) mixed model ANOVA (see above) and indicated a significant main effect of valence as well as interaction between emotional valence and emotion cuing. There was no significant effect of subsequent memory on the time to fixate within an area of interest. These results suggest that although emotionally salient information draws attention more quickly than salient information in neutral images, this effect of emotion on attention is not related to subsequent memory.

Processing of Salient Information. Analysis of visual processing within salient portions of stimuli involved 2 (cue group) x 2 (subsequent memory) x 3 (valence) mixed model ANOVAs for two variables: average number of fixations within areas of interest and average time spent looking in areas of interest. Analysis of the number of fixations within areas of interest identified a significant main effect of subsequent memory ($F(1, 38) = 18.587$, $p < 0.001$, $\eta_G^2 = 0.328$) such that subsequently remembered stimuli ($M = 5.399$, $SD = 0.683$) had significantly more fixations than non-remembered stimuli ($M = 5.077$, $SD = 0.790$). This analysis also indicated a significant interaction between emotional valence and subsequent memory ($F(1.759, 66.825) = 5.157$, $p = 0.011$, $\eta_G^2 = 0.119$). Further investigation of this interaction revealed that subsequently remembered negative ($M = 5.483$, $SD = 0.699$) and neutral ($M = 5.418$, $SD = 0.802$) stimuli had a significantly higher number of fixations in AOIs compared to non-remembered negative ($M = 4.911$, $SD = 1.082$; $t(39) = 4.357$, $p < 0.001$, $d = 0.689$) and neutral ($M = 4.987$, $SD = 0.999$; $t(39) = 2.628$, $p = 0.012$, $d = 0.415$) stimuli. However, there was no significant difference between subsequently remembered and non-remembered positive stimuli ($t(39) = 0.341$, $p = 0.735$, $d = 0.054$; see Figure 10). There were no other significant main effects or interactions for the number of fixations within areas of interest.

A 2 (cue group) x 2 (subsequent memory) x 3 (valence) mixed model ANOVA conducted on the average time spent looking in areas of interest indicated a significant main effect of subsequent memory ($F(1, 38) = 5.774$, $p = 0.021$, $\eta_G^2 = 0.132$) such that participants spent a longer time looking within salient areas of images for those stimuli that were subsequently remembered ($M = 1.287$, $SD = 0.221$) as opposed to those that were not remembered ($M = 1.230$, $SD = 0.266$). This 3-way ANOVA also indicated a trend towards a significant interaction between valence and subsequent memory on total time spent looking within areas of interest was also found ($F(1.819, 69.113) = 2.968$, $p = 0.063$, $\eta_G^2 = 0.072$; see Figure 11). This analysis replicated the results of the 2 (cue group) x 3 (valence) mixed model ANOVA (see above), revealing a significant main effect of emotional valence. Based on these results, subsequent memory is related to both increased visual search and increased time spent looking in salient areas of stimuli, but this relationship is only true for the visual search of negative and neutral stimuli while visual search behavior within the areas of interest of positive stimuli seems to have little relationship with subsequent memory.

Summary

The findings of the current study expand upon previous literature by evaluating the effects of emotional valence, emotion cuing, and subsequent memory on a wide range of eye gaze variables. As expected, there was a significant effect of emotion on memory performance such that negative stimuli were more confidently and accurately remembered than neutral stimuli. Analyses revealed that image-wide visual search was related to subsequent memory, such that remembered stimuli had a higher number of fixations during encoding. Emotion cuing and valence interacted to impact the initial capture of attention by salient information. Individuals fixated on salient information more quickly in emotional images, an emotion cue sped up this attentional capture for negative stimuli. Therefore, emotional information captures initial attention, but the anticipation of negative information exacerbates this effect of emotion on attention capture. Increased visual search within salient areas of stimuli, which was measured by the average number of fixations within areas of interest, was related to better memory performance for negative and neutral, but not positive, images. These results suggest that the amount of visual search of salient information during encoding is related to accurate subsequent memory for negative and neutral stimuli. The analyses conducted did not indicate any relations between the effects of emotion cuing on allocation of attention and memory, suggesting that anticipation of emotional information may not affect behavior in such a way that impacts memory. However, emotion cuing had significant effects on encoding behavior by enhancing the effects of negativity on initial attentional capture.

Discussion

As expected, recognition memory was enhanced for negatively valenced emotional stimuli (for review see LaBar & Cabeza, 2006). Recognition performance was also related to two different patterns of attention: increased image-wide visual search and the focusing of attention on salient information, suggesting that there are two mechanisms of attention that can be responsible for successful encoding. Additionally, interactions between emotional valence and subsequent memory are consistent with hypotheses and previous literature (Inman, 2010; Sharot et al., 2008). These interactions suggest that focusing attention and visual search may be the mechanism responsible for successful encoding of negative and neutral, but not positive stimuli. Because focusing visual search on salient information is related to enhanced memory for negative and neutral stimuli, the narrowing of attention does not account for the enhancing effects of negative emotion on memory. There may be processes unique to the encoding of negative information other than the preferential allocation of attention to salient information resulting in enhanced memory for negative stimuli.

In the investigation of emotion processing, the results of the current study were not consistent with the hypothesis that attention is focused on central, salient details during the viewing of negatively valenced scenes. These results are also inconsistent with the Easterbrook (1959) cue-utilization hypothesis which states that emotional arousal narrows attention, causing individuals to attend to a smaller range of cues or features within an image. The diversion of attention from salient details of negative images suggests that participants may be avoiding sustained processing of negative information. One hypothesis suggests that negative information is processed differently due to the activation of preparatory systems in the brain that may prepare individuals for the avoidance of aversive stimuli (Lang & Bradley, 2010). The visual processing of positive stimuli was not consistent with the Easterbrook hypothesis (1959) or our hypothesis that positivity enhances visual search behavior (Wadlinger & Isaacowitz, 2006). Although positive stimuli did not show differences in sustained allocation of attention, an emotion effect on the orienting of attention was identified such that positive and negative stimuli draw attention more quickly than negative stimuli. These results are consistent with theories of attentional capture that suggest emotional information draws immediate, but not necessarily sustained, eye gaze and attention (Calvo & Lang, 2004).

The results of the current study are also partially consistent with hypotheses regarding the effects of emotion anticipation on attention. In particular, the anticipation of emotion lead to a faster orienting of attention to salient negative information as expected. It was hypothesized that the anticipation of negative information would lead to more "objective" processing of images, resulting in increased sampling of details throughout the image and not just central details (Galli et al., 2011), but the results of the current study were not consistent with this hypothesis. Differences in attentional patterns resulting from emotion anticipation were not related to subsequent memory. This result may indicate that anticipation changes encoding and subsequent memory not by changing eye movement behaviors but via other processes. However, it is likely that other factors such as individual differences in emotion regulation and affect are interacting with the processes of emotion anticipation, attention, and memory (Galli, Grffiths, & Otten, 2012).

Mechanisms for the Encoding of Emotional Stimuli

The results of the current study are consistent with previous literature and indicate that memory accuracy is related to the focusing of attention on salient information as measured by the number of fixations on salient portions of images and the time spent looking at these salient areas (Gardiner et al., 2006). Therefore, preferential processing of central and salient information seems to be one mechanism or approach that leads to the successful encoding of complex scenes. However, this phenomenon is observed for negative and neutral scenes, but not positive. This suggests that the information necessary for successful encoding of negative and neutral scenes can be gained from increased processing and sampling of salient details during encoding. Increased attention to the central details of a stimulus is not sufficient for the successful encoding of positive stimuli which may require other patterns of visual processing such as attention to more cues and details within a visual scene.

