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# Memory for specific visual details can be enhanced by negative arousing content

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**Abstract**

Individuals often claim that they vividly remember information with negative emotional content. At least two types of information could lead to this sense of enhanced vividness: Information about the emotional item itself (e.g., the exact visual details of a snake) and information about the context in which the emotional item was encountered (e.g., the fact that the snake was sitting on a branch in a forest). The present study focused on the former, investigating how exposure duration at study and emotional content of an object affected the likelihood of remembering an item's specific visual details. Participants studied neutral objects (e.g., a barometer) and negative arousing objects (e.g., a grenade) and were later shown either the identical object or a different photo of the same type of object (e.g., another barometer). Across two experiments, emotional content enhanced the likelihood that specific visual details were remembered: Individuals were more likely to correctly indicate that an item was identical to the object studied earlier if it was an emotional object than if it was a neutral object. This memory benefit for the emotional items was most robust when items were shown for longer exposure durations (500 or 1000 ms) rather than only briefly (for 250 ms). Thus, with sufficient processing time, negative arousing content appears to enhance the likelihood that visual details are remembered about an object.


*Keywords:* Arousal; Emotion; Memory; Presentation rate; Specific recognition

We can remember information with varying amounts of detail. We might remember looking outside and seeing a cat perched on a bench. Or, we might remember a black and white cat sitting upright on a bench, licking its left paw. Both of these memories may be accurate, yet the latter memory contains much more visual detail than the former.

Recent attention has been focused on whether the emotional content of information affects the amount of detail remembered about an episode. In many instances, individuals will claim to remember an emotional event vividly. An extreme example occurs with *flashbulb memories*, when individuals believe that they have maintained an almost photographic-quality memory of an emotional event (Brown & Kulik, 1977). Even in the laboratory, individuals are more likely to claim that they can vividly retrieve details of an emotional item's occurrence than of a nonemotional item's presentation (Dewhurst & Parry, 2000; Kensinger & Corkin, 2003;

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Ochsner, 2000; Reisberg, Heuer, McLean, & O'Shaughnessy, 1988). These self-report data would suggest that emotional information is remembered with more detail than nonemotional information.

The validity of these self-reports has been brought into question, however, by studies indicating that an individual's confidence in a memory for an emotional event can be uncorrelated with its accuracy (Easterbrook, 1959; Loftus & Burns, 1982; Neisser & Harsch, 1992; Schmolck, Buffalo, & Squire, 2000; Talarico & Rubin, 2003). Furthermore, individuals often will claim that they vividly remember more emotional than neutral items even when there is no corresponding enhancement in old–new discrimination for the emotional items (Ochsner, 2000; Sharot, Delgado, & Phelps, 2004). These findings have led some researchers to propose that the negative, arousing content of information increases primarily the subjective richness associated with a memory, but not its objective accuracy (e.g., Sharot et al., 2004).

Moreover, even if we take these self-report results at face value (i.e., as indicating enhanced vividness for emotional memories), we cannot distinguish among any number of memory features that could be enhanced by emotional content. At a broad level, emotion could be enhancing memory for two types of information: information about the context in which the emotional item occurred (e.g., that a robbery took place late at night; thoughts as the perpetrator approached; etc.), or information pertaining to the visual details of the emotional item itself (e.g., the exact shape of a gun held by a perpetrator). In many prior studies, it has been ambiguous which of these aspects has been enhanced by emotion. For example, a number of studies have demonstrated that arousing content increases the likelihood that individuals will remember the color of font in which a word was written, the screen color on which a word was viewed (D'Argembeau & Van der Linden, 2004; Doerksen & Shimamura, 2001; Kensinger & Corkin, 2003; MacKay et al., 2004), the spatial location of a word (D'Argembeau & Van der Linden, 2004; MacKay & Ahmetzanov, 2005), or whether words or objects were imagined or visually presented (Kensinger & Schacter, 2005). Contextual information presented in a sentence also can be more likely to be remembered if the sentence is emotionally negative versus neutral (Kensinger, Anderson, Growdon, & Corkin, 2004; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002). It often has been argued that these results demonstrate that emotion enhances memory for contextual (''source'') details. However, it also could be postulated that these findings reflect enhancements in memory for visual details of the event: For example, a vivid visual memory for a word's presentation would likely include the color of font in which the word was presented. Moreover, in reality-monitoring studies, both of these enhancements could have contributed to the increased source discrimination for emotional items. Individuals may have remembered information about the context in which the item occurred (e.g., details of the cognitive operations used to form a mental image of the item; thoughts about the photo of the item as it appeared on the screen), and this contextual memory may have enhanced the ability to assign an item to a presented or internally generated source (e.g., Johnson, Hashtroudi, & Lindsay, 1993). However, memory for specific visual details also may have reduced the memory errors by diminishing item confusion. For example, after studying a picture of a cabbage, a participant may later falsely indicate that lettuce was presented if the participant remembers only nonspecific visual features (e.g., remembers seeing a green, leafy food on the computer screen; see Henkel, Johnson, & DeLeonardis, 1998). In contrast, this confusion may occur less frequently for emotional items if they tend to be remembered with more detail, allowing them to be distinguished from other items (see Kensinger & Schacter, in press, for further discussion).

