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The Effects of Emotion and Action on Binding in Memory

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THE EFFECTS OF EMOTION AND ACTION ON BINDING IN MEMORY

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Abstract

The ability to successfully bind features and objects at different levels of abstraction is important for everyday functioning of memory. The current study examined how actions and emotional arousal influence item recognition and between-item binding across two experiments. According to the Arousal-Biased Competition Theory (ABC; Mather and Sutherland, 2011), binding can be enhanced by emotional arousal, depending upon what is the focus of attention within a scene. In the current study, participants viewed a series of slides, each of which depicted a person performing an action with an object, as well as an object that is not interacted with. All of the actions performed were emotionally neutral. According to ABC, this difference between attended and non-attended items should be enhanced when in the presence of an emotionally arousing stimulus. In the current experiments, emotional arousal was manipulated using sounds presented before slides depicting a person performing an action using an object. In Experiment 1, actions led to enhanced attention to (and better item memory for) manipulated objects relative to objects that were not the focus of attention. Participants also gave higher confidence ratings for recognized interacted objects than recognized non-interacted objects. However, the predicted interaction between emotional arousal and item type was not obtained. The one impact of emotional arousal was that participants responded more conservatively to faces and items associated with a negative sound. In Experiment 2, there was no evidence for enhanced associative memory as a function of either emotion or action, although overall performance was very poor. The implications of these findings for theoretical views of memory are discussed, as well as future directions for research.

Introduction

Events are encoded and stored in the brain not as a movie of the event, but as pieces of information, which are then put together to form cohesive perception of an event (Buckner, 2003; Koutstaal & Cavendish, 2006; Schacter, Norman, & Koutstaal, 1998; Shiffrin, 2003). Different attributes of an event, such as emotion and movement, can impact how this process occurs and determine what is remembered about an event. There are times when accuracy for details of an event and how these details fit together would be critical to know. For example, if you witness a crime, it would be useful to know, not only what the victim, the assailant, and the weapon looked like, but how all of those items related to each other. This type of cohesive, detailed memory relies on *binding* together the aspects of the scene (e.g., Meiser & Bröder, 2002). Often, it is difficult to recall such information precisely because attention may be fixated a particular item that is relevant to the witness, causing other objects in the scene to be poorly encoded (Mather & Sutherland, 2011).

The current study set out to identify whether characteristics of a scene influence binding of objects. First, I discuss how binding of events occurs and how successful binding is inferred in the laboratory. Then, I discuss two facets of a scene that can impact binding: emotion and action. Finally, I explain how these two aspects can work together to enhance binding and discuss a series of studies to test this at both the feature and between-object level.

Evidence for Binding

The earliest empirical and theoretical work on binding focused on how different features of objects were bound together at the time of perception. The feature-integration theory of Treisman and Gelade (1980) argues that features are processed automatically, and simultaneously, early in perception. However, object recognition takes place later, after features that must be bound together are attended serially. If focal attention is inhibited or disrupted, illusory conjunctions can form, causing the perceiver to attribute a feature of an object to a different object (Treisman, 1977). In particular, when there is no overarching constraint to serve as a template for the features, illusory conjunctions can arise because inattention causes improper binding of features into objects (Treisman & Gelade, 1980). Illusory conjunctions are an example of binding-gone-wrong, but demonstrate the importance of attention during object recognition.

Researchers have also been interested in whether binding is present in long-term memory representations. Studies on the topic have attempted to measure binding in a number of ways. For instance, binding is thought to occur to the extent that a test cue (a feature from the encoding context) enhances retrieval of a related detail (e.g., Hollingworth, 2007; Starns & Hicks, 2005, 2008). If one feature cues the retrieval of another, it is thought that the features were associatively bound together. If they were not, then a cue feature that was previously presented with the target feature would be no more effective at enhancing retrieval than a randomly presented cue, or no cue. Similarly, if changing features of an object or a scene at test impairs memory performance (i.e., modifying available cues), this is also thought to provide evidence of binding (e.g., Godden & Baddeley, 1975; Hollingworth, 2007). A well-known example of such research examines the effect of changing the environmental context between encoding and test (e.g., Godden & Baddeley, 1975; Smith, 1979). A third type of evidence is provided by research that examines the relationship between the retrieval of one feature or item and the retrieval of another (e.g., Fisher & Cuervo, 1983; Meiser & Bröder, 2002; Wells & Leippe, 1981). For example, Meiser & Bröder found that, for words recognized at test, memory for the font color and location on a computer screen were highly correlated, which they interpreted as evidence of binding.

One question that has been debated in the literature is whether existing studies provide good evidence that within-object (feature-to-feature) binding occurs in memory. Although the correlational evidence noted above has been argued to be evidence of binding, such correlations can be observed without within-feature binding having occurred. For example, research suggests that features are not bound to each other, but are instead bound to the object they are a part of (Starns & Hicks, 2005; 2008). If features are bound to each other, in addition to the object, mutual cuing should occur such that the reinstatement of a feature would facilitate the retrieval of the associated feature, regardless if the object is present or not. This *mutual cuing hypothesis* is contrasted with the *binding variability hypothesis*. The binding variability hypothesis states that successful retrieval of one feature is positively correlated with successful retrieval of related features, but the correlation is dependent on the varying strength of memory for the object, to which these features are *independently* bound. In other words, while successful retrieval of one feature is correlated with retrieval of another, this is due to the strength of memory for the object and not necessarily the level of binding between features. Starns and Hicks (2005; 2008) found support for the binding variability hypothesis. Participants were cued with a feature of an item (e.g. its location) and were asked to recognize the associated feature (e.g. its color). When the object was not present to serve as a cue for both features, reinstating one feature did not enhance retrieval of the related feature (Starns & Hicks, 2008).

