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Effect of negative emotional pictures on associative memory for peripheral information

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We investigated the influence of negative emotional pictures on associative memory. A visual object was embedded in the periphery of negative emotional or neutral pictures. Memory was assessed for central item (pictorial) information, peripheral (object) information, and the association between item and peripheral information. On tests of item information, negative emotional pictures were remembered better than neutral pictures. However, associative memory between item and peripheral information was less accurate when the pictures were negative compared to neutral. This occurred despite equivalent recall (Experiments 1 and 2) and recognition (Experiment 2) for the peripheral objects themselves. Further experiments confirmed that performance on the associative test was not influenced by testing order (Experiment 3). These findings suggest that negative emotional arousal can particularly disrupt the associative binding of peripheral information to a central emotional event.

Buchanan and Adolphs (2004) defined emotional memory specifically as a "... domain of declarative memory, namely, memory for events or stimuli that are themselves emotional, or that occurred in an emotional context" (p. 43). Numerous studies have reported enhanced memory for information that is itself emotional (for reviews see Hamann, 2001; LeDoux, 2000; Reisberg & Hertel, 2004). In experiments involving human participants, information presented visually (i.e., pictures, film clips, and words) was remembered best when it was emotionally arousing versus when it was neutral (e.g., Cahill et al., 1996; Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000; Christianson, 1992; Doerksen & Shimamura, 2001; Hamann, Ely, Grafton, & Kilts, 1999; LaBar & Phelps, 1998). Such memory enhancements have been observed most robustly for *item information*, defined here as memory for a semantically unified event or stimulus (i.e., the gist of an event that is itself emotional; Burke, Heuer, & Reisberg, 1992; Christianson & Loftus, 1991). Remembering a car accident, a violent murder scene in a movie, or a particularly moving long-distance telephone conversation are all examples of emotional item memory. However, memory enhancements are not observed for all aspects of information associated with an emotional event. Memory for some types of *peripheral information* can be reduced in the context of an emotional event (Burke et al., 1992; Christianson & Loftus, 1991). Peripheral information is defined here as information that is presented with an event, but is semantically and/or spatially separate from that event. Remembering the colour of a car involved in an accident is an example of memory for peripheral information that is semantically separate from the gist of an

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emotional event (the car accident). Similarly, remembering the other bystanders present at the accident is an example of memory for peripheral information that is both semantically and spatially separate from the gist of the event.

In a study by Christianson and Loftus (1991), participants viewed one of two thematic slide series. In one group, participants observed a critical slide with emotional content; in another group, participants observed a neutral version of that critical slide. Participants in the emotional condition remembered details about the item information—information directly relevant to the gist or theme of the event—better than participants in the neutral condition. However, they were less likely to remember peripheral details that were spatially removed from item information, compared to participants in the neutral condition. Using a similar paradigm, Burke et al. (1992) found that participants who viewed an emotional slide series were more likely to remember plot-relevant item information, as well as plot-irrelevant peripheral information that was spatially central within the slide. Conversely, memory for plot-irrelevant material that was spatially peripheral was impaired in the emotional condition. Similar results have been reported in other studies utilising thematic slide series (e.g., Christianson, 1992; Loftus, Loftus, & Messo, 1987). Such findings are consistent with the *attentional narrowing hypothesis*, which states that heightened emotion directs attentional focus towards the emotion-eliciting stimulus at the expense of attention (and subsequent memory) for peripheral information that is spatially separate from the emotional event (Christianson, 1992; Easterbrook, 1959; Loftus et al., 1987; Reisberg & Hertel, 2004; Safer, Christianson, Autry, & Oesterlund, 1998; Schmidt, 2002).

However, not all studies testing memory for item and peripheral information have supported the attentional narrowing hypothesis. Libkuman, Nichols-Whitehead, Griffith, and Thomas (1999) found that an emotional slide series was associated with enhanced memory for both spatially central and spatially non-central peripheral information (compared to a neutral version), and that emotional arousal did not influence memory for item information. Similarly, memory for peripheral information was not reduced in a series of studies by Wessel, van der Kooy, and Merckelbach (2000), despite eye movement data consistent with an attentional narrowing mechanism. These studies imply that the impact of emotion on memory for peripheral information may extend beyond attention-modulated encoding. This idea is further supported by research demonstrating that emotional words were remembered better than neutral words after a delay, even when participants did not attend to those emotional words (Sharot & Phelps, 2004).

One type of memory that may be directly influenced by emotional arousal is associative binding—specifically, the binding of item and peripheral information in memory. That is, how does an emotional event influence the association between that event and peripheral information? Returning to the example of a car accident, how well will a bystander remember the person associated with the car that was hit, versus the person associated with the vehicle that caused the accident? This question moves beyond the mere presence or absence of some information in memory and asks how well different pieces are bound together. This issue was not addressed by the aforementioned studies. For example, in the Christianson and Loftus (1991) study, the memory tasks consisted of a cued recall test and a forced-choice recognition test. In the recall test, the critical emotional slide was presented with a missing central and peripheral detail, and participants were asked to describe what was missing. In the recognition test, participants were shown four versions of the critical slide (each with a different combination of central and peripheral details) and asked to choose the original version that they had seen during the study phase. Both tasks required participants to remember the central and peripheral information but did not test how well they were bound together in memory. In these tests, participants may have remembered the central detail *and/or* the peripheral detail, but there was no direct measurement of memory for the association between the peripheral and central (item) information.