During the processing of negative stimuli, individuals spent significantly less time looking at salient negative information. Therefore, although focusing attention on salient information during encoding helps enhance memory, it is not the reason that memory performance for negative stimuli is improved. The aversive nature of negative stimuli may cause individuals to avoid looking at salient negative information thereby decreasing the focus of attention to salient negative information (Lang & Bradley, 2010). However, it may be difficult to disengage attention from highly arousing negative information, leading to focused attention on this negative information and the enhancement of memory (Inman, 2010). Because emotional arousal is linked to enhanced memory (e.g. Hamann, 2001), patterns of attention reflect this relationship between arousal and subsequent memory. For neutral stimuli, we hypothesize that memory is enhanced as a function of attentional focus because individuals are able to gain more specific information through the processing of salient details versus peripheral details. Based on the current study, it is unclear if there are any patterns of attention specific to negative information that account for enhancements in memory. Although increased processing of salient details enhances encoding, this mechanism is not preferentially recruited for negative stimuli, suggesting that the emotional qualities of the stimulus itself, and not valence-specific pattern of attention, are enhancing memory performance.

An additional mechanism for encoding of visual scenes was identified in the current study: increased visual search and sampling of cues throughout an image. The number of fixations on an entire stimulus was related to memory performance, suggesting that the sampling of cues and information in both central and peripheral areas of scenes can also act as a successful encoding strategy. This approach to encoding may increase the number of cues and details which are encoded due to the wider distribution of attention. The fact that this is a successful encoding mechanism indicates that the sustained processing of few details and the processing of a wider range of details can both lead to enhanced memory. However, the success of each strategy depends upon the type of information present in the image. Focusing attention on central, salient details seems to only be a successful encoding mechanism for stimuli of the negative and neutral valences. Interestingly, the immediate capture of attention was the only variable in the current study for which positive stimuli differed from neutral stimuli. Salient positive information drew attention more quickly than salient features in neutral images (Calvo & Lang, 2004), indicating that positive information readily grabs attention but does not seem to have sustained effects on the allocation of attention. However, the orienting of attention was not related to subsequent memory for positive stimuli. No relationships between attention and subsequent memory were identified for positive stimuli. Further research should be conducted to determine the circumstances under which image-wide visual search is a successful encoding strategy. Evaluating what patterns of attention lead to the successful encoding of positive stimuli could also be significant in expanding this research.

Emotion Anticipation and Encoding Processes

The anticipation of emotion affects neural activity prior to a stimulus (Galli et al., 2011) and patterns of visual attention during stimulus presentation. Many studies have suggested that anticipatory neural activity predicts memory because it leads to changes in attention and visual processing during the presentation of a stimulus (Mackiewicz et al., 2006). However, the current study is the first to directly investigate this hypothesis by assessing the allocation of attention during the encoding of anticipated emotional stimuli and how it relates to subsequent memory. As expected, the anticipation of a negative stimulus lead to faster orienting of attention to salient negative information. However, the same phenomenon did not occur during the encoding of positive stimuli. Negative-specific anticipatory effects are consistent with the literature regarding neural anticipatory effects (Galli et al., 2011). These results demonstrate that there is something special about anticipating the negative valence, not emotion in general, that leads to differences in neural activity and behavior. Galli et al. (2011) speculate that anticipatory effects occur for negative but not positive stimuli because negative stimuli are aversive and possibly threatening. I propose that the expectation of negative content prepares individuals to quickly identify aversive information by orienting attention to that information. Attention is quickly oriented to negative information so that individuals can more effectively avoid allocating attention to aversive content, instead diverting attention elsewhere in an image.

Contrary to our hypotheses, there was no relation between anticipation-related patterns of attention and subsequent memory. Previous research proposed that anticipatory neural activity is predictive of memory accuracy due to its effects on attention and stimulus processing (Galli et al., 2011; Mackiewicz et al., 2006). Although the results of the current study suggest that emotion anticipation does affect the immediate allocation of attention during stimulus processing, this change in attention allocation was not predictive of memory. It is possible that changes in attention-related behaviors do not lead to enhanced encoding of anticipated negative stimuli, but that anticipatory neural activity is indicative of other cognitive strategies that may allow individuals to encode stimuli more effectively (Otten et al., 2006). However, it is more likely that there are individual differences affecting individuals' behavioral responses to emotion anticipation and their memory for anticipated stimuli. For example, Galli et al. (2012) found that emotion regulation strategies can negate the memory-predictive quality of anticipatory neural activity. These results suggest that if individuals respond to emotion cues by invoking certain emotion regulation strategies, they may alter their allocation of attention differently than individuals who are not regulating their emotions (Galli et al., 2012). Individuals who are more likely to regulate their emotions through selective attention may divert attention from negative information whereas those who regulate emotions using primarily reappraisal strategies may focus attention on negative information (see Gross, 1998 for review). Individual differences in emotion regulation strategies may affect the way that patterns of attention relate to encoding of information and subsequent memory for negative stimuli.

Limitations and Future Directions

Consistent effects of emotional valence on attention were found, but there are limitations of the current stimuli set that may have dampened the effects of emotion on attention. Because images were presented in grayscale, it is possible that they were less emotionally arousing than color images. Although previous research suggests that images do not lose their emotional qualities when they are in grayscale as opposed to color (Bradley, Codispoti, Cuthbert, & Lang, 2001), it is uncertain whether the particular stimuli used in the current study were experienced as less emotional due to their grayscale presentation. Additionally, the emotional stimuli used in the current study did not include highly aversive negative stimuli or erotic positive stimuli, which typically elicit the most emotional responses (Lang et al., 2008). These stimuli were chosen to ensure that all images were appropriate for the use of this paradigm in studies with child participants. The emotional stimuli were rated as significantly more arousing than neutral stimuli, but the arousal ratings for negative and positive stimuli were not significantly higher than an average level of arousal. Because the current stimuli were less arousing than stimuli used in previous research, we can conclude that the effects of emotion seen in the current study are robust phenomena. However, it is likely that the effects of emotion were dampened and that more effects of emotion and potentially of emotion anticipation may have been seen if more emotionally arousing images were selected as stimuli.

An additional limitation of the current study is the classification of non-confidently remembered stimuli as misses for analyses based on subsequent memory. These stimuli were grouped with non-remembered stimuli because, based on proportions of recognition, participants seemed to treat this unsure option as a guess. It is possible that not all participants were selecting this response to signal a guess, and some participants may have selected the unsure response when they remembered the stimulus. If non-confidently remembered stimuli were stimuli for which participants were guessing, it is appropriate to group them with non-remembered stimuli, as they were only correctly remembered by chance. However, if participants reported unsure responses for stimuli that they did remember, it may be more appropriate to consider those stimuli as a separate category which may have attention patterns at encoding similar to confidently remembered stimuli rather than non-remembered stimuli. In order to ensure appropriate trial counts and based on rates of recognition, non-confidently remembered stimuli were considered guesses and grouped with non-remembered stimuli for analysis. Future research should attempt to increase trial counts to examine the patterns of attention of confidently remembered, non-confidently remembered, and non-remembered stimuli separately.