Thus, although these studies have demonstrated that emotional content can enhance the binding of details present at encoding, it has not been clear whether emotional arousal enhances principally the binding of an emotional item to its context, or also the ability to retain specific visual details of the presented items. A recent set of studies by Adolphs, Denburg, and colleagues has suggested that emotional content of information increases the likelihood that the gist of information is remembered but decreases the likelihood that specific visual details are retained (Adolphs, Denburg, & Tranel, 2001; Adolphs, Tranel, & Buchanan, 2005; Denburg, Buchanan, Tranel, & Adolphs, 2003). In those studies, individuals studied scenes that were positive and arousing, negative and arousing, or neutral. To assess gist memory, participants either performed a recognition task for verbal descriptions of the scenes (e.g., ''dead person in the forest''; Adolphs et al., 2001), or were given a recall task (that the authors interpreted as requiring mostly gist information, because an answer such as ''snake on a branch'' would receive full credit, with no mention of the visual details of the snake or the branch; Denburg et al., 2003). To assess memory for visual detail, participants performed a forced-choice recognition task, where the foils were visually quite similar to the original image (e.g., four smiling babies were shown rather than three; or the orientation of a dead body was changed). Critically, emotion enhanced performance on the tasks assessing gist memory, but it impaired performance on the forced-choice recognition task requiring retrieval of specific visual details of the scenes. Their results, therefore, provide evidence that emotion may not always enhance, and in fact may sometimes impair, memory for visual detail.

An important caveat of their results, however, is that they did not distinguish visual details associated with the

emotional aspect of the scene from those peripheral to the emotional aspect: sometimes details of the emotional object were manipulated (e.g., changing the orientation of the dead body in the forest) and sometimes details associated with nonemotional elements of the scene were altered (e.g., changing details of the forest). A vast literature has demonstrated that memory for elements central to the emotional aspect of an event are remembered well, while elements peripheral to the source of arousal are likely to be forgotten. For example, individuals remember emotional scenes as having been "zoomed in" (i.e., they forget information present at the periphery and remember only the information central to the emotional element; Safer, Christianson, Autry, & Osterlund, 1998), and they are less likely to remember information present in the periphery if an emotional item was included in the scene than if only nonemotional items were present (e.g., Brown, 2003; Christianson & Loftus, 1991; Deffenbacher, 1983; Easterbrook, 1959; Kensinger, Piguet, Krendl, & Corkin, 2005; Pickel, French, & Betts, 2003; Shaw & Skolnick, 1994). Thus, it is quite plausible that the results of Adolphs, Denburg, and colleagues would have been different had they varied only aspects tied to the emotional item rather than aspects peripheral to the emotional content of the scenes. In fact, in a prior study that attempted to distinguish gist and specific visual memory separately for central and peripheral elements, it was demonstrated that both gist and specific visual memory were enhanced for aspects of a slide show that were central to the emotional event but that memory for peripheral details was impaired by emotion (Burke, Heuer, & Reisberg, 1992).

An inherent difficulty in these studies of complex scenes regards the definition of what is "central" to the emotional aspect and what is not. For example, while it probably would be agreed that the shape of a gun held by a perpetrator would be a "central" detail, other aspects such as the perpetrator's face, or the color of his or her shirt, are more ambiguous in their classification. Moreover, it is plausible that different mechanisms operate when an item is embedded in a complex display than when it is presented in isolation. To avoid the complications that result when emotional information is presented as part of a complex scene or slide show, we adapted a paradigm used to assess the visual detail remembered for single objects presented one at a time. In brief, this paradigm required participants to distinguish whether an object presented on a recognition test was identical to a studied item, or similar but not identical to a studied item. Similar objects were defined as those that shared the same verbal label as the studied object, but that differed in any number of visual features, including color, shape, size, or orientation (Garoff, Slotnick, & Schacter, 2005; Koutstaal, 2003). Thus, to distinguish same from similar objects, individuals had to remember the specific visual features of the studied objects. By manipulating the emotional nature of the objects, we were able to examine whether negative arousing information is remembered with more visual detail than nonemotional information.