The relationship between central–peripheral associative memory and emotional arousal has been discussed by others. Some researchers (e.g., Metcalfe, 1998; Payne, Nadel, Britton, & Jacobs, 2004) have suggested that stress can disrupt hippocampal processing (a neural structure related to memory formation and binding). The result can be memories that are fragmented, with aspects of episodic information that are unbound temporally and/or spatially. Indeed, a dissociation between central, emotion-eliciting events and peripheral, contextual information may contribute to the fragmented memories observed in patients with post-traumatic stress disorder (Elzinga & Bremner, 2002). This idea is further supported by animal research showing that high levels of stress can impair hippocampal function (Sapolsky, 2003).

In an earlier study we addressed the influence of emotional arousal on associative memory by testing participants' memory for emotional versus neutral words and colours associated with those words (Doerksen & Shimamura, 2001). In Experiment 1 participants showed enhanced memory for emotional words, as well as the colour of those words. This was consistent with prior research suggesting that emotional events draw focus towards themselves, improving memory for those events as well as conceptually peripheral details that are spatially central. However, the peripheral memory enhancement also occurred when the colours were presented as a frame around the words, and were thus spatially distinct from the central information (Experiment 2). In other words, memory for the association between a word and a colour was enhanced regardless of whether the peripheral information was spatially central or peripheral. This effect was not simply the result of mentally clustering the emotional words as a category (Experiment 3), but seemed to stem from the emotionality of the words. These findings imply that emotional arousal may influence associative memory, and that such effects are not always consistent with the attentional narrowing hypothesis.

However, there are many differences between the Doerksen and Shimamura (2001) study and studies involving thematic slide series (e.g., Burke et al., 1992). Doerksen and Shimamura (2001) used fairly simple stimuli: words as the emotional events and colours as the peripheral information. In contrast, the thematic slides were complex visual pictures. It could be that these differences contributed to these seemingly disparate findings. In the present experiments we further examine the influence of emotion on memory for associations between item and peripheral information, using a paradigm similar to Doerksen and Shimamura (2001) but with stimuli that are closer in complexity to the thematic slide series used by others (e.g., Burke et al., 1992; Christianson & Loftus, 1991; Libkuman et al., 1999). In particular, we were interested in the influence of emotion on associative memory when the peripheral information was both spatially and conceptually distinct from the item information. Participants viewed emotionally laden and neutral pictures from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999). Peripheral information was a neutral visual object placed in one corner of the picture. Participants were given memory tests for the content of the picture, for the peripheral object, and for the association between the picture and the peripheral object. In the critical cued association test, participants were cued by a study picture and asked to choose, among three objects (all of which had been presented during the study phase), the one that was presented with the picture. In this way, we could specifically assess associative memory between central and peripheral information without reliance on old–new recognition memory.

We assessed associative memory between central scene information and peripheral objects when the two were maximally disparate—both spatially and conceptually—for a variety of reasons. First, the manner and extent to which peripheral information is related to central information may significantly influence memory patterns. There is evidence that visual details are remembered best when they are relevant to the plot (Burke et al., 1992; Reisberg & Hertel, 2004)—that is, when there is a pre-existing semantic association. We wanted an approach that reduced the possibility of such pre-existing associations, since we were interested in how emotion modulated their production.

Additionally, the point at which information becomes "peripheral" as opposed to "central" can be difficult to define, as demonstrated by Libkuman et al. (1999). These researchers reported low reliability among independent judges when separating central from background detail, and gist from basic-level visual information. Modifying the test questions to better reflect the judges' ratings (as opposed to experimenters' ratings) influenced memory patterns. To reduce such ambiguity, we elected to use peripheral information (cartoon-like objects) that was obviously semantically and spatially distinct from the main pictures.

Counterbalancing the content of pictures that are negative versus neutral can also be problematic. As an example, the arousal condition used in Burke et al. (1992) showed an operation on a car accident victim, whereas the neutral condition showed a mechanic repairing a car. Although the authors attempted to balance content and complexity, there are obvious differences between these scenarios. The approach outlined here enabled us to better counterbalance peripheral information across participants. Half of the participants viewed one set of objects in the neutral pictures, while other participants viewed the same set in the negative pictures. However, the objects did not fit one group of pictures better than another group.

In summary, we assessed associative binding—the degree to which participants could associate peripheral information with item information—using negative emotional and neutral pictures. Peripheral information consisted of neutral visual objects placed in the corner of conceptually unrelated negative or neutral scenes. Memory for the item information (gist-related features of the scene), the peripheral information (objects), and associations between the item and peripheral information was assessed following the viewing of the negative and neutral scenes.