The findings of the current study raise many questions for future research. One potential direction is to investigate the two patterns of attention that were related to successful encoding. Although increased visual search of central and peripheral details was related to enhanced memory performance, it is unclear what prompts the use of this mechanism in some cases and the focusing of attention, which was also related to enhanced memory, in other cases. It would be useful to identify the circumstances under which each approach to encoding is successful, in order to identify how different types of stimuli are optimally encoded. Additionally, the focusing of attention to salient information was related to enhanced memory only for negative and neutral stimuli, suggesting that this encoding strategy is used in the presence of negative information as well as in the absence of emotional content. However, the current study does not shed any light on what patterns of attention lead to the successful encoding of positive stimuli, and this question should be evaluated further. Because emotion regulation strategies alter the relationship between anticipatory neural activity and subsequent memory (Galli et al., 2012), future research should investigate the effects of emotion regulation strategies on the interaction between attention and subsequent memory in order to disentangle the different effects that anticipation may have on encoding. Subsequent research should also investigate the effects of emotion anticipation on autonomic arousal, measured using pupil dilation, and how arousal relates to the allocation of attention during encoding and subsequent memory.

Conclusions

The results of the current study inform knowledge of emotional memory by investigating the relations between emotion anticipation, attention, and enhanced memory performance. Enhanced memory for negative and neutral stimuli was related to the focusing of attention to salient information. Although memory was enhanced for negative stimuli, we did not identify any patterns of attention during encoding specific to negative stimuli that could account for this memory enhancement, suggesting that other encoding mechanisms are involved in emotional memory. Effects of positive stimuli on attention were present in the orienting of attention to salient information, but no relations between this pattern of attention and subsequent memory were identified. Because no emotion-specific patterns of attention identified in the current study were related to memory, it is likely that the patterns of attention at encoding for both positive and negative stimuli are interacting with other encoding processes in order to enhance memory for emotional stimuli. Contrary to hypotheses, the anticipation of emotion did not alter visual search and attention patterns in a way that lead to enhanced memory. However, future research should investigate the role of individual differences in emotion regulation (Galli et al., 2012) in order to gain insight on the effects of anticipation on attention and memory.

References

Adcock, R. A., Thangavel, A., Whitfield-Gabrieli, S., Knutson, B., & Gabrieli, J. D. (2006). Reward-motivated learning: mesolimbic activation precedes memory formation. *Neuron*, *50*(3), 507. doi: 10.1015/j.neuron.2006.03.036

Amaral, D. G., Price, J. L., Pitkanen, A., & Carmichael, S. T. (1992). Anatomical organization of the primate amygdaloid complex. *The amygdala: Neurobiological aspects of emotion, memory, and mental dysfunction*, 1-66.

Bebko, G. M., Franconeri, S. L., Ochsner, K. N., & Chiao, J. Y. (2011). Look before you regulate: Differential perceptual strategies underlying expressive suppression and cognitive reappraisal. *Emotion*, *11*(4), 732. doi:10.1037/a0024009

Beck, A.T. (1967) Depression: clinical, experimental, and theoretical aspects. New York: Harper and Row.

Bollinger, J., Rubens, M. T., Zanto, T. P., & Gazzaley, A. (2010). Expectation-driven changes in cortical functional connectivity influence working memory and long-term memory performance. *The Journal of Neuroscience*, *30*(43), 14399-14410. doi: 10.1523/ JNEUROSCI.1547-10.2010

Bradley, M. M. (2008). Natural selective attention: Orienting and emotion. *Psychophysiology*, *46*(1), 1-11. doi: 10.1111/j.1469-8986.2008.00702.x

Bradley, M.M., Codispoti, M., Cuthbert, B.N., & Lang, P.J. (2001). Emotion and motivation I: Defensive and appetitive reactions in picture processing. *Emotion*, *1*, 276-298. doi: 10.1037//1528-3542.1.3.276

Bradley, M. M., Houbova, P., Miccoli, L., Costa, V. D., & Lang, P. J. (2011). Scan patterns when viewing natural scenes: Emotion, complexity, and repetition. *Psychophysiology*, *48*(11), 1544-1553. doi: 10.1111/j.1469-8986.2011.01223.x

Bradley, M.M., Keil, A., & Lang, P.J. (2012). Orienting and emotional perception: Facilitation, attenuation, and interference. *Frontiers in Psychology, 3,* 493. doi:10.3389/fpsyg.2012.00493

Bradley, M. M., & Lang, P. J. (1994) Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry, 25,* 49-59. doi: 10.1016/0005-7916(94)90063-9

Calvo, M. G., & Lang, P. J. (2004). Gaze patterns when looking at emotional pictures: Motivationally biased attention. *Motivation and Emotion*, *28*(3), 221-243. doi: 10.1023/B:MOEM.0000040153.26156.ed

Christianson, S.A., & Fallman, L. (1990). The role of age on reactivity and memory for emotional pictures. *Scandinavian Journal of Psychology*, *31,* 291-301. doi: 10.1111/j.1467-9450.1990.tb00841.x

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature reviews neuroscience*, *3*(3), 205-215. doi:10.1038/nrn755

Derryberry, D., & Reed, M. A. (1998). Anxiety and attentional focusing: Trait, state and hemispheric influences. *Personality and Individual Differences*, *25*(4), 745-761. doi: 10.1016/S0191-8869(98)00117-2

Dewhurst, S.A., & Conway, M.A. (1994). Pictures, images, and recollective experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*, 1-11. doi:10.1037//0278-7393.20.5.1088

Easterbrook, J.A. (1959). The effect of emotion on cue utilization and the organization of behavior. Psychology Review, 66, 183–201.

Gable, P.A. & Harmon-Jones, E. (2008). Approach-motivated positive affect reduces breadth of attention. *Psychological Science*, 19(5), 476-482. doi: 10.1111/j.1467-9280.2008.02112.x

Galli, G., Griffiths, V. A., & Otten, L. J. (2012). Emotion regulation modulates anticipatory brain activity that predicts emotional memory encoding in women. *Social cognitive and affective neuroscience*. doi: 10.1093/scan/nss145

Galli, G., Wolpe, N., & Otten, L. J. (2011). Sex differences in the use of anticipatory brain activity to encode emotional events. *The Journal of Neuroscience*, *31*(34), 12364-12370. doi: 10.1523/JNEUROSCI.1619-11.2011

Gardiner, J.M., Gregg, V.H., & Karayianni, I. (2006). Recognition memory and awareness: occurrence of perceptual effects in remembering or in knowing depends on conscious resources at encoding, but not at retrieval. *Memory and Cognition, 34*, 227–39. doi: 10.3758/BF03193401

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of general psychology*, *2*(3), 271. doi: 10.1037/1089-2680.2.3.271

Gruber, M. J., & Otten, L. J. (2010). Voluntary control over prestimulus activity related to encoding. *The Journal of Neuroscience*, *30*(29), 9793-9800. doi: 10.1523/ JNEUROSCI.0915-10.2010

Hamann, S. (2001). Cognitive and neural mechanisms of emotional memory. *TICS.* 5(9), 394-400. doi:10.1016/S1364-6613(00)01707-1

Hartley, C. A., & Phelps, E. A. (2009). Changing fear: the neurocircuitry of emotion regulation. *Neuropsychopharmacology*, *35*(1), 136-146. doi: 10.1038/npp.2009.121

Henderson, J. M., Weeks Jr, P. A., & Hollingworth, A. (1999). The effects of semantic consistency on eye movements during complex scene viewing. *Journal of Experimental Psychology: Human Perception and Performance, 25*(1), 210.

Herwig, U., Abler, B., Walter, H., & Erk, S. (2007). Expecting unpleasant stimuli--an fMRI study. *Psychiatry Research: Neuroimaging*. doi:10.1016/j.pscychresns.2006.02.007

Inman, C. S. (2010). Experience-related eye movements and pupillary responses reflect declarative memory for emotional and neutral pictures. (Master's Thesis). Emory University, Atlanta, GA.

Inman, C.S. & Hamann, S. (2012, April). Eye movements and pupil dilation predict interactions of valence and memory. Presented at the annual meeting of the Cognitive Neuroscience Society, Chicago, IL.

