Published in final edited form as:
Cogn Emot. 2011 February ; 25(2): 229–243. doi:10.1080/02699931.2010.483123.

Emotion's Influence on Memory for Spatial and Temporal Context

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Abstract

Individuals report remembering emotional items vividly. It is debated whether this report reflects enhanced memory accuracy or a bias to believe emotional memories are vivid. We hypothesized emotion would enhance memory accuracy, improving memory for contextual details. The hallmark of episodic memory is that items are remembered in a spatial and temporal context, so we examined whether an item's valence (positive, negative) or arousal (high, low) would influence its ability to be remembered with those contextual details. Across two experiments, high-arousal items were remembered with spatial and temporal context more often than low-arousal items. Item valence did not influence memory for those details, although positive high-arousal items were recognized or recalled more often than negative items. These data suggest that emotion does not just bias participants to believe they have a vivid memory; rather, the arousal elicited by an event can benefit memory for some types of contextual details.

Keywords

affect; arousal; recognition; space; time; valence

Over the past several decades, much attention has been focused on emotion and its effect on memory. Our daily lives are laced with emotion, and so it is important to understand what role emotion plays in shaping our memory. It has been argued that the triggering of an emotional response may be an important signal that information should be encoded and retained, with research revealing that memory is enhanced for emotional information (e.g. Hamann et al., 1999; Cahill and McGaugh, 1998, Kensinger & Corkin, 2003).

Although it is evident that emotion can enhance the ability to remember that an event has occurred, what is less well understood is whether emotion enhances memory for event details. Memory for an item often involves more than simply remembering its occurrence, and in fact the hallmark of an episodic memory is that it includes not only the 'what' but also the 'where' and the 'when' of an experience (e.g., Clayton & Dickinson, 1998; Conway, 1992; Tulving, 1983). Both of these types of information can broadly be conceived of as "source" attributes, referring to the context in which information is presented (Johnson & Raye, 1981).

It has been debated how emotion might influence memory for these contextual characteristics. Some studies have found that source memory is enhanced for emotional items (D'Argembeau & van der Linden, 2004; Doerksen & Shimamura, 2001; Kensinger & Schacter, 2006b; MacKay & Ahmetzanov, 2005; Mather & Nesmith, 2008). However, other

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studies either have found either no effect of emotion on source attribution (Kensinger & Schacter, 2006a; Davidson, McFarland, & Glisky, 2006; Dougal, Phelps, & Davachi, 2007) or have revealed a detrimental effect of emotion (Cook et al., 2007; Jurica & Shimamura, 1999).

At first blush, this inconsistency is surprising given the seeming similarity in methods used across studies. However, most of this prior research has not paid careful attention to two factors that are likely to influence the effects of emotion on memory for detail: interactions between item valence (whether positive or negative) and item arousal (whether exciting or calming), and the type of contextual detail remembered. It often has been argued that arousal is the key dimension contributing to emotion's effects on source attribution (Bradley, Greenwald, Petry & Lang, 1992; Kensinger & Corkin, 2003; MacKay et al., 2004; Mather & Nesmith, 2008); however, there also may be instances when valence plays a role as well (Cook et al., 2007; D'Argembeau & Van der Linden, 2005; Kensinger, Garoff-Eaton, & Schacter, 2007a; Kensinger, O'Brien et al., 2007). Yet the vast majority of studies examining emotion's effects on source memory either have collapsed positive and negative information together into a single "emotional" category or have focused exclusively on negative information. Importantly, to our knowledge, no study of source memory has fully crossed the valence and arousal dimensions. Although intuitively it may seem to be sufficient to control for arousal level and to examine effects of valence, or vice-versa, doing only this prevents us from understanding whether item valence and arousal interact to influence memory for detail. For example, if the effect of valence on memory were more pronounced for arousing items than for nonarousing ones (or if effects of arousal were more pronounced for negative items than for positive ones), then ignoring the simultaneous influences of valence and arousal could contribute to the difficulties reconciling the extant data (and see Kensinger, 2008 for evidence that the effects of valence on memory are not always equivalent at high and low levels of arousal).

A second factor that must be considered is the type of detail being remembered. Source memory assessments have asked participants to report a variety of details, ranging from the color of font in which a word was written (D'Argembeau & van der Linden, 2004; Doerksen & Shimamura, 2001; MacKay et al., 2004), to the spatial location of an item (D'Argembeau & van der Linden, 2004; MacKay & Ahmetzanov, 2005), to the temporal context of an item (D'Argembeau & Van der Linden, 2005), to the modality in which the item was presented (Cook et al., 2007; Kensinger & Schacter, 2006a). Memory for these different attributes is supported by different encoding processes (Uncapher, Otten, & Rugg, 2006), and it is possible that emotion does not have an equivalent influence on all of those processes. It is well known that emotion does not have a ubiquitous influence on memory, and that instead the effects of emotion on memory may be selective (see reviews by Levine & Edelstein, 2009; Reisberg & Heuer, 2004). The extant data make it difficult to draw conclusions about what sorts of details may be remembered well for emotional stimuli, however, because the studies not only assessed different types of details but also used different types of stimuli (e.g., pictures versus words) and different methodologies (e.g., testing after different delay intervals or with different types of retrieval tasks).