Starns and Hicks' (2008) research also provided an important improvement to existing methods that have been used to examine binding. They noted that many previous studies have the original object available as a cue at test. For example, at test, the studied word may be presented in red ink and the participant needs to determine where on the screen the word was located. They argue that participants are not recalling other features of an object because the feature serving as a cue facilitated retrieval. Instead, they are simply recalling the object and all features associated with it. While Starns and Hicks (2008), among others (Meiser & Bröder, 2002) examined feature-level, or *within-item binding*, the same procedure can be used to examine binding between multiple objects, as well as objects and background, in complex scenes, or *between-item* binding. For example, Martin (2013) showed participants a series of complex scenes that contained a variety of objects (e.g., a living room scene). In Experiment 1, at test, the scene was not presented in its entirety. Instead, participants received no-object cue and object-cued trials. The former provided only a marker on a blurred version of the background to indicate what object should be selected. The latter still included a target marker on a blurred background, but also included three, clearly presented objects in their original locations. Experiment 2 was similar, but utilized an intact background to examine object-context binding. Across experiments, Martin (2013) found evidence for both object-object binding and object-context binding.

In addition to behavioral data, there is evidence for associative binding of features and objects in the neurological literature as well. Uncapher, Otten, and Rugg (2006) observed activity in the intra-parietal sulcus related only to successful encoding of multiple features using a procedure adapted from Starns and Hicks (2005) in which participants encoded words in different colors and locations and were later asked to recall them. These findings lend credence to the hypothesis that features must be bound into a singular representation when an event is first encoded. Similar findings have been found at the object level as well. Hollingworth (2007) manipulated scenes that included a complex background and multiple features (i.e. a living room scene) or a blank screen with objects positioned around the screen. Participants were required to detect the change in the scene or array at test, which consisted of no change, replacement, left-right mirror reflected, or changed position. Across nine experiments, Hollingworth (2007) observed a same-position advantage when context was present and when the target object was in the same position relative to the other objects. If associative binding did not occur between the target object and the surrounding context, these advantageous effects would not have been observed.

Overall, the evidence does seem to suggest, at both at a neurological and a behavioral level, that representations of features are bound together in memory. However, the mechanisms involved in binding are likely to be influenced by where people focus their attention (e.g., Martin, 2013). In the context of dynamic real-world events, such focus is likely to be influenced by a number of factors including actions and emotional arousal. I discuss these factors, and their potential influence on binding, in the following sections.

Impact of Action on Memory

Action is an attentional magnet that can divert resources away from other objects within a scene. Although motion can be preferentially attended to, several studies have shown that the onset of action causes automatic attentional capture to a moving item (Abrams & Christ, 2003; Abrams & Christ, 2006; Hillstrom & Yantis, 1994). For example, in Abrams and Christ (2003), participants were asked to find target letters that were either moving prior to the task, started moving during the task, or remained still. Although motion overall did not provide an advantage for finding target letters, the onset of motion, compared to other types of motion (i.e. deceleration or no motion), resulted in faster identification of the target letter. Other researchers (Franconeri & Simons, 2005) have argued that motion always provides attentional capture, but this finding appears to only hold in highly constrained circumstances, namely when action occurs in a spatial location previously unoccupied by an item (Abrams & Christ, 2006). Abrams and

Christ (2003, 2006) suggested that onset of motion captures attention to a greater extent than motion already taking place because onset of movement of an item tends to be more important than an item already in motion. In the context of events, this suggests that actions might draw our attention towards the component elements involved in the action (the performer and any objects involved). But how will this influence memory for the events?

There is relatively little research on long-term memory for actions. There is some evidence to suggest that visual long-term memory (VLTM) stores “high fidelity” representations of viewed actions (Urgolites & Wood, 2013a). Although actions may be well-remembered, there is some evidence suggesting that this may come at a cost to memory for context, at least in some circumstances. In research by Urgolites and Wood (2013b), participants viewed action-scene pairs and later recalled either the scene or action separately, or together. It was found that participants were able to accurately recall either context or action, but lacked the ability to accurately associate the two. This finding suggests that action might reduce memory binding. However, this is not necessarily the case. The biased competition models of attention (e.g., Beck & Kastner, 2009) that motivate ABC theory predict that salient aspects of an event will be enhanced at the expense of less salient aspects. There was nothing in the Urgolites and Wood (2013b) scenes that would have denoted salience insofar as there was nothing in the scenes that cued the participants that they should have paid attention to contextual details. In this situation, action may have served as an attentional magnet at the expense of surrounding contextual information. Thus, existing work in this area does not rule out that memory binding might be present under the right conditions. Furthermore, these studies have only examined memory for the background. It is not clear whether actions influence memory for objects or the people that perform them, either individually or together as unit. One can hypothesize that actions could serve as a means to integrate the performer, the action, and the associated action into a single representation. In other words, actions might increase memory binding of the constituent elements. It is also possible that actions might draw attention to individual elements (e.g., to the person or the object involved), and subsequently enhancing item memory.