EXPERIMENT 1

Method

Participants. A total of 38 undergraduates (12 men and 26 women) from the University of California, Berkeley, were recruited and received course credit for their participation. The participants averaged 20.4 years of age and 13.6 years of education. Treatment of participants was in accordance with the ethical standards of the APA and the University of California; informed consent was obtained from all participants. All participants reported normal or corrected-to-normal vision.

Stimuli and design. A total of 40 pictures were selected from the IAPS (Lang et al., 1999) on the basis of the normative ratings provided. Of these pictures, 20 were rated negatively valenced (average rating $= 2.3 \pm 0.4$ *SD*; 1 = highly negative, 8 = highly positive) and highly arousing (average rating $= 6.0 \pm 0.7$; 1 = lowest arousal, 8 = highest arousal) according to the IAPS scales. The remaining pictures were rated as neutrally valenced and moderately to minimally arousing (5.0 ± 0.8 and 3.9 ± 0.7, respectively). Analyses of these picture groups showed they were significantly different in terms of valence ratings, $t(38) = 13.2$, $p < .001$, $d = -4.18$, and arousal ratings, $t(38) = 9.26$, $p < .001$, $d = 2.96$. The pictures depicted complex scenes (e.g., a robbery on a subway) rather than single dominant items (e.g., a single chair in an empty room). In terms of semantic content, 17 of the pictures within each valence depicted people or animals.

Placed in one corner of each picture was a single object (e.g., mitten, feather) that was conceptually unrelated to the picture. These objects were coloured line drawings obtained from ClickArt (1999) software (Broderbund Software Inc. www.broderbund.com). Each peripheral object was approximately 1.5 inches by 1.5 inches, and was placed on a grey box scaled to the object's size. We did not choose objects that were likely to be construed as emotional in nature (e.g., knife, flower). The corner designated for object location was randomly determined, with the condition that the objects would be evenly distributed among the four corners, across valence. These composite stimuli were presented on an 18-inch computer screen, scaled to the screen size. Study and test phases were presented using a Dell Dimension series computer. Stimuli were created using Microsoft Paint (1998) and presented using Presentation® software (Version 0.75, www.neurobs.com). All participants were presented with the same pictures and objects; however, the specific objects used for each picture type (negative, neutral) were counterbalanced across participants (therefore we did not feel it was necessary to obtain separate emotion ratings for these objects). Stimulus presentation during the study phase was pseudo-random, with no more than three consecutive negative or neutral pictures.

Picture memory was assessed using both a free recall test and a mirror-reversal test. The mirror-reversal test enabled us to test memory for a scene while controlling for any distinctive elements that it contained. All pictures were clearly asymmetrical, although the relative increased difficulty of the test, compared to a standard old–new recognition test, had the additional benefit of preventing ceiling effects, which had been a concern given that testing occurred soon after the study phase. In terms of object memory, we were primarily interested in how an emotional stimulus influences the binding of peripheral information to that central emotional stimulus. To assess this, we used a cued association test. To determine the impact of the scenes on memory for the objects themselves when no cues were given, we also included an object free recall test. Detailed descriptions of the recall and recognition procedures that we used to assess memory for the pictures and the objects are below.

Object free recall. Using pencil and paper, participants were given 4 minutes to recollect as many of the peripheral objects as possible. A response was scored as correct if the description could be uniquely applied to one object. Responses were scored by two independent raters; disagreements were resolved by mutual consent of the raters. (On average, disagreements between raters were rare, occurring for $<3\%$ of responses, on average, per participant for Experiments 1 and 2.)

Picture free recall. Using pencil and paper, participants were given 5 minutes to recollect as many of the pictures as they could. They were asked to give enough descriptive detail so that the specific picture to which they were referring could be identified. A response was scored as correct if the description could be uniquely applied to one picture. Thus, correct responses mainly relied on identifying the main theme of the picture, although enough detail was also required to uniquely identify the picture. Responses were scored by two independent raters; disagreements were resolved by mutual consent of the raters. (On average, disagreements between raters were rare, occurring for $<3\%$ of responses, on average, per participant for Experiments 1 and 2.)

Mirror-reversal test. In this test two versions of the same picture were shown, one above the other. One picture was in its original form and one was in its mirror-reversed form (i.e., horizontally flipped 180 degrees). Participants were asked to choose the version of the picture that they had seen during the study phase and make their selection using the keyboard. All of the pictures presented during the study phase were presented in this test (i.e., no new pictures were presented), with the placement of the original version counterbalanced across trials and valence conditions. Compared to the picture recall test, this test requires greater specificity of knowledge of the pictures, as opposed to simple memory for distinctive elements.

Cued association memory. In the cued association memory test, a study picture was presented at the top of the screen (smaller and without a peripheral object embedded within it) with a choice of three objects below (numbered one to three). One object (the target) had been embedded in the cue during the study phase, and the other two objects (distractors) had been embedded in other pictures during the study phase. In other words, neither distractor object was a new object: one had been studied within a picture of the same valence condition, and the other had been studied within a picture of the alternate valence condition. Participants were asked to choose the object that appeared in the top picture during the study phase and to make their selection using the keyboard. Object presentation was counterbalanced so that participants saw each object exactly three times during this test. Placement of the target (i.e., whether the target was designated object 1, 2, or 3) was also counterbalanced across trials and valence conditions.