The current experiments concurrently examine the effects of emotion on memory for spatial location and temporal order. In two experiments, participants studied neutral stimuli and four different types of emotional stimuli: positive high arousal, positive low arousal, negative high arousal, and negative low arousal. In Experiment 1, the stimuli were complex colored photographs presented one at a time in different screen locations and in different lists. Participants were asked to perform a recognition memory task and to remember in which spatial location and in which list the picture was presented. In Experiment 2, the stimuli were images of objects placed within realistic scenes (e.g., a snake in a forest). Sets of three objects were incorporated into each scene one at a time, and participants were later asked to recall which objects had been incorporated into each scene, the location of each object within the scene, and the temporal order in which each object had been incorporated into the scene.

These methods allowed us to adjudicate among four alternate hypotheses regarding the effects of emotion on memory for source information. The first alternative is that emotion may have no enhancing effect on memory for source information; according to some accounts, emotion biases a person to believe that they remember information with vivid detail, but it may have no impact on the likelihood that details are accurately remembered (see Dougal & Rotello, 2007; Neisser & Harsch, 1992; Sharot et al., 2004 for discussion). This framework predicts that spatial and temporal context would be no better remembered for emotional items than for neutral items. By contrast, the second, third, and fourth alternatives all predict that emotion will have a beneficial impact on memory for detail, but they differ in regard to the qualities of the affective response that will elicit that effect on memory. The second alternative is that emotion may have an impact on memory for detail, with arousal being the dominant factor and with valence not having an additional influence. Many theories regarding emotion’s effects on memory have proposed that it is the arousal elicited by the information that causes it to be attended to and consolidated (e.g., McGaugh, 2000), and that it is arousal which allows contextual elements to be bound together into a memory representation (e.g., MacKay et al., 2004; Mather, 2007). By these accounts, memory for all high-arousal information should be remembered with enhanced source information when compared to low-arousal information. The third alternative is that valence may need to be considered in order to understand how emotion impacts source memory. In a few prior studies, contextual memory has not been enhanced equally for positive and negative stimuli, even when those stimuli are matched in arousal (see Kensinger, 2009; Levine & Edelstein, 2009). In a few instances, negative valence has led to an increase in contextual memory but positive valence has not (e.g., Kensinger, O’Brien et al., 2007), although there may be other illustrations in which there is a memory advantage for positive information (Levine & Edelstein, 2009). Although the directionality of the effect of valence is difficult to hypothesize based on the existing data, these findings suggest that arousal levels may not be sufficient to explain the effects of emotion on memory for context. Valence may either act independent of the effects of arousal or may interact with the effects of arousal. The fourth alternative is that the effects of valence and arousal on memory may depend on the type of contextual detail being assessed. Not all details of an emotional experience are remembered equally well (see Mather, 2007; Kensinger, 2009 for recent reviews), and memory for different types of contextual details can be supported by different encoding processes (Uncapher, Otten, & Rugg, 2006). There is, therefore, reason to anticipate that the effects of emotion may not be equivalent across all types of contextual details; the dimensions of an emotional experience (valence vs. arousal) that influence memory for spatial location may differ from those that influence memory for temporal order. The present study examined which of these alternative hypotheses seems most viable in explaining how emotion affects memory for the episodic contexts of spatial location and temporal order.

EXPERIMENT 1

Method

Participants—Participants were 24 adults (10 men, 14 women) ranging from 18 to 24 years of age (mean age = 19.7). All participants were Boston College undergraduate or graduate students. Participants were screened to exclude those with any history of neurological or psychiatric disorder, including a history of depression or anxiety disorders. No participant was taking any medications that affected the central nervous system, and according to participants' self reports and their scores on the Beck Depression Inventory (Beck et al., 1988), no participant was depressed (all scores on the Inventory were less than 10).

Materials—Materials comprised 540 images from the IAPS set (Lang et al., 2005). These images were divided into two lists of 270 images each. Each of these lists included 54 pictures that, according to the normative data gathered for the IAPS, were negative high arousal, 54 that were negative low arousal, 54 that were positive high arousal, 54 that were positive low arousal, and 54 that were neutral. Negative images all had valence ratings less than 3.6 on a 9-point scale ($M = 3.06$), and positive images all had valence ratings greater than 6.4 ($M = 6.98$). Low arousal images all had arousal ratings less than 5 on a 9-point scale ($M = 4.19$), and high arousal images had ratings greater than 5.5 ($M = 5.92$). High arousal images were significantly more arousing than low arousal images ($p < .001$). Positive and negative images were matched on arousal (i.e., positive high arousal images were just as arousing as negative high arousal images) and absolute valence. High and low arousal images were matched on valence (i.e., positive high arousal images were just as positive as positive low arousal images). Neutral images ranged in valence from 4.5 to 5.5 ($M = 5.08$) and had received arousal ratings less than 5 ($M = 3.10$). Images from each category were selected so that they did not differ in terms of visual complexity (as assessed by a separate group of participants; Kensinger & Schacter, 2006a) nor in brightness (as determined by Adobe Photoshop).