To summarize, action can serve as an attentional magnet, capturing attention via bottom-up processes. Actions themselves are also well-remembered in LTM (e.g., Urgolites & Wood, 2013a). What is less clear is how actions influence memory for items related to the action, or for the associative relationship between the items (binding). In Experiment 1, I examined how actions influence item memory, and in Experiment 2, I examined how actions influence associative binding. Both experiments examined the additional influence of emotional arousal in enhancing observed effects.

Impact of Emotion on Memory

Emotion is an important element of both everyday experiences, as well as more unique situations such eyewitness events. Furthermore, emotion is an important influence on what information is remembered (e.g Kensinger, 2007; 2009). Researchers typically describe emotion as involving two components: valence and arousal (e.g. Mather, 2007). Valence denotes how positive or negative a stimulus is and arousal denotes how physically stimulating a stimulus is. However, most research on the topic of emotion and memory focuses exclusively on negatively emotional arousing stimuli (Mather, 2007), and this focus will similarly be adopted in the proposed studies.

Emotional arousal is often described as an attentional magnet, causing a narrowing effect that draws attention to the emotional item, enhancing memory (Easterbrook, 1959). Research on the impact of negatively emotionally arousing stimuli on memory has found positive, negative, and null effects (e.g., Mather, 2007). It has been argued that emotion may bolster memory because emotional stimuli are considered a higher priority than a neutral stimulus. As such, some research has shown that emotional items are preferentially bound to their context, creating a lack of resources to bind neutral items within the same scene (MacKay & Ahmetzanov, 2005). In contrast, because arousal impairs hippocampal functioning, which aids in memory consolidation and the integration of items, associative binding ability should be impaired as well (Murray & Kensinger, 2013). However, item memory should remain intact because of increased arousal by way of increased amygdala functioning (Anderson & Phelps, 2001; Radley & Morrison, 2005).

There are two theories that attempt to rectify discrepancies within the literature and propose when memory will be enhanced and when it will be impaired by emotional content. In the first, Mather (2007) suggests an object-based framework that focuses on what is interpreted and grouped as an "object" to discern how emotion will affect representations of objects. According to Mather (2007), within-object (feature) binding should be enhanced by arousal at encoding because the arousing nature of the stimuli narrows and focuses attention (Mather & Knight, 2006; Nashiro & Mather, 2011). While features of an item and overall item memory may be enhanced, Mather (2007) predicts that associations between an emotional and a neutral item should either be impaired or the emotion should have no effect. While some research does show this pattern of findings (e.g. Nashiro & Mather, 2011), others have found that between-item binding is enhanced in the presence of emotional arousal, even under divided attention (e.g., Guillet & Arndt, 2009; Maddox, Naveh-Benjamin, Old, & Kilb 2012).

The Arousal-Biased Competition (ABC) theory was put forth by Mather and Sutherland (2011) to explain the contradictory evidence found in the literature; and to provide a better explanatory framework. Critically, Mather and Sutherland (2011) addressed a major issue in how emotional memory is typically studied. In a number of studies noted above, memory was examined in situations where an emotional item was essentially competing with a neutral item for attentional resources. In this case, emotion should detract from between-item binding because of its attentional narrowing properties and enhance within-item binding. But, in other situations, one can expect enhancement of between-object binding. As will be discussed below, the predictions of ABC vary depending on stimuli relevance (i.e., what aspects are the focus of attention at encoding).

ABC Theory. First, ABC expands upon biased-competition models of attention. ABC argues that arousal moderates the strength of representations at the perceptual and encoding level all the way through consolidation and retrieval (Mather & Sutherland, 2011). Enhancement occurs for aspects of a stimulus or scene that are prioritized for either bottom-up (e.g., perceptual salience) or top-down (goal-relevant) reasons. ABC theory of attention assumes that representations compete for visual processing resources, such that the greater the neural activation in response to an object, the greater the decrease in activation for another object within the field of view. In addition, ABC posits that arousal should enhance both bottom-up and top-down priority. Bottom-up processing is the processing of the environment without any prior schematic representation. This is the process that is responsible for automatic shifts in attention to salient items in a scene. For example, a loud noise automatically draws attention to the source of the noise. Similarly, a red letter in an array of black letters stands out to a viewer because of its attention-grabbing nature, generating the “pop-out” effect. The latter, top-down, is an enhancement to stimuli that stems from internal goals and expectations about the world. For example, when someone is looking for a friend in a crowd they have the intention of finding that person. Both of these processes work together to orient attention.