Itti, L., & Koch, C. (2000). A saliency-based search mechanism for overt and covert shifts of visual attention. *Vision research*, *40*(10-12), 1489-1506.

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of memory and language*, *30*(5), 513-541. doi: /10.1016/0749-596X(91)90025-F

Kensinger, E.A. (2009). Remembering the Details: Effects of Emotion. *Emotion Review, 1*(2), 99-113. doi: 10.1177/1754073908100432

Kensinger, E.A., Garoff-Eaton, R.J., Schacter, D.L. (2007). Effects of emotion on memory specificity: Memory trade- offs elicited by negative visually arousing stimuli. *Journal of Memory and Language, 56*, 575– 591. doi: 10.1016/j.jml.2006.05.004

LaBar, K.S. & Cabeza, R. (2006). Cognitive neuroscience of emotional memory. *Nat Rev Neurosci, 7* (1), 54-64. doi:10.1038/nrn1825

Lang, P. J., & Bradley, M. M. (2010). Emotion and the motivational brain. *Biological Psychology*, *84*(3), 437-450. doi: 10.1016/j.biopsycho.2009.10.007

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). International affective picture system (IAPS): Affective ratings of pictures and instruction manual. *Technical Report A-8.* University of Florida, Gainesville, FL.

Lovibond, P. F., & Lovibond, S. H. (1995). The structure of negative emotional states: Comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. *Behaviour research and therapy*, *33*(3), 335-343. doi: 10.1016/0005-7967(94)00075-U

Mackiewicz, K. L., Sarinopoulos, I., Cleven, K. L., & Nitschke, J. B. (2006). The effect of anticipation and the specificity of sex differences for amygdala and hippocampus function in emotional memory. *Proceedings of the National Academy of Sciences*, *103*(38), 14200-14205. doi: 10.1073/pnas.0601648103

Mickley, K.R., & Kensinger, E.A. (2008). Emotional valence influences the neural correlates associated with remembering and knowing. *Cognitive, Affective, & Behavioral Neuroscience*, *8*(2), 143-152. doi: 10.3758/CABN.8.2.143

Mogg, K., Bradley, B. P., Dixon, C., Fisher, S., Twelftree, H., & McWilliams, A. (2000). Trait anxiety, defensiveness and selective processing of threat: An investigation using two measures of attentional bias. *Personality and Individual Differences*, *28*(6), 1063-1077. doi: 10.1016/S0191-8869(99)00157-9

Nitschke, J. B., Sarinopoulos, I., Mackiewicz, K. L., Schaefer, H. S., & Davidson, R. J. (2006). Functional neuroanatomy of aversion and its anticipation. *Neuroimage*, *29*(1), 106-116. doi:10.1016/j.neuroimage.2005.06.068

Niu, Y., Todd, R., & Anderson, A. K. (2012). Affective salience can reverse the effects of stimulus-driven salience on eye movements in complex scenes. *Frontiers in Psychology*, *3*, 336. doi: 10.3389/fpsyg.2012.00336

Niu, Y., Todd, R. M., Kyan, M., & Anderson, A. K. (2012). Visual and emotional salience influence eye movements. *ACM Transactions on Applied Perception (TAP)*, *9*(3), 13. doi: 10.1145/2325722.2325726

Ochsner, K. N. (2000). Are affective events richly recollected or simply familiar? The experience and process of recognizing feelings past. *Journal of Experimental Psychology: General*, *129*, 242-261. doi: 10.1037//0096-3445.129.2.242

Otten, L. J., Quayle, A. H., Akram, S., Ditewig, T. A., & Rugg, M. D. (2006). Brain activity before an event predicts later recollection. *Nature neuroscience*, *9*(4), 489-491. doi:10.1038/nn1663

Park, H., & Rugg, M. D. (2010). Prestimulus hippocampal activity predicts later recollection. *Hippocampus*, *20*(1), 24-28. doi: 10.1002/hipo.20663

Phelps, E.A. (2004). Human emotion and memory: Interactions of the amygdala and hippocampal complex. *Current Opinion in Neurobiology, 14*, 198-202. doi: 10.1016/j.conb.2004.03.015

Rajaram, S. (1993). Remembering and knowing: Two means of access to the personal past. *Memory & Cognition, 21*, 89-102. doi: 10.3758/BF03211168

Rizzolatti, G., Riggio, L., Dascola, I., & Umiltá, C. (1987). Reorienting attention across the horizontal and vertical meridians: evidence in favor of a premotor theory of attention. *Neuropsychologia*, *25*(1), 31-40. doi: 10.1016/0028-3932(87)90041-8

Rowe, G., Hirsh, J. B., & Anderson, A. K. (2007). Positive affect increases the breadth of attentional selection. *Proceedings of the National Academy of Sciences*, *104*(1), 383-388. doi: 10.1073/pnas.0605198104

Sabatinelli, D., Bradley, M. M., Fitzsimmons, J. R., & Lang, P. J. (2005). Parallel amygdala and inferotemporal activation reflect emotional intensity and fear relevance. *Neuroimage*, *24*(4), 1265-1270. doi:10.1016/j.neuroimage.2004.12.015

Sharot, T., Davidson, M. L., Carson, M. M., & Phelps, E. A. (2008). Eye Movements Predict Recollective Experience. *PLoS ONE* , *3*, 2884. doi: 10.1371/journal.pone.0002884.t002

Simmons, A., Matthews, S. C., Stein, M. B., & Paulus, M. P. (2004). Anticipation of emotionally aversive visual stimuli activates right insula. *Neuroreport*, *15*(14), 2261-2265. doi:10.1097/00001756-200410050-00024

Wadlinger, H. A., & Isaacowitz, D. M. (2006). Positive mood broadens visual attention to positive stimuli. *Motivation and Emotion*, *30*(1), 87-99. doi: 10.1007/s11031-006-9021-1

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of personality and social psychology*, *54*(6), 1063.

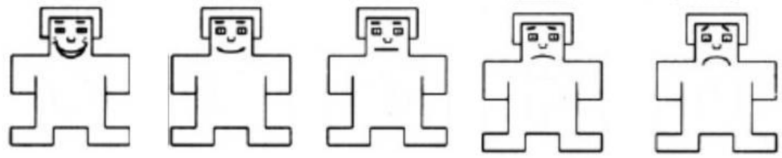

Figure 1a. Adapted Self-Assessment Manakin Valence Rating Scale. This figure contains the scale used by participants to rate whether images they viewed made them feel positive, neutral, or negative.

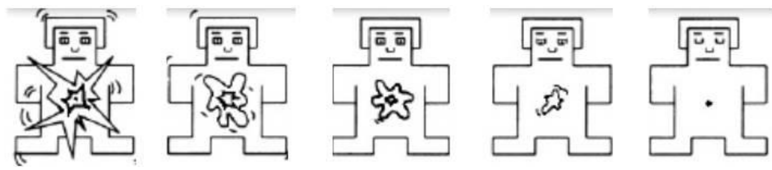

Figure 1b. Adapted Self-Assessment Manakin Arousal Rating Scale. This figures contains the scale used by participants to rate how images made them feel in terms of emotional arousal.