Rating test. In the rating test, participants were shown all of the study phase pictures, without the peripheral objects, and were asked to rate their emotional response. This involved a 9-point Likert scale ranging from 1 (extremely aversive) to 9 (extremely positive), with 5 indicating a neutral valence; responses were indicated using the keyboard. We did not obtain separate measures of valence and arousal since we were simply interested in confirming that the participants found the negative pictures aversive and the neutral pictures neutral.

Procedure. In the study phase, participants were told that they would be viewing pictures and that each picture would have a small object embedded in one corner. Although they were not specifically instructed to focus on either the picture or the peripheral object (i.e., they were allowed to free-view the scene), they were asked to remember as much about each stimulus as possible. To better ensure that participants attended to the objects for some minimum amount of time, they were told to respond to the location of each object using keyboard input (one key for each of the four corners).

Each stimulus was presented for 6 seconds with an inter-trial interval of 1 second. A 6-second presentation was selected based on prior memory studies that showed pictures for similar lengths of time (Bradley, Greenwald, Petry, & Lang, 1992; Burke et al., 1992; Canli, Zhao, Desmond, Glover, & Gabrieli, 1999; Hamann et al., 1999). Additionally, we wanted to ensure that participants would have enough time to free-view the composite stimuli. To control for primacy and recency effects, four neutrally valenced buffer stimuli (two at the beginning and two at the end of the study phase) were included. Memory for these buffer stimuli was not included in any analysis.

Following the study phase, a 5-minute filler test was administered in which participants solved mathematical problems. Memory tests were presented in the following order. First, the object recall test was presented in which participants reported as many objects as possible; identification of the pictures was not required. Second, the picture recall test was presented in which participants reported as many pictures as possible; identification of the objects was not required. The mirror-reversal test followed, in which participants were given 8 seconds per query to choose the version of the picture they saw during the study phase. Next was the cued association test, in which participants were given 10 seconds per query to choose the object originally embedded in the picture during the study phase. Last was the rating test in which participants were given 4 seconds per query to indicate their emotional response to each picture. Stimulus time limits were based on pilot data suggesting that these intervals were sufficient for participant responses.

A fixed testing order was necessary due to the nature and content of the tests. Since the recognition tests required second presentations of the pictures and the objects, the recall tests preceded them. Given the relative difficulty participants displayed in the object recall test, it was presented first to avoid floor effects. Finally, since the pictures were shown during the cued association test, it was necessary to present the mirror-reversal test beforehand. The rating test was presented last, as it did not have a memory component. For the three computer-based tests participants were asked to make no more and no less than one selection per query and to respond within the specified time limits. If more than one response was made, only the first was included in the subsequent analyses. In the unlikely event of a missing response, an error was counted.

Results and discussion

A total of 36 participants were included in the statistical analyses (one participant who performed below chance on the cued association test was not included in any analysis, and one participant did not finish the experiment). The participants' picture ratings confirmed those assessed by Lang et al. (1999). The mean rating for the neutral pictures was 5.27 (0.07 *SEM*) and was significantly higher than the mean rating for the negatively valenced pictures, 2.44 ± 0.11; $F(1,\ 35) = 395.3$, $MSE = 0.36$, $p < .001$, $d = -3.57$.

Memory for item information was assessed using tests of picture recall and mirror-reversal recognition. In the picture recall test (Table 1), negative pictures were remembered better than neutral pictures, $F(1,\ 35) = 60.2$, $MSE = 0.01$, $p < .001$, $d = 1.70$. Comparable effects were observed in the mirror-reversal test. In that test, participants recognised the original orientation of negative pictures (0.87 ± 0.12) better than the orientation of neutral pictures, 0.83 ± 0.18; $F(1, 35) = 4.18$, $MSE = 0.01$, $p < .05$, $d = 0.39$.

In the object recall test (Table 1), there was no significant difference in memory for peripheral objects paired with negative or neutral pictures, $F(1,\ 35) = 0.94$, $MSE = 0.005$, $p > .10$. However, in the cued association test (Figure 1), the ability to associate the peripheral objects with the pictures was poorer for objects associated with negative pictures compared to neutral pictures, $F(1, 35) = 14.1$, $MSE = 0.16$, $p < .001$, $d = -0.48$.

These findings are consistent with reports of enhanced memory for negative arousing pictures (e.g., Bradley et al., 1992; Burke et al., 1992; Cahill et al., 1996; Canli et al., 1999; Christianson & Loftus, 1991; Hamann et al., 1999). Results from the mirror-reversal test suggest that this enhancement is not simply due to remembering the presence of particularly distinctive elements. Despite enhanced memory for negative pictures, the cued association test demonstrated that objects were less likely to be associated with negative pictures compared to neutral pictures. This suggests that negative arousing stimuli have disruptive effects on the binding of peripheral information to central information in memory.