Procedure—Participants studied one list of 270 pictures. The studied list was counterbalanced across participants so that 12 participants studied the first list and 12 participants studied the second list. Pictures were presented one at a time and for 3 sec apiece. Pictures were displayed on a 14″ Macintosh iBook G4 laptop and were resized to be 700 pixels in their longest dimension.

This study list was further subdivided into three sub-lists of 90 pictures (18 of each emotion type). Within each sub-list, one-third of the pictures (6 from each emotion category) were presented on the left side of the screen, one-third were presented on the right side of the screen, and one-third were presented in the center of the screen. One-third of the pictures were accompanied by the prompt "Living?," one-third by the prompt "Common?," and one-third by the prompt "Approach?" When the "Living" prompt accompanied the picture, participants made a key press to indicate whether the picture displayed something that was alive. When the "Common" prompt accompanied the picture, participants made a key press to indicate whether the picture displayed something that they would encounter in a typical month. When the "Approach" prompt accompanied the picture, participants made a key press to indicate whether the picture displayed something that they would move closer to if they were to encounter it in "real life" (see Figure 1 for study phase design).

Immediately after the study phase, participants performed a surprise recognition task (When asked upon debriefing, no participant indicated that they had expected their memory to be tested). They were shown 540 pictures consisting of the 270 pictures they had studied and the 270 pictures from the list that they had not studied. These latter items served as the foil items. Participants first were asked to decide whether the picture was an "old," studied item or a "new," nonstudied foil. If a participant indicated that a picture was "new," the next picture was shown to him or her. If a participant indicated that a picture was "old," the participant was then asked a series of additional questions. First, the participant was asked whether he or she vividly "remembered" the item's presentation or simply "knew" the item had been presented because it was familiar to him or her (Instructions regarding the remember/know distinction were modeled after those used by Rajaram, 1993). Second, the participant was asked whether the picture had appeared in the first, second, or third sub-list.

Third, the participant was asked whether he or she had made the “Living,” “Animate,” or “Common” decision about the picture[1]. Fourth, the participant was asked whether the picture had appeared on the left side, right side, or in the center of the computer screen. Analyses examine participants’ abilities to remember the spatial and temporal context associated with the presentation of those items.

Results

Effects of Valence and Arousal on Discrimination (d’)—The results from Experiment 1 were examined to see what effect valence and arousal had on participants’ abilities to discriminate “old” from “new” items. We computed d’ scores using the formula d’ = z(H) - z(F) where H=hit rate (saying “old” to an *old* item) and F=false alarm rate (saying “old” to a *new* item). The results of an ANOVA conducted on these d’ values with emotion (emotional, neutral) as a factor revealed a significant effect of emotion, $F(4,20) = 10.31$, $p<.001$, partial eta-squared = .67, with emotional items associated with higher d’ than neutral items (see Table 1).

Among the emotional items, an ANOVA was conducted with valence (negative, positive) and arousal (high, low) as factors. This ANOVA revealed only an interaction between the two factors, $F(1,23)=6.01$, $p<.05$, partial eta-squared =.21. This interaction arose because positive high arousal items were recognized more accurately than negative high arousal items, whereas negative low arousal items were recognized better than positive low arousal ones (see Table 1).

Effects of Valence and Arousal on Location and List Memory—To examine the effect of emotion on memory for spatial (location) and temporal (list order) information, an ANOVA was conducted using emotion (emotional, neutral) and scene memory component (location, order) as within-subject factors. This ANOVA, conducted only on the subset of items that received a “remember” response, revealed only a significant main effect of emotion, $F(1,23) = 6.07$, $p < .03$, partial eta-squared = .21, with emotional items remembered with better detail than neutral items (for emotional items, M =.39, SE =.02; for neutral items, M = .34, SE =.03).

Among the “remembered” emotional items, an ANOVA was conducted with valence (negative, positive), arousal (high, low) and scene memory component (location, order) as within-subject factors. The results of this ANOVA revealed a significant effect of arousal, $F(23,1) = 4.71$, $p < .05$, partial eta-squared = .17, with memory for detail being better for high arousal items, $M(SE)$ = .42 (.02), than low arousal items, $M(SE)$= .36(.02). There was no significant effect of valence, $p > .2$. There was a significant effect of scene memory component, $F(23,1) = 4.54$, $p < .05$, partial eta-squared = .17, with list, $M(SE)$ = .41 (.02), being better remembered than location, $M(SE)$ = .37 (.02). There were no significant interactions revealed, all $p > .15$ (see Table 1).