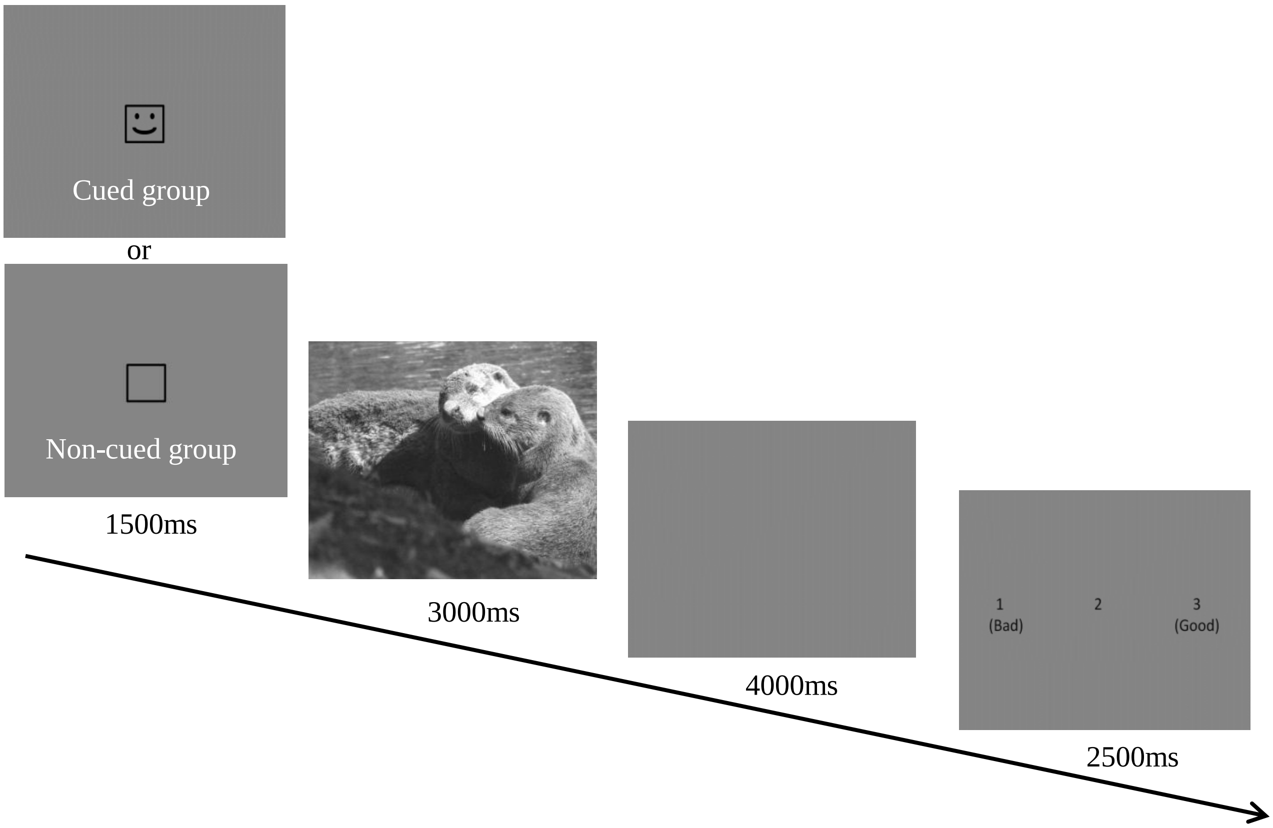

Figure 2a. Representative Encoding Trial. This figure displays a representative encoding trial including examples of both the emotion cued and non-cued fixation squares.

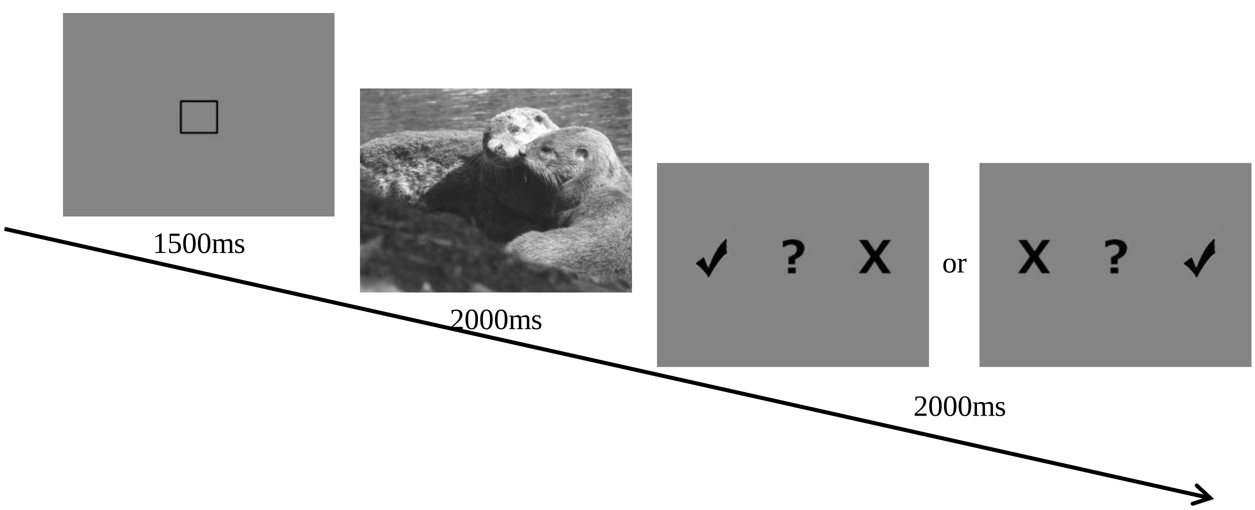

Figure 2b. Representative Retrieval Trial. This figures displays a representative retrieval trial including rating screens with potential recognition responses in both counterbalanced directions.