ABC posits that as long as the arousing information is not in competition with the stimuli observed, then it should not negatively impact the processing and later retrieval of neutral information that is present at the time of encoding. More generally, ABC says that objects that are the focus of attention should receive greater activation, while objects that are not the focus of attention will receive less activation. In order to prevent competition, an emotional stimulus can be part of the to-be remembered information, or, it can be in a separate modality. For example, Zeelenberg and Bocanegra (2010) used multiple modalities to determine if emotional arousing stimuli interfere with neutral stimuli. Participants either heard or read an emotional or neutral word. After this word, participants always read a neutral word. Enhancement for memory for the always-read neutral word was found only when it was paired with an emotional auditory word. Auditory neutral words had no effect and visually presented emotional words impaired memory for the visually presented neutral word (caused by same modality interference). In this situation, associative binding between the emotional auditory stimulus and the visual word had occurred to create a singular representation, creating an enhancement effect because the auditory stimulus did not interfere with the visual stimulus.

The ABC Theory put forth by Mather and Sutherland (2011) suggests that what is bound at perception and encoding, and subsequently retrieved, depends on what is important and salient in a scene. This importance, whether signaled by top-down or bottom-up influences, is moderated by arousal, which enhances the differences between salient and non-salient information. In this manner, emotional arousal can, depending on the conditions, potentially enhance item memory or associative binding depending on what type of information is of central importance. As mentioned previously, one type of potential influence of salience in complex events involves action.

The Current Study

The current study examined the influence of action and emotional arousal on item memory and associative binding. As described later in greater detail, the stimuli consisted of two slides (a pair) depicting an actor, an action, an interacted object, and a non-interacted object. In the first experiment, participants studied sets of pairs of an actor performing a neutral action. The scene included an object that was used by the actor, and an object that was not. At the onset of the slides, participants heard either a neutral or negative sound (Ponzio & Mather, 2011). After a 5-minute delay filled with a Sudoku, participants were given a recognition test. Participants saw a sequential presentation of a mix of target items, which were either an object in the scene, the actor, or the lures of the objects and actors. Participants were tested on each object type (or its lure) for each scene. Participants then made an old/new recognition judgment for each item presented, as well as a confidence judgment. It was predicted that actions would enhance item memory for the elements of scenes related to the action (interacted objects) relative to non-interacted objects. Consistent with ABC theory (Mather & Sutherland, 2011), it was predicted that emotionally arousing sounds would enhance this difference, enhancing memory for "central" elements of the scene and reducing memory for the "peripheral" aspect.

Experiment 2 was almost identical, except that participants received an associative recognition test. In this experiment, one of the objects was used as a cue for the actor and was presented clearly, with the remainder of the scene blurred. Although I discuss the hypotheses in more detail in the introduction to the second experiment, it was expected that actions would enhance memory binding, with emotional arousal increasing these effects.

Experiment 1: Methods

Participants

A power analysis for Experiment 1 was computed using G*power (Faul, Erdfelder, Buchner, & Lang, 2009). The analysis suggested that the amount of participants need to achieve 80% power was 138. This analysis assumed: a 2 (sound type) x 4 (target type) within-subjects ANOVA an *ES f* of 0.10 (small effect size *f*); a type 1 error rate of 0.05; and an estimated 0.50 correlation between measures. Participants were students taking psychology courses at Louisiana State University and received course credit for their participation. A total of 130 students participated.

Experimental Design

This experiment utilized a 2 (sound type: emotional or neutral) x 4 (target type: actor, interacted object, non-interacted object, lure) within-subjects ANOVA. Sounds were either emotional or neutral. That is, the emotional content of the scene came from the nature of the sounds and not the actions or objects. The dependent variable was item memory, as assessed using proportion of accuracy responses and signal detection theory (SDT) measures d' and C.

Stimuli

Study phase slides. A series of 36 slide pairs were used for the current study. Each pair consisted of: A start scene in which an actor is reaching for an object and an action scene in which they are performing an action (see Figure 1 for an example).

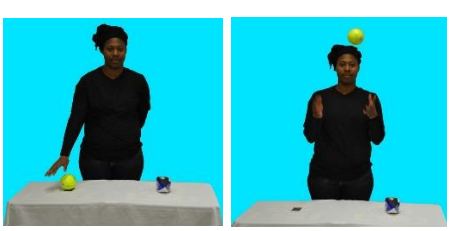

Figure 1. Example of a study pair.

Each pair contained two objects, one that was interacted with and one that was not. These objects were similar in nature, such that each action can be performed with either item in the scene (across the experiment, each was performed with an action equally often). For example, in Figure 1, both the softball and the football can be tossed into the air. In addition, the background was different for each scene to later serve as a cue during testing. Since the general context was identical for each pair, it was necessary to give an additional cue to discern what “event” participants were supposed to recall (Martin, 2013). In the current study, the relevant stimuli are the acted-upon objects.

Test phase. Each participant was tested on 108 total items, 54 old, 54 new. These were evenly divided across the item times; 36 faces, 36 interacted objects, and 36 non-interacted objects. Both targets and lures were presented in a randomized order. Lures were objects similar in appearance to items that the participants actually saw, but differed in terms of a critical feature. For example, if a participant saw a red stapler, the lure was a blue stapler. The face lures consisted of faces normed on similarity for an actually presented face (See Figure 2 for an example). These items were equally divided among emotional and neutral action scenes. Participants made an item judgment and a confidence judgment for each pair. Confidence was rated on a 1-7 Likert-type scale. A value of 1 meant “not at all confident,” while a value of 7 meant “extremely confident.”