Discussion

Although some research has suggested that emotion may primarily inflate a person’s confidence in a memory (e.g., Dougal & Rotello, 2007; Neisser & Harsch, 1992; Sharot et al., 2004; Talarico & Rubin, 2003), the present results emphasize that emotion can elicit

[1]Consistent with prior research (Kensinger & Schacter, 2006; Dougal et al., 2006; Sharot et al., 2008), emotion never influenced the ability to remember which decision had been made about the picture (accuracy ranged from 58-64% for all item types). Because the reasons why this type of decision may not be enhanced by emotion have been elaborated previously (e.g., Kensinger et al., 2007; Kensinger, 2009), and because this detail is not a key feature of episodic memory in the same way that spatial and temporal specificity are requirements of episodic memory (see Clayton & Dickinson, 1998; Conway, 1992; Tulving, 1983), we do not further discuss memory for the “decision” attribute.

mnemonic benefits. Participants showed better discrimination for emotional items than they did for neutral items. Participants also were more likely to remember contextual details about emotional items than they were to remember details about neutral items.

The results of Experiment 1 also reveal that not all aspects of emotion yield the same effects on memory. In terms of recognition memory accuracy (d' scores), valence and arousal interacted to predict memory performance: For the high arousal items, positive valence was beneficial, whereas for the low arousal items, negative valence conveyed an advantage. This finding is consistent with prior research demonstrating that the recognition advantage for negative items may be particularly large when stimuli are low in arousal (Kensinger, 2008), perhaps because negative items are more likely to benefit from the types of self-referential or elaborative processes that contribute to memory enhancements for low-arousal items (Buchanan et al., 2006; Kensinger, 2004; Talmi et al., 2007). Importantly, the revelation of this interaction between valence and arousal highlights the need to consider these affective qualities of emotion when examining how emotion and memory interact.

Whereas both valence and arousal influenced recognition memory accuracy, arousal was the key contributor to the memory enhancement for spatial and temporal context. For both types of contextual details, memory was better for high-arousal information than it was for low-arousal information. Valence did not yield an influence on memory for either of these types of details. These findings are consistent with a few proposals that have purported that arousal is the dominant factor that will influence the likelihood that stimuli are bound together with their context and are retained with at least some types of contextual details (e.g., MacKay et al., 2004; Mather, 2007).

Given the divergent findings in the extant literature with regard to the effects of emotion on contextual memory, it seemed essential to examine whether these results would generalize across different types of stimuli and be replicable across different assessments of memory for spatial location and temporal order. Experiment 2, therefore, focused again on participants' abilities to remember items as well as to remember their spatial and temporal context, but it assessed these abilities in a different fashion from Experiment 1. In Experiment 2, photo objects were placed against realistic background images and participants were asked to recall which objects had been placed on each background and to remember the location of the objects within the scene and the order in which the objects had been added to the scene. In addition to providing a different means of examining memory for spatial location and temporal order, the use of these photo objects also facilitated the ability to match the different types of emotional items on dimensions including visual complexity, object familiarity, and category membership, all of which could influence source memory ability.

EXPERIMENT 2

Methods

Participants—Participants were 24 Boston College students (mean age = 19.7 years; 13 female) meeting the criteria outlined for Experiment 1.

Materials—Stimuli presented during the task consisted of scenes containing a neutral background image and three objects all of which were from the same emotional category (positive low arousal, positive high arousal, negative low arousal, negative high arousal, or neutral). Objects and backgrounds were all previously rated for arousal and valence using a 7-point scale. These ratings were obtained by a separate group of participants (stimuli were selected from those that had been rated by Kensinger et al., 2007a, and Waring & Kensinger, 2009). Negative objects were rated less than 3 in valence, neutral objects were in the midrange for valence (rated 3-5), and positive objects were those images with valence ratings greater than 5. All neutral objects were judged to be low in arousal (arousal ratings less than 4.5). A median split was applied to the sets of positive and negative objects to create distinct high arousal and low arousal stimulus sub-groups; stimuli with arousal levels of greater than 4.5 were considered high arousal while those with lower values of arousal were considered low arousal. For positive and negative objects, high arousal items were rated significantly more arousing than low arousal items ($p<.001$), and the difference between high- and low-arousal items was of a comparable magnitude for positive and negative items. All scene backgrounds were rated as low in arousal (arousal ratings less than 4.5) and all were within the midpoint of the valence rating scale (rated 3-5).

A total of 75 neutral backgrounds were used in the experiment. Three different sets of 75 scenes were created using these backgrounds, so that each background would be presented with three neutral items, three negative items, or three positive items (see Figure 2). A scene with positive arousing items, for example, could consist of a park background with a clown, a birthday cake and a magician. A scene with negative high arousing items could be an airport background with a policeman, a bomb, and a crying woman. Care was taken when creating scenes, to ensure that the items could realistically be found in the context portrayed in the background and to make certain that the items were placed in plausible locations within that context. For example, in the scene depicted in Figure 2, a squirrel, a chipmunk and a cardinal are placed in a forest; the squirrel and chipmunk are placed on the ground and the cardinal is located in a tree.