TABLE 1
Proportion of pictures and objects recalled (Experiments 1 & 2)

	Neutral		*Negative*	
	M	*SEM*	*M*	*SEM*
Experiment 1				
Pictures***	0.26	0.02	0.47	0.15
Objects	0.17	0.02	0.15	0.02
Experiment 2				
Pictures***	0.23	0.02	0.45	0.02
Objects	0.17	0.02	0.19	0.02

***$p < .001$

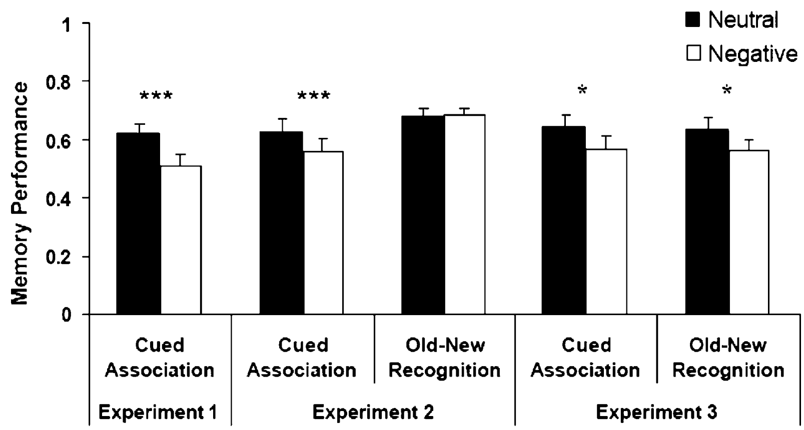

Figure 1. Memory performance in Experiments 1, 2, and 3. *$p < .05$. ***$p < .001$.

That this was observed despite similar recall for objects in both the neutral and negative conditions further suggests that the attentional narrowing may not underlie this disruption.

A potential explanation is that the performance in the cued associative test reflects participants' differential memories for the emotional and neutral pictures. That is, as the number of remembered pictures increases, the number of picture–object associations that require tracking also increases. In terms of this experiment, remembering picture–object associations may be more difficult in the negative condition because a greater number of negative pictures are remembered compared to neutral pictures. To address this concern, difference scores were calculated for the picture recall task (the proportion of negative pictures recalled minus the proportion of neutral pictures recalled; average difference score $= 0.21 \pm 0.03$ *SEM*). These difference scores were then correlated with performance on the cued associative task. If performance on the cued associative task is a function of differential recall of negative versus neutral pictures, we would expect a negative correlation between the difference score and cued associative performance in the negative condition. That is, as participants remembered relatively more negative pictures, performance in the cued associative task should decrease in the negative condition, simply because there were more picture–object associations to track. However, we did not observe a significant relationship between difference scores and cued associative memory in either the negative condition, $r^2 = .0027$, $t(35) = 0.30$, $p > .10$, or the neutral condition, $r^2 = .028$, $t(35) = 0.99$, $p > .10$. This suggests that performance in the cued associative test was not a function of memory for the pictures.

Another concern is that, given that associative memory was assessed using a recognition-style paradigm, the use of an object recall task to assess straightforward memory for peripheral information may not be the most appropriate metric. To address this concern, we replicated Experiment 1 and introduced an object recognition test.

EXPERIMENT 2

The similar recall performance for objects embedded in both neutral and negative emotional pictures observed in Experiment 1 suggests that the objects were encoded with similar success. Thus, the relatively poor performance on the cued association task specific to negative pictures seems to result from a failure of binding the objects and pictures, rather than lack of memory for the objects themselves. However, object recall was relatively low compared to performance in the recognition-style associative memory task (average object recall $= 0.16$, average cued association hits $= 0.57$). Perhaps this lower performance masked differences in the recall of neutral- versus negative-related objects. Additionally, since recall and recognition, to some extent, tap different processes (Doerksen & Shimamura, 2001; Flexser & Tulving, 1978; Nyberg et al., 2003), it is difficult to draw general conclusions about the relationship between performances on the object recall and cued association tasks.

These concerns led to a replication of Experiment 1, with the inclusion of an old–new object recognition task. Additionally, to ensure that the findings of Experiment 1 were not based on extraneous factors specific to the stimulus sets used, different sets of objects and pictures were used in Experiment 2. Finally, the mirror-reversal test was not included, as it did not provide any new information about item memory compared to the picture recall test.

Method

Participants. A total of 36 undergraduates (17 men and 19 women) were recruited and received course credit for participation. The participants averaged 20.5 years of age and 14.7 years of education. Treatment of participants was in accordance with the ethical standards of the APA and the University of California; informed consent was obtained from all participants. All participants reported normal or corrected-to-normal vision.