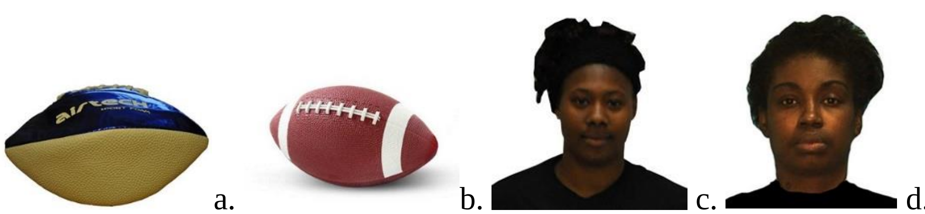

Figure 2. An example of test items and their lures in Experiment 1. From left to right, old object (a), lure object (b), old face (c), and lure face (d).

Sounds. Participants heard negative or neutral sounds before viewing the slide pairs. These sounds were presented just prior to study slide onset and lasted for approximately 5s. The sounds are from the International Affective Digital Sounds (IADS) database. They are normed for valence and arousal on 1-7 scales, corresponding to increasing level of intensity for each facet. The negative sounds used are approximately a "5" on the rating scales. The neutral sounds are approximately a "3."

Procedure

The procedure was divided into a study phase and a testing phase.

Study phase. Participants were told that they would see a series of slide pairs and that they should attempt to remember the scene in its entirety because they will be tested on the information in the pairs later. Each pair was preceded by a fixation cross, which was presented for 1 second. Each scene of the pair appeared sequentially and stayed on screen for 500ms, totaling 1 second per pair. In addition to viewing the 36 slide pairs, each slide pair was associated with either a neutral or a negative sound that played for 5s prior to the onset of the slides. There was an ISI of 3s between each slide set. After the study phase was completed, instructions appeared on the screen to wait for the experimenter. After all participants were finished, they were given the instructions for the filler task.

Testing phase. After a 5-minute delay filled with a Sudoku puzzle, participants were presented with a series of test items that were a mix of correct targets and lures. Participants were tested on all facets of a scene. That is, participants were test on the actor face, the non-interacted object, and the interacted object (or their lure counterparts). Participants were tested on half lures and half old items, divided evenly by emotion type. Participants made a yes/no recognition judgment. Participants also made confidence judgments on a 1-7 scale after they made their decision. After the testing phase was completed, they were verbally debriefed.

Variability in number of item types. Due to a programming error, participants early in data collection (n = 66) encountered different numbers of items of each type (e.g., the number of items seen with an emotionally arousing sound versus a neutral sound). These differences were generally small, and were accommodated in the final analysis by computing proportion of responses per item type. Later participants completed a revised program that did not have these issues.

Experiment 1: Results and Discussion

Analysis and Results

Although there were three item types – faces, interacted objects, and non-interacted objects – the critical hypotheses focused on the difference between the latter two item types. For that reason, memory for faces was examined separately (described below). Signal Detection Theory (SDT) measures of recognition memory include discrimination (d') and response bias (C). The key predictions for this study concerned the impact of the key variable on d'. Although there were no *a priori* predictions of these variables on response bias, I report this measure below for the sake of completeness (See Table 1). Item memory was assessed using

Table 1: Mean d' and C for items divided by valence. Neg=Negative, Neu=Neutral.

	NegIO	NegNIO	NegFace	NeuIO	NeuNIO	NeuFace
d'	0.313 [0.2,0.43]	0.25 [0.14,0.40]	0.42 [-0.08,0.21]	0.34 [0.23,0.50]	0.17 [0.07,0.28]	0.36 [-0.08,0.21]
C	-0.10 [-0.17,0.03]	0.43 [0.34,0.52]	0.19 [0.12,0.28]	-0.17 [-0.22,-0.13]	0.42 [0.33,0.50]	-0.01 [0.12,0.28]

signal detection (SDT) measures (d' and C), and analyzed using 2 (sound type: negative/neutral) x 2 (Item type: interacted/non-interacted) within-subjects ANOVAs. For d', a measure of sensitivity, only a main effect of item type was found, F(1,129)=4.26, $p<0.05$, η_p^2 =0.032. Supporting one of my hypotheses, interacted objects (M=0.33) were remembered better than non-interacted objects (M=0.21). The main effect of valence and the interaction was not significant. For C, a measure of response bias, a main effect of item type was found, F(1,129)=183.168, $p<0.01$, η_p^2 =0.60. Participants responded more liberally to interacted objects (M=-0.14) than to non-interacted objects (M=0.24). There was also a main effect of valence, F(1,129)=4.00, $p<0.05$, η_p^2 =0.03. Participants responded more conservatively to items associated with a negative sound (M=0.17), than to items associated with a neutral sound

(M=0.12). The other hypothesis, based on ABC Theory, was not supported. Despite this, valence did influence behavior, as noted in the response bias measures.

While not the focus of Experiment 1, exploratory analyses on d' and C for faces were performed. Again, participant memory was not enhanced under emotional arousal, $t(129)=0.855$, $p>0.30$. However, paralleling the object data, participants responded more conservatively to faces paired with a negative sound (M=0.20) than faces paired with a neutral sound (M=-0.01), $t(129)=4.78$, $p>0.01$.