Participants viewed a total of 75 scenes, each consisting of three objects placed upon a neutral background. Twenty-five scenes contained three negative objects, twenty-five scenes contained three positive objects and twenty-five scenes contained three neutral objects. Of the twenty-five negative scenes, about half were high arousal and half were low arousal (Because twenty-five was not divisible by two, the numbers could not be exactly equivalent). Similarly, of the twenty-five positive scenes, about half were high arousal and half were low arousal. The particular objects incorporated into each scene were counterbalanced across participants, so that if one participant saw three negative objects placed on a background, another participant saw three positive objects placed on that background, and a third participant viewed three neutral objects placed on that background.

Procedure—During the study phase, participants studied 75 scenes on a computer screen. In order to facilitate memory, participants studied the scenes in blocks of 25 followed by a cued recall test. Within each list of 25 scenes, scenes incorporating positive objects, negative objects, or neutral objects were intermixed randomly. For each scene, the background image first appeared on the computer screen for 1.5 seconds. Three objects were then incorporated into the scene, one object at a time, at 1.5 second intervals. Once all three objects were incorporated, the entire scene was then presented for another 1.5 seconds. Total viewing time of each scene composition was therefore 7.5 seconds. Participants were told that they would be later asked what they remembered about the objects and the scenes, and they were instructed to formulate a short story about each scene during the 7.5 second encoding time, in order to facilitate their retention of the scenes.

After participants viewed a block of 25 scenes, they were shown just the background of each scene for a maximum of 20 seconds, and they were asked to recall the names of the objects that appeared in that scene. Participants were instructed to write down as many objects as they could recall, even if they were not confident. Backgrounds were presented in a different random order for each participant, and in an order that differed from the order used at study. Participants completed three of these study-test cycles, so that they ultimately viewed 75 scenes and completed a cued recall test for all 75 scenes (The recall test was broken into these three cycles to avoid floor effects).

After completion of the cued recall task, participants were asked to remember the order in which the objects were incorporated into the scenes and to recall the spatial location in which each object had been presented. To complete the task, participants were given 8 ½″ × 11″ laminated sheets of the backgrounds, void of any objects. On the computer screen in front of them were the three objects that had been viewed with that scene. Participants were asked to study the objects on the screen and to record the order in which they believed those objects were incorporated into the scenes by writing a 1, 2, or 3 on a piece of paper in front of them. To determine the location of the objects in each scene, participants were provided with a transparency of a 3 × 3 grid, which they placed over the scene background in front of them. Each box on the grid contained a number one through nine. With the grid in place, participants were asked to record the number of the box in which they believed each object had appeared. If the object spanned more than one box, they were instructed to write down two numbers (If the object spanned more than two boxes, participants were instructed to write down the numbers of the two boxes that contained the majority of the object). Once the order and location for each object in that scene was determined, participants were instructed to flip to the next laminated sheet in front of them and to click the mouse so the next set of objects would appear on the computer screen (The laminated sheets were numbered, and these numbers matched with numbers presented on the computer screen, to make it easy for participants to confirm that they were looking at the correct object-background pairings). Participants were not timed during this portion of the experiment and were instructed to go at their own pace until they had completed the temporal and spatial recall for all 75 scenes.

Results

Effects of Valence and Arousal on Cued Recall—To examine the effects of emotion on cued recall, an ANOVA was conducted on the object recall rates, with emotion (emotional, neutral) as a within-subjects factor. The ANOVA revealed a significant main effect of emotion, $F(1,23) = 18.17$, $p < .001$, partial eta-squared = .44, indicating better cued recall for emotional items when compared to neutral ones (emotional items, *M(SE)* = .27 (.02); neutral items, *M(SE)* = .24 (.02)).

A second ANOVA, restricted to the emotional subset of items, was conducted with valence (negative, positive) and arousal (high, low) as within-subject factors. The ANOVA revealed a significant effect of valence, $F(1,23) = 13.26$, $p < .001$, partial eta-squared = .37, with positive items remembered better than negative items (*M(SE)* = .57 (.03) and .50 (.03), respectively). There was also a significant effect of arousal, $F(1,23) = 22.8$, $p < .001$, partial eta-squared = .50, with high arousal items remembered better than low arousal items (*M(SE)* = .59 (.03) and *M(SE)* = .49 (.03), respectively). There was no significant interaction between valence and arousal, $p > .2$ (see Table 2).

Effects of Valence and Arousal on Location and Order Memory—To reveal the effect of emotion on memory for location and order, data were scored to determine the percentage of trials on which participants were able to remember all locations or all orders correctly. Using these scores, an ANOVA was conducted using emotion (emotional, neutral) and scene memory component (location, order) as within-subject factors. The ANOVA revealed an effect of emotion that was approaching significance, $p = 0.058$, with emotional items being remembered with more detail than neutral items (*M(SE)* = .31 (.03) and *M(SE)* = .20 (.02), respectively). There was also a significant main effect of scene memory component, $F(23,1) = 29.05$, $p < .0001$, partial eta-squared = .56, with better memory for location than for temporal order. There was no significant interaction between emotion and scene memory component, $p > .1$.