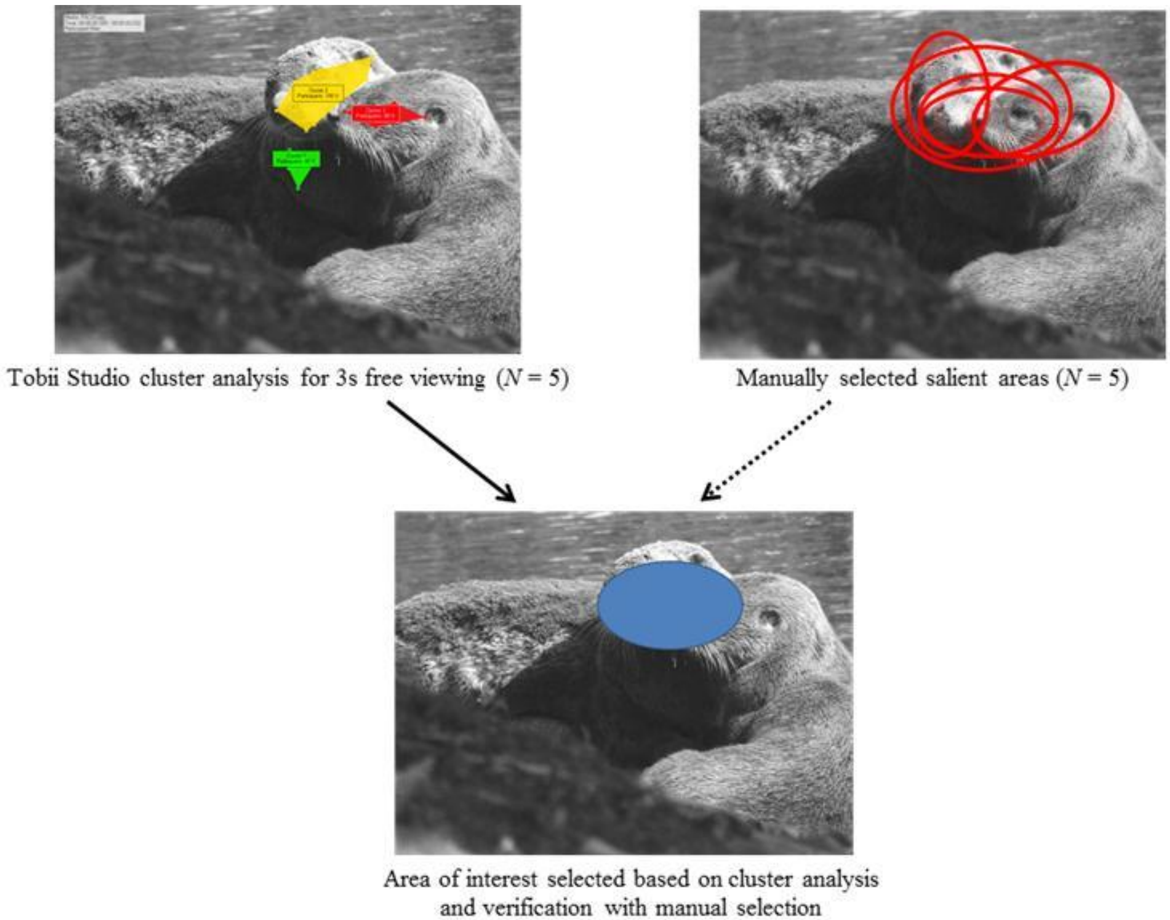

Figure 3. Example of Area of Interest Selection Procedure. This figure depicts a representative example of the method used to select areas of interest for experimental stimuli.

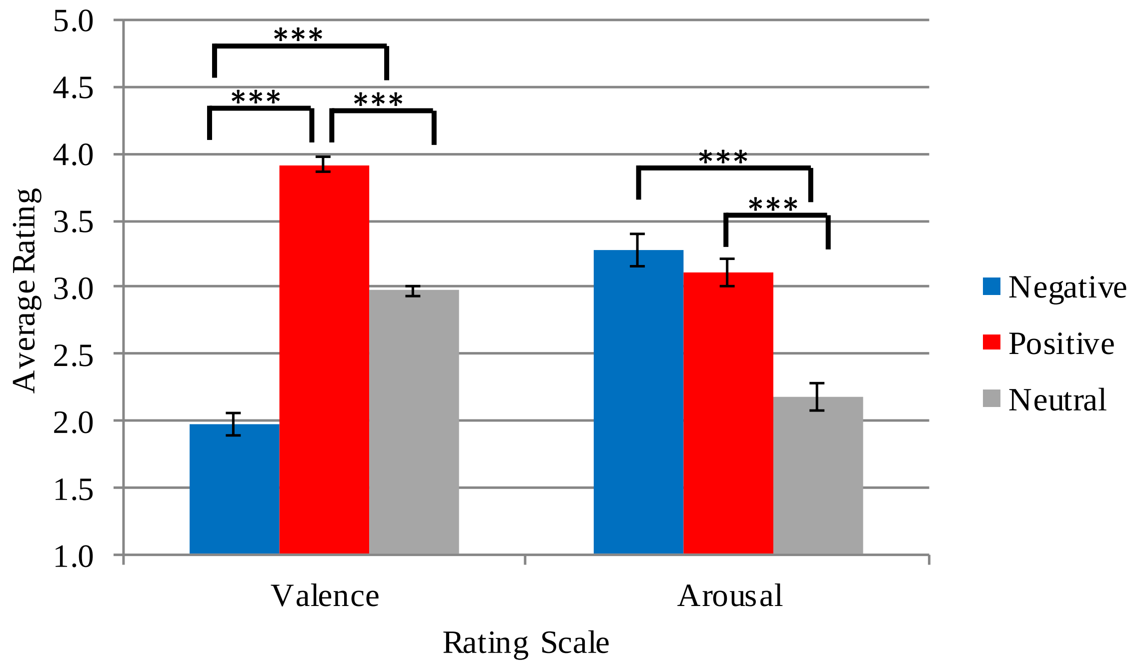

Figure 4. Self-Assessment Manakin Valence and Arousal Ratings. This figure contains the average valence and arousal Self-Assessment Manakin ratings for stimuli in the negative, positive, and neutral valences from participants in the current study. Error bars show the standard error of the mean for each category. ***$p < 0.001$

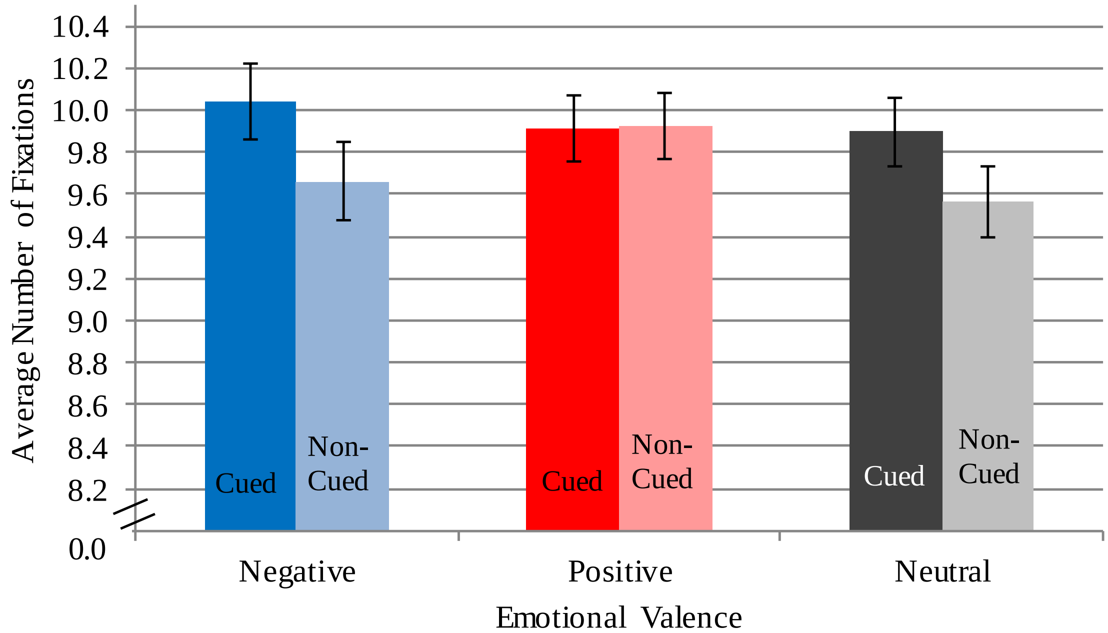

Figure 5. Average Number of Fixations on Entire Image as a Function of Valence and Cue Group. The average count of fixations across images of each emotional valence for participants in the emotion cued and non-emotion cued groups is presented. Error bars depict the standard error of the mean for each category. Note that differences between categories are not significantly different, but these data were characterized by a trend towards an interaction between valence and cue group.