Stimuli, design, and procedure. The design was similar to Experiment 1; however, a new stimulus set of pictures and objects was used. As in Experiment 1, 40 pictures were selected from the IAPS (Lang et al., 1999) on the basis of the normative ratings provided. (Some pictures within each valence group overlapped with those used in Experiment 1—six negatively valenced pictures and five neutrally valenced pictures—this enabled us to keep the semantic content of the pictures balanced between valence groups, as well as maintain similar arousal and valence ratings compared to Experiment 1.) Of these pictures, 20 were rated negatively valenced (average rating $= 2.4 \pm 0.4$ *SD*) and highly arousing (average rating $= 5.9 \pm 0.7$). The remaining pictures were rated neutrally valenced and moderately to minimally arousing (5.5 ± 0.4 and 4.1 ± 1.1, respectively). Analyses of these picture groups showed that they were significantly different in terms of valence ratings, $t(38) = 24.6$, $p < .001$, $d = -7.93$, and arousal ratings, $t(38) = 6.05$, $p < .001$, $d = 1.90$. As in Experiment 1, the pictures depicted asymmetrical, complex scenes. Also, an effort was made to balance the groups more broadly in terms of semantic content, compared to Experiment 1. Included in each group were a similar number of pictures depicting humans (negative = 15, control = 14), animals (3 each), and inanimate objects (negative = 2, control = 3).

A new set of 80 objects (coloured line drawings) was also selected. Again, we did not choose objects that were likely to be construed as emotional in nature. These objects were randomly divided into two groups. Using these object groups, four sets of composite study stimuli (i.e., a picture with a single object embedded in one corner) were created. More specifically, all participants were presented with the same pictures, but during the study phase half viewed one group of objects in the pictures, while the rest viewed the other group of objects in the pictures. Furthermore, the objects were counterbalanced across valence conditions.

The test phase and general procedure were identical to those described in Experiment 1, however an old–new object recognition task was included and the mirror reversal test was removed. For the old–new object recognition test, participants were presented with all 80 objects: 40 were "old" (previously viewed during the study phase) and 40 were "new" (not viewed during the study phase). Objects were presented in random order and participants were asked to determine whether each object was old or new, indicating their response using the keyboard. For the old–new object recognition, cued association, and rating tests, stimuli remained on the screen until a response was made, rather than for a fixed length of time. We did not feel that this was a critical modification given that, in the analogous tests in Experiment 1, only the first response was counted in the event that more than one response was given. The order of test administration was as follows: object recall, picture recall, old–new object recognition, cued association, picture ratings.

Results and discussion

All participants were included in the statistical analyses. The mean rating for the neutral pictures was 5.73 (0.10 *SEM*), and was significantly higher than the mean rating of the negative pictures, 2.59 ± 0.08; $F(1, 35) = 816.7$, $MSE = 0.22$, $p < .001$, $d = -5.85$. In the picture recall test (Table 1), negative pictures were remembered better than neutral pictures, $F(1, 35) = 63.6$, $MSE = 0.01$, $p < .001$, $d = 1.73$. In the object recall test (Table 1), there was no significant difference in memory for peripheral objects paired with negative or neutral pictures, $F(1, 35) = 1.06$, $MSE = 0.006$, $p > .10$. However, in the cued association test (Figure 1), the ability to associate pictures with peripheral objects was poorer for objects associated with negative pictures compared to neutral pictures, $F(1, 35) = 13.5$, $MSE = 0.006$, $p < .001$, $d = -0.27$.

Difference scores for picture recall were also calculated as in Experiment 1 (average difference score $= 0.22 \pm 0.03$ *SEM*), and correlated with performance on the cued associative task. As before, we did not observe a significant relationship between difference scores and cued associative memory in either the negative condition, $r^2 = 0.08$, $t(35) = 1.73$, $p > .05$, or the neutral condition, $r^2 = 0.09$, $t(35) = 1.78$, $p > .05$. This suggests that performance in the cued associative test was not a function of memory for the pictures.

For the old–new object recognition test, the proportion of hits (i.e., the proportion of objects correctly identified as "old") was calculated separately for objects associated with neutral and negative pictures for each participant. Corrected recognition rates (hits minus false alarms) were not calculated, as the new objects were not associated with neutral or negative pictures. Therefore, false alarms could not be parsed into neutral versus negative categories. Analysis of the hit rates (Figure 1) did not reveal a significant difference in memory for objects associated with neutral versus negative pictures, $F(1, 35) = 0.024$, $MSE = 0.01$, $p > .1$. This is consistent with findings by Smith, Henson, Dolan, and Rugg (2004). In that study, participants encoded objects transposed onto the centre of complex scenes (neutral, negative, or positive in valence), and were instructed to actively form associations between the objects and the scenes. After a 5-minute delay, participants completed an object recognition task. Similar to our findings, there were no significant differences in memory for objects associated with neutral versus negative scenes (associations between the pictures and objects were not tested).

In sum, we replicated the pattern of findings observed in Experiment 1. That is, we observed disrupted performance in the cued association task when pictures were negative compared to neutral. This occurred despite enhanced memory for the negative pictures and, importantly, despite similar memory (recall and recognition) for objects embedded in negative and neutral pictures. These results support the idea that negative arousing stimuli have disruptive effects on the binding of peripheral information with item information in memory, and furthermore that these findings are neither due to a failure to encode the peripheral objects, nor are they due to the particular stimulus set used in Experiment 1.