I also assessed confidence in responses to Hits and FA (See Table 2 for means). Confidence was rated on a 1-7 scale; 1 meaning "not at all confident," and 7 meaning "extremely confident." These data were analyzed using 2 (Item type: interacted/non-interacted) x 2 (sound type: negative/neutral) within-subjects ANOVAs. Examining confidence with respect to hits, only the main effect of item type was statistically significant, $F(1,122)= 42.34$, $p<0.01$, $\eta_p^2 =0.26$. Participants were more confident when they correctly identified an interacted object (M=5.84) than a non-interacted object (M=5.32). Participants were significantly more confident in responses to lures, $F(1,113)=18.193$, $p<0.01$, $\eta_p^2 =0.14$. Participants were more confident in their false alarms to interacted object lures (M=5.6) than in their false alarms to non-interacted object lures (M=5.16).

Table 2: Mean hits and FAs for items. IO= interacted objects, NIO= non-interacted objects.

	NegIO	NegNIO	NegFace	NeuIO	NeuNIO	NeuFace
Hits	0.59 (0.02)	0.37 (0.02)	0.5 (0.02)	0.62 (0.02)	0.37 (0.02)	0.5 (0.02)
FA	0.48 (0.02)	0.3 (0.02)	0.36 (0.02)	0.5 (0.02)	0.32 (0.02)	0.38 (0.02)

Exploratory analyses on confidence ratings for face hits and FAs were also conducted. Unlike the object confidence ratings, there were no significant differences between confidence ratings for negative or neutral face hits; nor were there significant differences between confidence ratings for negative or neutral face FAs, both *ps*>0.90.

Discussion

It was predicted that objects involved in the action, regardless of emotion, should be better remembered than the non-interacted object. The results were consistent with this prediction, although the effect size was small. Participants' attention appears to have been drawn by the action to the object. Participants also responded more liberally to interacted objects than non-interacted objects. The pattern for confidence paralleled the pattern for response bias. Participants were more confident in their responses to Hits and FAs for interacted objects than for their responses to non-interacted objects.

As predicted by ABC, the advantage of interacted over non-interacted objects should have been greater when the actions were coupled with a negatively emotionally arousing sound than when they were with a neutral sound. In this case, a sound type x object type interaction would be expected. However, this prediction was not supported, as there was no evidence of interaction regardless of the dependent measure. Furthermore, there was no overall effect of emotional arousal on discrimination, although it did appear to influence response bias. Participants who heard a negative sound preceding a scene responded more conservatively not only to the objects in that scene, but also responded more conservatively to the faces as well. Finally, overall memory performance was low, for which the issues will be addressed in the general discussion. The goal of this experiment was to evaluate the effects of action and emotion on memory for individual components (i.e., item memory), not the relationships between components (i.e., object binding). This latter topic was the focus of Experiment 2.

Experiment 2

Experiment 2 examines the extent to which associative binding is a relatively automatic outcome of observing actions. An answer to this question influences the predictions of ABC theory about enhancement due to emotional arousal. Specifically, ABC predicts that emotional arousal should enhance binding when associative information is salient. If action leads people to integrate the elements involved in the action (i.e., the actor, the interacted object), then binding should be observed. Additionally, ABC theory predicts that emotional arousal should reduce associations to unimportant elements in a scene (i.e., the non-interacted object). In the following experiment, participants studied the same scenes as in Experiment 1, but were tested on the faces of the actors in the presence or absence of test cues. Specifically, participants saw a test scene with either the interacted object, the non-interacted object or no additional cue visible.

Experiment 2: Methods

Participants

A power analysis for Experiment 2 was computed using G*power (Faul et al., 2009). The analysis suggested that the amount of participants need to achieve 80% power was 138. This analysis assumed: a 2 (Sound type) x 3 (Cue type) within-subjects ANOVA; an *ES f* of 0.10 (small effect size *f*); and a type 1 error rate of 0.05. Participants were students taking psychology courses at Louisiana State University and received course credit for their participation. A total of 143 students participated.

Experimental Design

A 2 (Sound type) x 3 (Cue type) within-subjects ANOVA was used. Cue type consisted of three types: Interacted object, non-interacted object and No cue. Sound type, emotional and neutral, was the same as Experiment 1.The dependent variable was recognition accuracy for the Actor, measured using SDT measures (d' and C).

Stimuli

Study phase. Stimuli identical to the study phase in Experiment 1.

Test phase. Participants saw a scene similar to one presented at study (see Figure 3 for an example), except that everything besides the cue was blurred and the face of the actor was covered by a green square. Below this scene was a single face (either a target or a lure).

a. b.

Figure 3. An example of a test scene from Experiment 2. Participants saw scenes similar to (a). Beneath was a face, similar to (b). Participants judged if the face matched the scene.

Procedure

Experiment 2 had the same study phase as Experiment 1.