A second ANOVA was restricted to the emotional items, with valence (negative, positive), arousal (high, low) and scene memory component (location, order) as within-subject factors. The results of this ANOVA revealed a significant effect of arousal, $F(23,1) = 7.30$, $p < .02$, partial eta-squared = .24, with high arousal items remembered with better detail than low arousal items (*M(SE)* = .29 (.02), and *M(SE)* = .25 (.02), respectively). The ANOVA revealed no significant effect of valence, $p > .15$. There was a significant effect of scene memory component, $F(23,1) = 27.59$, $p < .001$, partial eta-squared = .55, with memory for location being better than memory for order (*M(SE)* = .32 (.03) and .22 (.02), respectively). There were no significant interactions, all $p > .3$ (see Table 2).(insert Table 2 about here)

As noted above, this first set of analyses examined the instances in which location or temporal order memory was "perfect" (i.e., all locations or orders were reported correctly). Because of the contingencies involved in remembering temporal order information, we considered anything less than perfect to indicate relatively poor retention of item order. However, for location memory, we reasoned that retention of two of the three items could signify "very good" retention of location information. We therefore computed the proportion of trials on which participants remembered either two or three of the objects' locations as another measure of spatial memory. Using these scores, an ANOVA was conducted with emotion (emotional, neutral) as a within-subjects factor. The results of this ANOVA revealed a significant main effect of emotion, $F(1,23) = 10.39$, $p < .005$, partial-eta squared = .31, with "very good" location memory occurring more often for emotional information than for neutral information (see Table 2). An ANOVA conducted on these location scores with valence and arousal as within-subject factors revealed no significant effect of valence, $p > .7$ and no significant effect of arousal, $p > 0.3$. There was also no significant interaction between valence and arousal, $p > .1$ (see Table 2).

Discussion

The results of Experiment 2 replicated the three main findings from Experiment 1. First, the results of Experiment 2 further underline the benefit of emotion on memory. Just as participants in Experiment 1 showed better discrimination for emotional items than for neutral items, so did participants in Experiment 2 have better cued recall memory for emotional items than for neutral ones. This memory enhancement for emotional items is consistent with prior literature (see Hamann, Ely, Grafton & Kilts, 1999, Hamann, 2001, Kensinger and Corkin, 2003) and suggests that although emotion can sometimes simply bias participants to endorse emotional items as studied ones (e.g., Dougal & Rotello, 2007), at other times, emotion can enhance the likelihood that events are remembered.

Second, the cued recall data from Experiment 2 were consistent with the recognition data from Experiment 1 in suggesting that both valence and arousal must be considered in order to understand how emotion affects memory accuracy. The results revealed that positive valence as well as high arousal exerted a beneficial influence on cued recall. Although these results diverge slightly from those of Experiment 1, in that the prior experiment revealed an interaction between valence and arousal whereas the current results revealed a main effect of each factor, both studies are consistent in pointing to an influence of both dimensions upon the ability to remember emotional items.

It is interesting that in both experiments, the largest memory advantage occurred for positive high-arousal items. This result contrasts with some prior research, suggesting that negative valence may enhance memory more than positive valence (e.g. Ochsner, 2000, Kensinger & Corkin, 2003, Charles, Mather, & Carstensen, 2003). However, the results are consistent with studies of autobiographical memory, in which memory is often better for positive as compared to negative experiences (Erdogan et al., 2008, D'Argembeau, Comblain & Van der Linden, 2003). It is possible that the memory advantage for positively-valenced experiences is more likely to be revealed in experiments such as the ones reported here, which draw attention to the spatial and temporal context in which information is presented, thereby replicating the key features of autobiographical memory. It is also possible that the current experiments encouraged participants to encode scenes in a self-referential fashion. For example, in Experiment 2, participants were asked to create a story about each scene, and it is likely that they would have come up with these stories based on their own prior experiences. There is some evidence that self-referential processing is particularly efficient for positive information (Watson et al., 2007) and can convey a memory advantage for positive information (Kensinger & Leclerc, 2009), and so the present results may reflect one instantiation of that influence of self-referential processing on memory.

Third, the results of Experiment 2 mirrored those of Experiment 1 in revealing that arousal was the key predictor of memory for spatial and temporal context, while valence had no influence on the ability to remember these contextual details. Experiment 2 revealed that no matter the type of source memory, location or order, arousal enhanced memory for those details. This finding is consistent with previous proposals that arousal will enhance memory (e.g., Bradley et al., 1992; Hamann et al., 1999; McGaugh, 2000) and will increase the likelihood that contextual details are bound into a stable memory representation (e.g., McGaugh, 2000; MacKay et al., 2004; Mather, 2007). The finding also aligns with prior research, revealing a beneficial effect of arousal on memory for spatial location (Mather & Nesmith, 2008).

An important caveat to emerge from Experiment 2, however, is that the effect of arousal on source memory is only apparent when assessing "perfect" location and order memory. When the criteria are reduced so that "very good" location memory is considered to be sufficient, there is no longer an influence of arousal on memory. These results suggest that arousal may be particularly important in influencing retention of a highly accurate memory. It is interesting to note that this finding generally aligns with the original proposals that arousal might enhance "picture-perfect" memory (i.e., the "Flashbulb memory" phenomenon reported by Brown & Kulik, 1977). Although there is now extensive evidence to suggest that arousal does not lead to a memory that is "perfect" in all regards, it is possible that arousal increases the likelihood that select types of contextual details (such as spatial location) are preserved with particularly high fidelity.