EXPERIMENT 3

In Experiments 1 and 2 the order of testing remained constant for all participants. Thus, it is possible that performance on the cued or recognition tests was influenced by the testing order. To address this concern we conducted a between-groups study where one group of participants only completed the cued association test and another group only completed the object recognition test.

Method

Participants. A total of 54 undergraduates (24 men and 30 women) were recruited and received course credit for participation. The participants averaged 23.7 years of age and 15.0 years of education. Treatment of participants was in accordance with the ethical standards of the APA and the University of California; informed consent was obtained from all participants. All participants reported normal or corrected-to-normal vision.

Stimuli, design, and procedure. The design was similar to Experiment 2, however one group of participants (Cued group) only completed the cued association test and a separate group (Recog group) only completed the object recognition test. Both groups completed the picture-rating task. The recall tests were not administered to avoid contaminating the association and recognition data. Therefore, the filler task was extended to 15 minutes so that the time between the study and test phases was similar to that in Experiments 1 and 2.

Results and discussion

A total of 48 participants ($N = 24$ per group) were included in the statistical analyses (6 participants who performed below chance on the cued association or recognition tests were not included in any analysis). Picture ratings were analysed in a 2 (group: Cued, Recog) × 2 (valence: neutral, negative) ANOVA. (In the Recog group, three participants were not included in the rating analysis due to misuse of the scale or declining to complete the task.) There was a main effect of valence, $F(1, 39) = 431.7$, $MSE = 0.57$, $p < .0001$, $d = -5.31$, such that mean ratings for the negative pictures (2.34 ± 0.09 *SEM*) were lower compared to the neutral pictures (5.84 ± 0.10). There was neither a main effect of group nor a group × valence interaction.

For participants in the Cued group, the ability to associate pictures with peripheral objects was poorer for objects associated with negative pictures compared to neutral pictures, $F(1, 23) = 6.40$, $MSE = 0.01$, $p < .05$, $d = -0.39$ (Figure 1). Thus we replicated the findings of Experiments 1 and 2. Importantly, these results suggest that performance on the cued associative test in those experiments was not contaminated by completion of the prior recall and recognition tests.

Recognition performance was calculated as in Experiment 2. For participants in the Recog group, the proportion of hits (Figure 1) was poorer for objects associated with negative pictures compared to neutral pictures, $F(1, 23) = 5.34$, $MSE = 0.01$, $p < .05$, $d = -0.34$. Thus, it is possible that in Experiment 2 the recall tests interfered with performance on the subsequent recognition test, potentially boosting memory for the negatively associated objects. The implication is that the reduced performance for emotion-related items in the cued association test may be the result of inattention to the peripheral objects, rather than disruption in associative memory specifically.

As a way to address this concern, data from Experiment 2 were reanalysed. Participants from that experiment were divided into three groups: those who recalled an equal proportion ($\pm .05$) of negative- and neutral-related objects (Equal group, $N = 18$), those who recalled a greater number of negative-related objects (Negative group, $N = 11$), and those who recalled a greater number of neutral-related objects (Neutral group, $N = 7$). Performance on the cued associative test was then compared across these three groups. In this way, we could specifically determine whether poorer memory for the negative-related peripheral objects was a prerequisite for poorer associative memory for negative pictures and objects. We based our groups on object recall performance, as it was the first memory test administered; therefore the results were not contaminated by prior tests.

Cued associative performance from Experiment 2 was analysed in a 3 (group: Equal, Negative, Neutral) × 2 (valence: neutral, negative) ANOVA, where group was a between-subjects factor and valence was a within-subjects factor. There was a main effect of valence, $F(1, 33) = 14.08$, $MSE = 0.006$, $p < .001$; memory was better in the neutral condition compared to the negative condition, as reported previously (Figure 1). There was neither a main effect of group nor a group × valence interaction. Planned comparisons showed that associative memory was better in the neutral compared to the negative condition for the Equal group (neutral $= 0.58 \pm 0.06$ *SEM*, negative $= 0.53 \pm 0.06$) $F(1, 33) = 3.70$, $MSE = 0.006$, $p = .06$, $d = -0.21$; the Negative group (neutral $= 0.67 \pm 0.07$, negative $= 0.60 \pm 0.08$) $F(1, 33) = 4.78$, $MSE = 0.006$, $p < .05$, $d = -0.30$; and the Neutral group (neutral $= 0.69 \pm 0.09$, negative $= 0.59 \pm 0.10$) $F(1, 33) = 5.75$, $MSE = 0.006$, $p < .05$, $d = -0.36$. The similar pattern of cued associative memory across groups implies that, regardless of memory for the peripheral objects, binding between negative emotional pictures and peripheral objects is reduced compared to neutral emotional pictures and peripheral objects.

GENERAL DISCUSSION

In three experiments, we investigated memory for associations between item information (negative and neutral pictures) and concomitantly presented peripheral objects. Negative pictures were remembered better than neutral pictures, as measured by picture recall (Experiments 1 and 2) and mirror-reversal recognition (Experiment 1) tests. This is consistent with other reports (e.g., Burke et al., 1992; Cahill et al., 1996; Canli et al., 2000). However, we also observed that memory for associations between item and peripheral information was reduced when the item information was negative as opposed to neutral. This finding was independent of the order of testing, as we observed the same reduction in memory even when the cued associative test was administered alone (Experiment 3).