The test phase in Experiment 2 differed from Experiment 1 in that only memory for the actor was assessed. The target person was indicated by a green square (See Fig. 3 for an example of a test scene). In addition, there were three types of altered test scenes that varied with respect to the type of cue that was presented. The no cue version was simply a blurred background. In the other object cue conditions, either the interacted or non-interacted object was clearly seen against the blurred background. Contrasts between the object cue conditions and the no cue condition will allow for an assessment of binding between the actor's face and the cue type. As in Experiment 1, participants will make a yes/no recognition judgment of the face presented. Participants were instructed to select Old if the face was presented with the scene, or new if it was not. After each recognition judgment, participants were asked to determine how confident they are on a 1-7 scale.

Variability in number of cue types. Due to a programming error, participants early in data collection (n = 36) encountered different numbers of cues of each type. The number of cues seen with were not evenly congruent with the studied scene. That is, at test, some participants did not see an equal amount interacted object cues and non-interacted object cues. These differences were generally small, and were accommodated in the final analysis by computing proportion of responses per cue type. Later participants completed a revised program that did not have these issues.

Experiment 2: Results and Discussion

Results and Analysis

Associative binding was assessed using signal detection (SDT) measures (d' and C), and analyzed using 2 (Sound type) x 3 (Cue type) within-subjects ANOVAs (See Table 3 for means).

Table 3: Mean d' and C for items divided by valence. Neg=Negative, Neu=Neutral.

	NegIO	NegNIO	NegNoCue	NeuIO	NeuNIO	NeuNoCue
d'	0.23 [0.13,0.34]	0.27 [0.18,0.37]	0.28 [0.17,0.4]	0.22 [0.12,0.32]	0.2 [0.1,0.29]	0.27 [0.16,0.39]
C	-0.08 [-0.13,-0.04]	0.03 [-0.02,0.07]	0.04 [-0.03,0.1]	-0.07 [-0.12,-0.02]	0.06 [0.01,0.12]	0.04 [-0.02,0.12]

Follow-up t-tests used a Bonferroni correction. As in Experiment 1, there were no *a priori* predictions for response bias (C), but these data were also reported for the sake of completeness.

Recognition discrimination (d') in this experiment did not vary as a function of cue type, valence type, or the interaction (all ps > .40). However, there was a main effect of cue type with respect to response bias, $F(2,141)=13.49$, $p<0.01$, $\eta^2=0.16$. Follow-up t-tests revealed more liberal responses for faces cued with the interacted object (M=-0.22), than for faces cued with either the non-interacted object (M=0.1; $t(142)=-6.6$, $p<0.01$) or no cue (M=0.07 $t(142)=-7.13$, $p<0.01$).

As in Experiment 1, we also examined the confidence ratings for hits and FAs (See Table 4 for means).

Table 4: Mean hits and FAs by cue type.

	NegIO	NegNIO	NegNoCue	NeuIO	NeuNIO	NeuNoCue
Hits	0.66 (0.02)	0.52 (0.03)	0.51 (0.02)	0.66 (0.03)	0.47 (0.03)	0.51 (0.02)
FA	0.6 (0.03)	0.43 (0.03)	0.43 (0.02)	0.56 (0.03)	0.39 (0.03)	0.43 (0.02)

A 2 (Valence) x 3 (Cue type) within-subjects ANOVA assessed participants' confidence ratings for both measures. There was a main effect of cue type, $F(2,74)=8.35$, $p<0.01$, $\eta^2=0.18$. Follow-up planned comparisons revealed that participants were more confident in their responses to Hits when the face was paired with an interacted object cue (M=5.05), than when the face was paired with either a non-interacted object (M=4.63) or no cue (M=4.6), $t(132)=4.52$, $p<0.01$; $t(141)=6.34$, $p<0.01$. Confidence responses to false alarms revealed a similar pattern, with only a main effect of cue type, $F(2,57)=13.77$, $p<0.01$, $\eta^2=0.33$. Follow up t-tests revealed that participants were more confident in their FA responses when the lure face was paired with an interacted-object cue (M=4.90) than when a lure face was paired with either a non-interacted object cue (M=4.31) or no cue (4.43), $t(128)=5.51$, $p<0.01$; $t(135)=5.93$, $p<0.01$.

Experiment 2: Discussion

The current study examined binding between the actor performing an action and the objects present in a scene. Based on previous research (Martin, 2013), it was expected that binding would be observed in terms of improved discrimination in the interacted object cue condition relative to the no cue condition. There was no evidence of binding, as performance was uniformly very low across the conditions. The low levels of performance in the task may have been due to high similarity between the study items, between the old and lure items, or both. This issue will be discussed in the general discussion. Additionally, ABC theory predicts that binding should be enhanced by emotional arousal when it is a focus at encoding. There was no evidence of an interaction of item type with emotional arousal, and as in Experiment 1, there was no overall effect of emotional arousal on discrimination. However, it is possible that the lack of a significant effect may be due to the very low d' values.

While memory was not impacted by cue type or valence, cue type impacted response bias. Participants responded more liberally to faces that were cued by an interacted object, than faces cued by a non-interacted object or no cue. This suggests that participants were not ignoring the cue and were able to use it, but the interacted object was not useful enough to effectively cue memory. In other words, participants may have not had a good representation for the face in memory such that, while the target interacted object cues were familiar, they were not able to cue face memory to accurately discriminate old faces from lure faces. However, the familiarity of the interacted objects increased their willingness to call the test face old, regardless of its actual status. Again, the pattern for confidence ratings paralleled the response bias data. Participants were more confident in both their hits and FAs when they rated interacted objects (and lures) than when they rated non-interacted objects (and lures).