GENERAL DISCUSSION

The present experiments were designed to adjudicate among four alternate hypotheses regarding the effects of emotion on memory for spatial and temporal context: that emotion would have no beneficial influence on memory for contextual details; that arousal would be the dominant factor influencing memory for these contexts; that valence would need to be considered in order to understand how emotion impacts source memory; and that whether valence or arousal was the key predictor would depend on whether temporal or spatial detail was assessed. The present experiments provide evidence in support of the second alternative: When it came to remembering the spatial and temporal context in which information was presented, emotion did enhance the ability to remember those details, and arousal was the key predictor. This finding was revealed in two experiments that used different stimuli and different methods for assessing spatial and temporal memory.

The fact that high-arousal items are remembered with more contextual detail than low-arousal items is consistent with the binding hypothesis, which states that "emotional reactions trigger binding mechanisms that link an emotional event to salient contextual features such as event location" (MacKay & Ahmetzanov, 2005, pg. 26). In other words, in the current experiments, the emotional reactions people had to the images may have caused the contextual features associated with the image, such as its location or temporal order, to be bound to the image, thereby leading those details to be remembered. Our finding is also congruent with a study by Mather & Nesmith (2008), in which they found enhanced memory for the location of high arousal pictures. Mather suggests that since attention is required to bind features to an item during initial perception, and since the amygdala plays a key role in providing attentional advantages to emotional stimuli (see Vuilleumier & Driver, 2007), then there should be a benefit for binding of features to emotional stimuli (Mather, 2007). Arousal may enhance the binding process of location to item in two ways: increasing the selectivity of attention and increasing the activation level of the features associated with the object (and see Mather & Nesmith, 2008).

Although the present findings are consistent with some past literature as just reviewed, it is worth noting that other studies have revealed an effect of valence on the ability to retain contextual information, with negative valence providing a benefit to contextual memory (reviewed by Kensinger, 2008). Although further research will be needed to clarify the best way to characterize the effects of valence on memory for contextual detail, one possibility is that negative valence may be more likely to enhance memory for contextual details tied to the sensory features of an event (e.g., its sights, sounds, etc) or to more internal details such as one's thoughts or feelings while experiencing the event (and see Mickley & Kensinger, 2009, for evidence that these dimensions are remembered in a subjectively rich fashion for negative items). But for the critical episodic details of spatial and temporal context, negative valence appears to convey little specific benefit.

Whereas arousal was the dominant predictor of memory for contextual details, when it comes to remembering that an item was presented, both valence and arousal appear to play a role. The fact that high arousal items were better remembered than low arousal items is consistent with prior evidence that arousal can enhance recognition and recall (Bradley, Greenwald, Petry & Lang, 1992, Hamann, Ely, Grafton, & Kilts, 1999, Ochsner, 2000, Kensinger & Corkin, 2003). The physiological response that results when a participant views a highly arousing photo may lead to some of the distinctiveness that causes an enhancement in memory (Ochsner, 2000), and the specific stress hormones that are released under highly arousing conditions may also interact with the amygdala and lead to improvements in memory (McGaugh et al., 2000). However, the present results emphasize that taking arousal into account is not sufficient to explain the effects of emotion on item memory. Rather, in both experiments, valence needed to be considered as well, such that positive items were more likely to be remembered than negative items, particularly when those items were of high arousal. Thus, in both experiments, there was an influence of valence on memory for the item itself, whereas there was no effect of valence on memory for the spatial or temporal context. We cannot rule out that valence exerts a more modest effect on memory for contextual details which we did not have power to detect in the present experiment. Yet it is plausible that this pattern reflects the fact that memory for the 'what' of an item is supported by different processes than memory for the 'where' or the 'when' of an item (e.g., Glisky et al., 1995; Davachi et al., 2003). Emotion may not have a parallel effect on all of these processes, consistent with prior suggestions that the effects of emotion on memory may be selective, leading to differences in the way items and their details are remembered (see reviews by Reisberg & Heuer, 2004; Levine & Edelstein, 2009). It is possible that the item memory benefit conveyed by positive valence reflects the fact that positive emotion increases the ability to remember general and heuristic aspects of an experience and enhances activity within neural regions that support feelings of familiarity (e.g., Mickley & Kensinger, 2008; Levine & Bluck, 2004). These influences of positive valence may be particularly advantageous when it comes to remembering which items were presented, whereas they may be less relevant to the retention of contextual details associated with those items (and see Kensinger, 2009 for further discussion).

At a more general level, the present results emphasize that emotion does not merely inflate a person's confidence in a memory (Sharot et al., 2004) or lead to a bias to endorse emotional items as studied (Dougal & Rotello, 2007). Rather, emotional items can be remembered more often, and with more contextual detail than neutral items. However, the effects of emotion are not equal across all affective experiences, emphasizing the need to consider the underlying features of an emotional reaction (e.g., its arousal and valence) in order to understand how emotion interacts with memory processes.