These studies add to previous reports in that the impact of negative arousal on memory for associations between item and peripheral information has not been extensively investigated. To examine this issue, we used a cued associative test that offered a novel means of assessing the binding of peripheral information and item information. This paradigm did not simply assess the mere presence or absence of study items in memory (since no new items were presented during the cued associative test), but asked participants to remember which particular peripheral objects were related to particular central pictures. The results indicated that negative arousal can reduce memory for these associations, beyond the influence of memory for the peripheral information per se. That is, regardless of participants' memory for the peripheral objects, and despite their enhanced memory for the negative pictures, memory for the associations between negatively arousing item and peripheral information was reduced.

These findings are consistent with a study by Anderson and Shimamura (2005). In that study, associative memory for auditory words presented during the viewing of emotional film clips was also impaired when compared to words presented with neutral film clips. However, a reduction in recall for words presented during negative film clips was also noted. In another study by Morgan and colleagues (2004), military personnel participating in a survival training interrogation were less likely to identify the interrogator following high-stress versus low-stress interrogations. Put another way, correctly matching a face to a situation was reduced when that situation was highly emotionally charged, supporting the idea that emotional arousal disrupts associative memory. Of course, the participants in the Morgan et al. (2004) study were under greater physical and psychological duress than our participants (Morgan et al., 2001). Additionally, it may be that the interrogators' faces were central, rather than peripheral, elements. The latter point highlights the potential ambiguities of differentiating central and peripheral information and underscores the importance of disentangling these concepts, as we have attempted to do in these experiments.

In terms of the mechanism underlying the memory disruption we observed, the attentional narrowing hypothesis states that emotional events capture attention at the expense of attention and memory for peripheral information (Christianson, 1992). This idea is consistent with the observed reductions in cued associative performance in the negative condition. Within the attentional narrowing framework, our data can be interpreted as resulting from reduced attention and encoding of the peripheral objects in the negative condition, leading to reduced performance in tasks where knowledge of those objects is required (such as the cued association test). However, this framework would also predict reduced memory for the peripheral objects themselves when they are placed in negative pictures. In contrast, we observed the same pattern of cued associative results regardless of object memory. Thus, it seems that processes other than attentional narrowing are also involved in disrupting memory for associations between negative emotional events and peripheral information.

An alternative mechanism is suggested by a reported reduction in activity in the dorsolateral prefrontal cortex (DLPFC) during a working memory test involving negative emotional stimuli (Perlstein, Elbert & Stenger, 2002). Although we did not explicitly disseminate whether encoding, consolidation, or retrieval was disrupted by emotion in the associative test, the Perlstein et al. (2002) findings suggest that the disrupted associative binding resulted from emotional modulation of working memory during information retrieval. That is, the Perlstein et al. (2002) results suggest that performance in the cued association test was disrupted when participants attempted to recreate and manipulate the information they had stored in memory. Given that the object recall and recognition tests did not require such manipulation, it follows that they were less sensitive to emotional arousal.

Interestingly, the results reported here are not consistent with our previous findings in which memory for colours associated with emotional words was enhanced compared to memory for colours associated with neutral words (Doerksen & Shimamura, 2001). One potential reason for this discrepancy may be due to the relatively low affective impact of emotional words compared to other types of emotional stimuli. Phelps, LaBar, and Spencer (1997) found that patients with unilateral damage to the medial temporal lobe (including the amygdala) were not differentially impaired at remembering emotionally valenced words compared with neutral words. However, these patients were impaired in a fear-conditioning paradigm. These results demonstrate that viewing verbal stimuli elicits less arousal compared to a fear-conditioning paradigm (but see also LaBar & Phelps, 1998).

In summary, we observed enhanced memory for negative emotional stimuli accompanied by reduced associative binding of peripheral information to those emotional stimuli. Although these studies are not a definitive statement on this interaction, they do offer new ways to explore extant questions. For example, as reported by Bradley et al. (1992), arousal seems to be a better predictor of long-term memory than pleasantness; whether this differentiation extends to memory for peripheral information has not been explored. The temporal extent of the influence of emotion on associative binding is also unknown. This is of interest, as some researchers (Burke et al., 1992; Schmidt, 2002; Strange, Hurlemann, & Dolan, 2003) have noted temporally extended effects on memory for item information. These studies also suggest further areas of investigation. Our hypothesis, that emotional arousal influences associative memory during retrieval, should also be explicitly investigated. In addition, we instructed participants to attend and respond to the location of peripheral information, so the extent to which our findings generalise to cases where peripheral information is not intentionally encoded remains an open question. Related to this is the question of how intentional efforts to form associations between peripheral and central information (as in Smith et al., 2004) might influence associative memories. Based on our research it is clear that the impact of emotional arousal on peripheral memory is complex, and further research is needed to expand our understanding of its various facets.

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