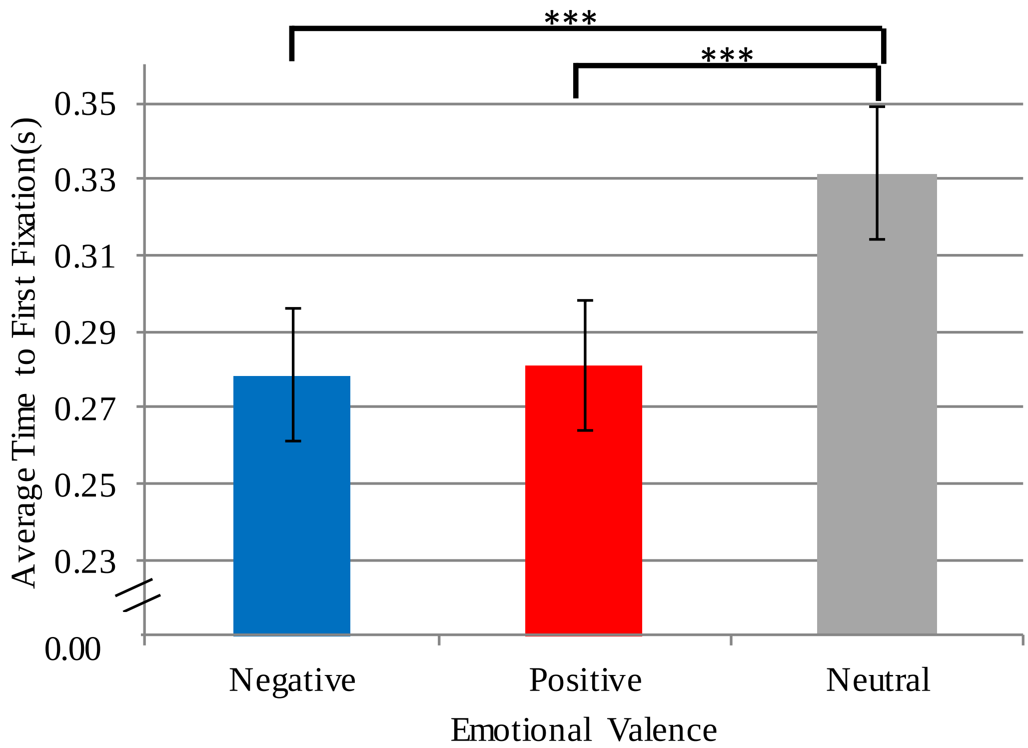

Figure 6. Average Time to First Fixation in Areas of Interest as a Function of Valence. This chart depicts the average amount of time before participants fixated within an area of interest for images of each emotional valence. Error bars show the standard error of the mean for each category. ***$p < 0.001$

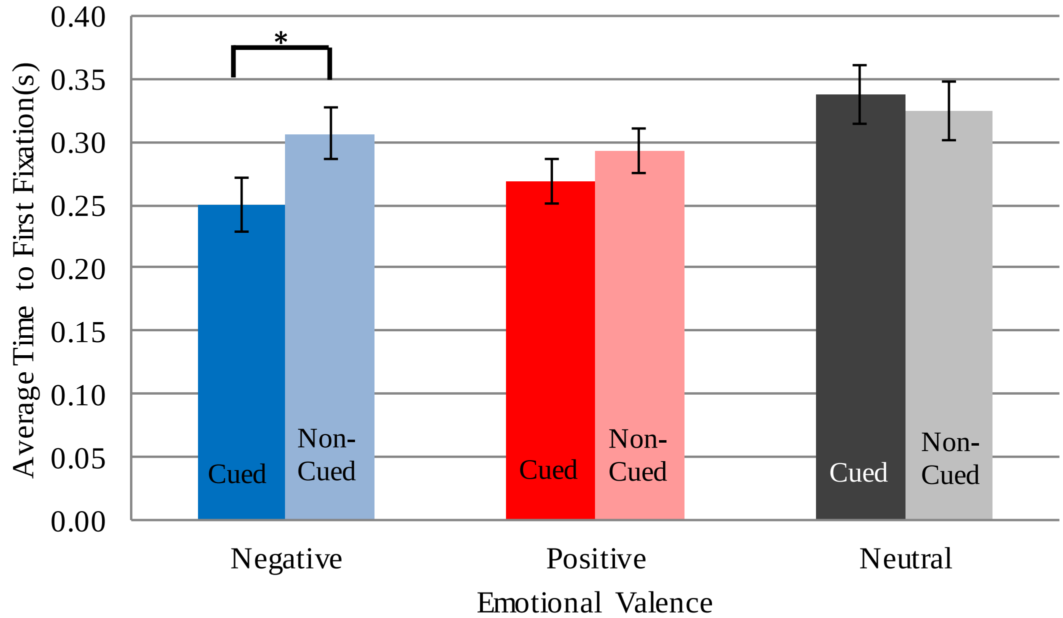

Figure 7. Average Time to First Fixation in Areas of Interest as a Function of Valence and Cue Group. The average amount of time before participants in the emotion cued and non-emotion cued groups fixated within an area interest for stimuli of each valence is shown in this bar graph. Error bars show the standard error of the mean for each category. $^*p < 0.05$

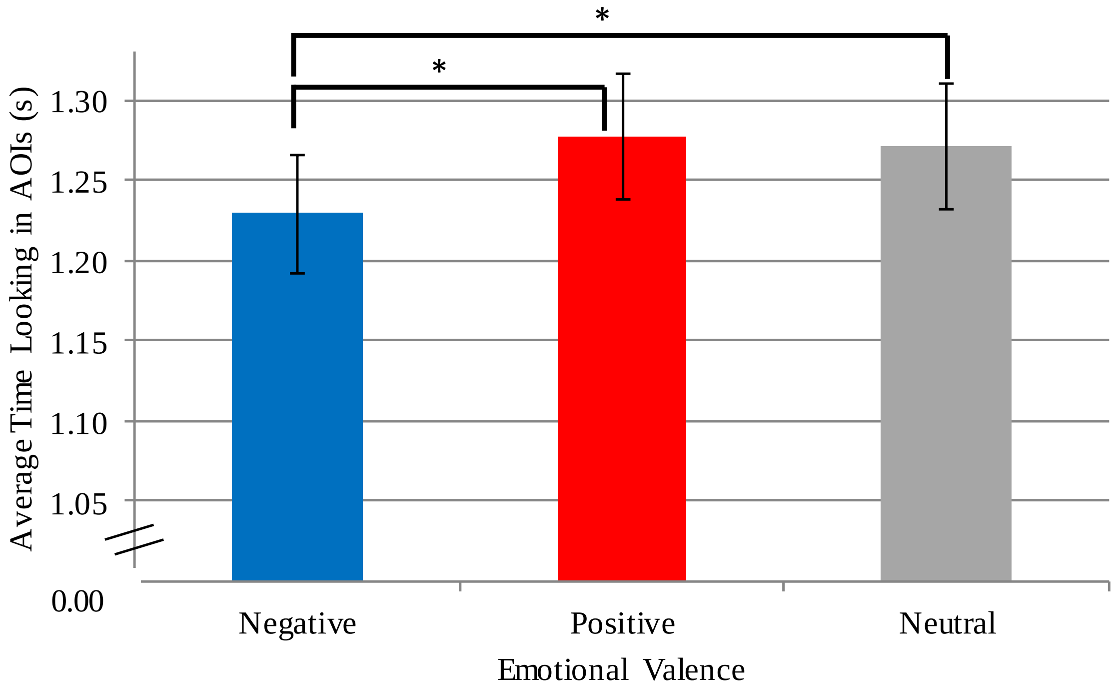

Figure 8. Average Time Looking in Areas of Interest as a Function of Valence. This chart displays the average amount of time, during each 3.00s stimulus presentation, that participants spent fixating within the areas of interest for stimuli in each emotional valence. Error bars depict the standard error of the mean for each category. *$p < 0.05$