General Discussion

Different factors may determine how we remember individual aspects of events and the relationship between these components. In this research, the primary prediction was that emotion and action would jointly affect what was remembered from a scene. Specifically, these experiments examined whether action and emotion preferentially directed attention to relevant stimuli, and how this influenced item and associative memory. One general prediction was that action would capture and focus attention, ultimately creating a stronger representation of the object and person associated with that action in memory. In addition, ABC theory (Mather & Sutherland, 2011) predicts enhancement for both item memory and associative memory, provided that the emotional arousal in place is not in competition with the to-be encoded stimuli. The design of the current studies ensured that emotionally arousing information did not come from the same modality, which eliminated the potential for competition with the visually presented to-be remembered stimuli.

In Experiment 1, actions did serve to enhance memory for objects that were integral to the action, which supported one hypothesis. Participants were also more confident in their responses to old items when these items had been interacted with than when they had not. However, there was also an effect on response criteria, as participants responded more liberally to interacted objects, regardless if the object had been previously seen. This translated in to higher confidence ratings for FAs for the interacted object lures as well. This may have occurred because the action made objects similar to the target object more familiar, leading to a liberal response bias. However, a clear interpretation of this shift in bias is made difficult by the fact that differences were also found in d’. Finally, although participants were able to discriminate old interacted objects from lure interacted objects better than old and lure non-interacted objects, this enhancement may have been larger if the studied objects were less similar from their lures and other objects. To wit, the scenes that participants saw involved 36 people from, roughly, the same demographic; and 72 hand-held items. Additionally, despite the change in background, all of the scenes took place in a similar setting. Interference from previous scenes may have started to build-up, effectively reducing the fidelity of memories of faces and objects.

Also in Experiment 1, it was predicted that the advantage of interacted over non-interacted objects would be greater when the actions were preceded by a negative, emotionally arousing sound. This prediction, which stemmed from ABC Theory, was not supported. Although the predicted interaction was not obtained, there was a main effect of emotional arousal on response bias. Participants were more conservative in their responses to items associated with a negative sound. Because there were no overt cues on the test to signal whether an item had been studied with an emotional versus a neutral sound, this suggests that participants may have remembered associated information about the item even though emotional arousal did not influence memory for the item itself. In addition, the findings are somewhat unusual as it is not uncommon to see emotional arousal lead to liberal criterion shifts in recognition (e.g., Dougal & Rotello, 2007). However, conclusions about ABC theory and the nature of the response criteria shift may be a function of the very low levels of discrimination that were observed.

While Experiment 1 only examined item memory, Experiment 2 examined associative memory. It was predicted that binding would be observed between the actor and the interacted object, resulting in better face memory when a face was cued with an interacted object. Again, in line with ABC Theory, this effect should be enhanced under negative emotional arousal. There was no evidence of enhanced binding due to action nor was there an effect of emotional arousal on discrimination in this experiment. However, discrimination was extremely low for all conditions. Actions did influence response bias and confidence ratings. Participants responded more liberally to faces that were cued with an interacted object than faces that were cued with a non-interacted object, or did not have a cue. Participants were also more confident in their responses to faces that were cued with an interacted object (hits and FAs). Thus, the familiarity of the interacted object cue did appear to influence decision criteria, but was likely not strong enough to help recover a clear memory for the face. Thus, the lack of a binding effect here is likely due to poor memory for the constituent components (faces and objects).

The poor discrimination observed in Experiments 1 and 2 are likely due to choice of stimuli, as both experiments utilized the same faces and objects. The difficulty participants had in making these discriminations are likely to due to the similarity of faces and objects across the different scenes, the similarity of target and lure items at test, or both. Future efforts will focus on decreasing this similarity. In addition, one option is to use shorter study-test blocks in the future. Not only would this help reduce the build-up of proactive interference, but would also shorten the time between study and test, which may increase performance. Finally, actions may not automatically draw attention to both the actor and the item, but perhaps the item only. If this is the case, then a top-down goal to integrate the actor and the item may be necessary to observe binding.

This study is a first attempt to explore the effects of action and emotional arousal on item and associative memory. Although there was evidence that actions draw attention to objects (Exp. 1), the effects on item memory were small. Answers to questions about the interactive effect of emotional arousal, and the effects of both variables on binding, are less clear due to the poor levels of discrimination observed. Tests of these questions will await future research that strengthens the materials and design used in the current experiments. Additional tools might also be useful in exploring this topic, such as utilizing oculomotor measures including eye tracking and pupillometry to disentangle the effects that emotion and action exert on attentional mechanisms. In addition, research that focuses on building a deeper theoretical understanding of the cross-modal memorial effects of auditory stimuli will also be critical. Future work should explore how sounds interact with visual stimuli when simultaneously presented and determine how the sound is ultimately bound to the scene. Altogether, the goal of increasing our understanding of how scene components are represented in memory, and how emotional arousal can influence these representations is an important one, with both theoretical and potentially applied implications.

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Vita

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