Acknowledgments

This research was supported by grant MH080833 from the National Institute of Mental Health, by the American Federation for Aging Research, and by the Searle Scholars Program (grants to E.A.K.). Portions of this research were conducted as the Senior Thesis of the first author (Expt. 2) or as the Independent Research Project of the second author (Expt. 1). We thank Ranga Atapattu, Matthias Faeth, and Keely Muscatell for assistance with data collection and data management and for helpful discussion.

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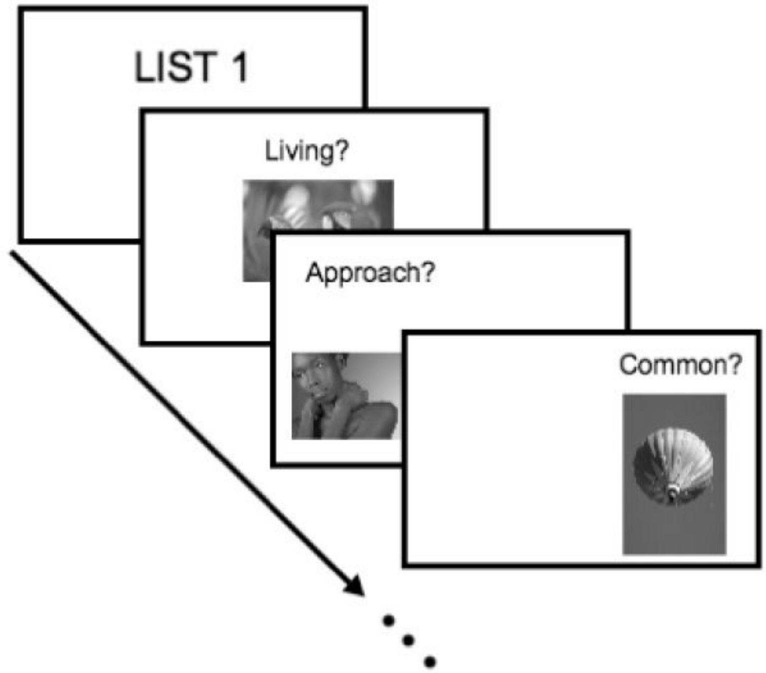

Figure 1.
Study phase for Experiment 1. Participants saw images appear in different screen locations (center, left, right) and in three different lists. Participants answered one of three questions about each image (Living?, Approach?, or Common?). Later, participants were asked to remember each of these event details.

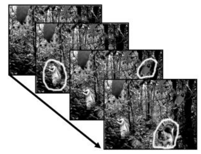

Figure 2.
An example of one trial (incorporating positive low-arousal objects onto a background) from the study phase in Experiment 2. Objects are circled here for depictive purposes only; in the experiment, these circles were not present.

Table 1

Memory Performance within Experiment 1 as a Function of Emotional Category (Positive Low arousal, Positive High arousal, Negative Low Arousal, Negative High Arousal, Negative Low Arousal, and Neutral)

Emotion Category	Mean (SE) of d' Scores	Mean (SE) of Hit rate	Mean (SE) of False Alarm rate	Mean (SE) of Location Recognition	Mean (SE) of List (Temporal Order) Recognition
Pos Low	2.7 (.12)	.74 (.03)	.03* (.01)	0.30 (.03)	0.39 (.04)
Pos High	3.0* (.08)	.81* (.02)	.03* (.01)	0.41* (.03)	0.42* (.04)
Neg Low	3.0* (.16)	.87* (.02)	.05 (.01)	0.35 (.03)	0.40 (.03)
Neg High	2.9* (.11)	.80* (.02)	.06 (.01)	0.42* (.03)	0.44* (.04)
Neu	2.5 (.13)	.74 (.04)	.05 (.01)	0.32 (.04)	0.36 (.04)

* Indicates a value that was significantly ($p < .05$) different than neutral

Table 2

Memory Performance within Experiment 2 as a Function of Emotional Category (Positive Low arousal, Positive High arousal, Negative Low Arousal, Negative High Arousal, Negative Low Arousal, and Neutral)

Emotion Category	Mean (SE) Recall	Mean (SE) "Perfect" Location Recall	Mean (SE) "Very Good" Location Recall	Mean (SE) Temporal Order Recall
Pos Low	0.51* (.03)	0.29 (.04)	0.59 (.05)	0.19 (.02)
Pos High	0.63* (.03)	0.34* (.03)	0.66* (.04)	0.22* (.02)
Neg Low	0.47 (.03)	0.31 (.03)	0.64* (.04)	0.22 (.02)
Neg High	0.54* (.03)	0.35* (.03)	0.62* (.03)	0.24* (.02)
Neu	0.45 (0.03)	0.30 (.03)	0.55 (.03)	0.18 (.02)

*Indicates a value that was significantly ($p < .05$) different than neutral