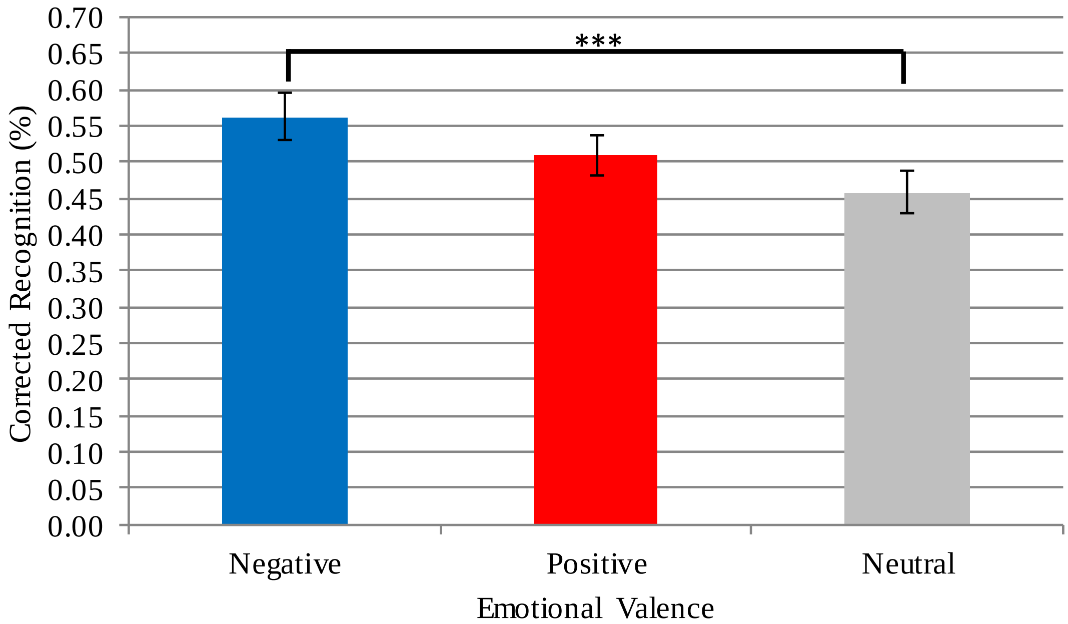

Figure 9. Corrected Proportion of Subsequently Remembered Stimuli as a Function of Valence. This chart presents the average corrected recognition scores for the number of hits, or correctly and confidently remembered stimuli, in each emotional valence. Corrected values were obtained by subtracting the proportion of false alarms from the proportion of hits for each valence. Error bars depict the standard error of the mean for each category. ***$p < 0.001$

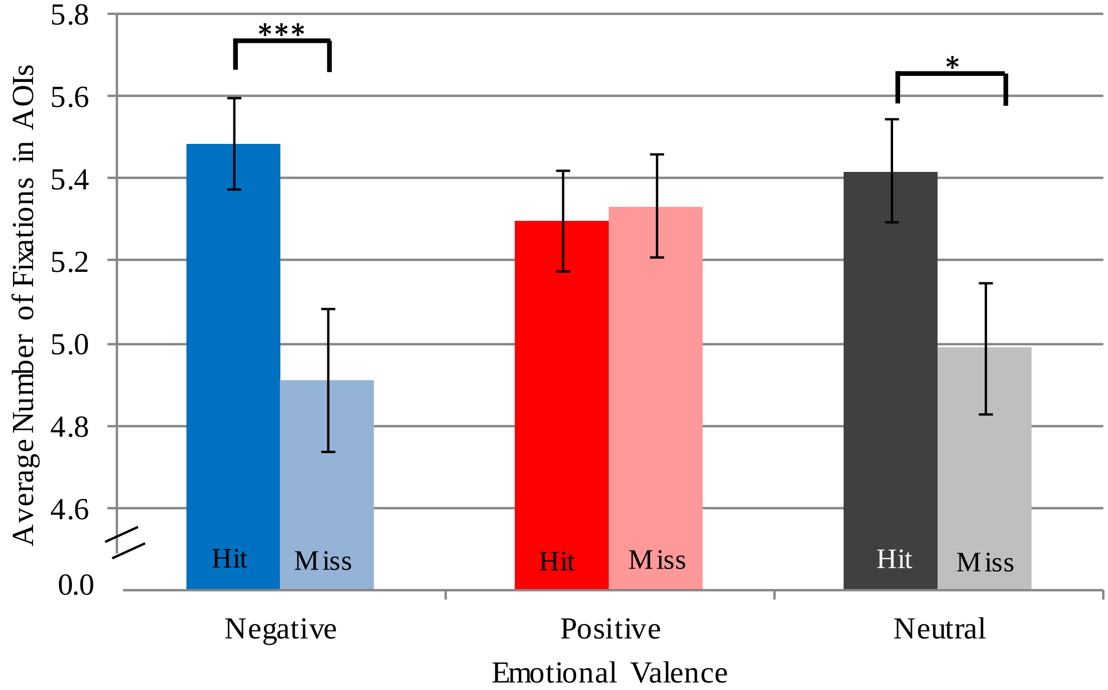

Figure 10. Average Number of Fixations in Areas of Interest as a Function of Valence and Subsequent Memory. This chart depicts the average number of fixations within areas of interest for hits (correctly and confidently remember stimuli) and misses (non-remembered and non-confidently remembered stimuli) in each emotional valence. Error bars show the standard error of the mean for each category. ***$p < 0.001$ *$p < 0.05$

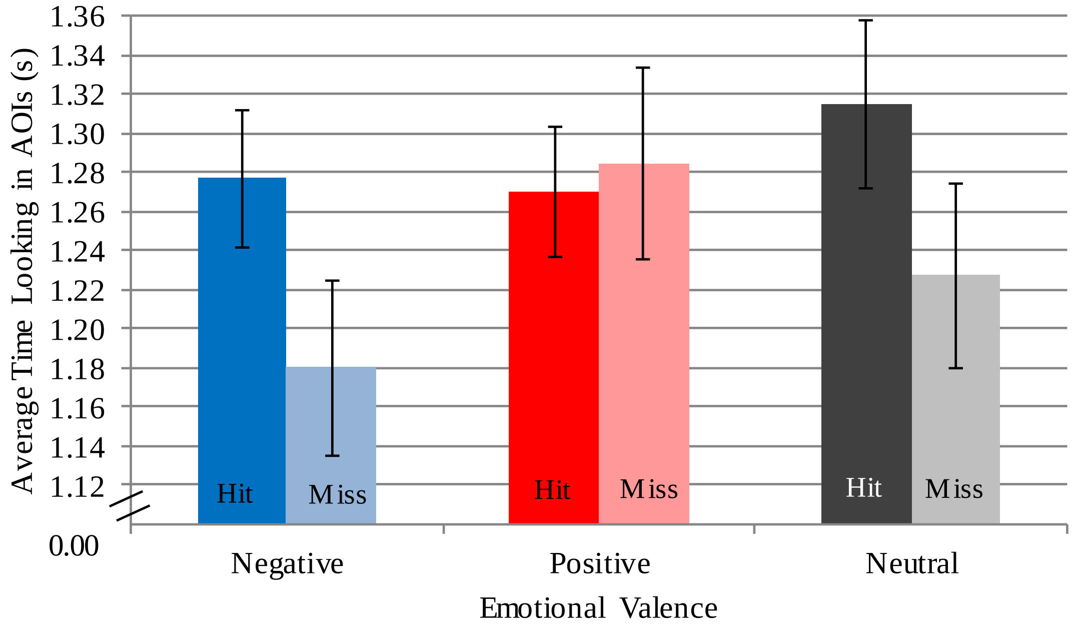

Figure 11. Average Time Looking in Areas of Interest as a Function of Valence and Subsequent Memory. This chart displays the average amount of time, during each 3.00s stimulus presentation, that participants spent fixating within areas of interest for subsequently remembered and non-remembered stimuli in each emotional valence. Error bars show standard error of the mean for each category. Note that statistical analysis of these data indicated a trend towards an interaction between subsequent memory and emotional valence.