Another goal of the present study was to examine what effect an item's exposure duration at encoding would have on memory for emotional and neutral objects. A vast literature speaks to the relatively automatic and facilitated processing of emotional information (reviewed by Dolan & Vuilleumier, 2003; LeDoux, 1995). On the one hand, it is plausible that this rapid processing of emotional items would increase the likelihood that visual details of an object were encoded, regardless of the object's presentation rate. On the other hand, it also is possible that primarily low-level visual features of emotional objects are processed rapidly. This rapid extraction of low-level visual features, but not of more specific visual information, could explain why, for example, we come to a halt upon encountering a wavy branch in the forest: We have processed the rudimentary visual details suggesting that the stimulus could be a potential threat but not the visual details that would allow us to determine whether something is a twig or a snake (discussed by LeDoux, 1995). Thus, at fast presentation rates, individuals may not be better able to encode visual details of emotional objects as compared to neutral objects. To distinguish these alternatives, the present experiments examined whether exposure duration at encoding interacted with the emotional content of items in influencing the likelihood that visual details of studied objects were remembered.

## Experiment 1

Two central questions were examined in Experiment 1. First, we asked whether negative arousing content enhances the likelihood that objects are remembered with visual detail. Second, we examined whether the effect of negative arousing content is modulated by the exposure duration of objects during encoding. To address these questions, we asked participants to study negative arousing objects and neutral objects. Half of the items were presented for 250 ms and half for 500 ms. At retrieval, participants indicated whether each object on the recognition test was the "same" as a studied item, "similar" to a studied item, or a "new" item. Consistent with previous studies using variants of this paradigm (Garoff et al., 2005; Koutstaal, 2003), we considered "same" responses to a studied item to reflect memory for specific visual details ("specific recognition") and "similar" responses to a studied item to indicate memory for at least some (but not all) aspects of the studied item. Collectively, studied items given either a "same" or a "similar" response reflected those for which

at least some information was remembered (referred to below as "general recognition"). We considered "new" responses to a studied item as indicative of forgetting. Thus, this paradigm allowed us to assess the effects of negative arousing content and study duration on memory for (a) specific visual details ("specific recognition") and (b) the likelihood that any information was remembered about a studied item ("general recognition"). It also allowed assessment of what proportion of items that were recognized were remembered with specific visual detail (i.e., "specific recognition"/"general recognition").

## Materials and methods

### Participants

Twenty-four participants (11 men, 13 women[1]) took part in this experiment. All were native English-speaking Harvard University students (mean age = 19.9 years, range = 18–27 years). All participants had normal or corrected-to-normal vision, and all were screened to exclude those with a history of neurological trauma or psychiatric disorder. No participant was taking any centrally acting medications. Informed consent was obtained from all participants in a method approved by the Harvard University Institutional Review Board.

### Materials

Materials comprised colored, nameable photo objects (Hemera Technologies, 2002, Canada). Images were shown on a white background and were formatted using PicStationX so that they were 300 pixels in their longest dimension (many objects taken from Kensinger & Schacter, in press). Three hundred and eighty-six pairs of objects were selected, such that the two items of a pair shared the same verbal label (e.g., were both umbrellas) but differed in other perceptual features (e.g., color, shape, size, and orientation). One hundred and ninety-three of the object pairs consisted of objects that had been rated by 20 Harvard University undergraduate students as negative and arousing objects. The other 193 object pairs consisted of objects that had been rated as neutral. The negative, arousing objects all had received mean valence ratings of less than −2 (on a scale of −5 to +5, with negative values indicating negative valence, and positive values indicating positive valence) and mean arousing ratings of more than 2.5 (on a scale of −5 to +5, with negative values indicating that an item was calming or soothing, and positive values indicating that an item caused excitation or agitation). The neutral objects all had received mean valence ratings between −1 and +2.5, and mean arousal ratings lower than +1. Thus, the emotional items were significantly lower in valence and significantly higher in arousal than the neutral items (all $p < .001$). The two members of an object pair were selected such that they were items with nearly identical arousal ratings.

Pairs of stimuli (e.g., two barometers; two grenades) were selected to assure that the emotional and neutral item pairs were matched for (a) the overall similarity of the two items, (b) the dimensions (color, size, shape, and orientation) that differed between the two items, (c) the number of items that were bigger or smaller than a shoebox, and (d) the familiarity of the items (as explained below).

### Overall similarity

Overall similarity of each pair of items was rated by 10 Harvard University summer school students, with each pair being rated on a scale of 1 (members of a pair were incredibly similar to one another) to 10 (incredibly different). For the final pairs of objects that were used in the experiment, there was no difference between the similarity ratings for the emotional object pairs (mean = 5.85, $SD = 1.15$) and for the neutral object pairs (mean = 5.99, $SD = .92$, $t < 1$, $p > .2$).

### Dimensions of change

The dimensions that could differ between the two items of a pair (color, shape, size, and orientation) were rated by two Harvard University students. A rating of 0 indicated that no change in a particular dimension occurred (e.g., if both pumpkins were orange, the rating for color change would be 0); a rating of 0.5 indicated a slight change in a dimension (e.g., a light green pine tree versus a dark green pine tree would receive a rating of 0.5 for color) and a rating of 1 indicated a substantial change (e.g., a red apple versus a green apple would receive a rating of 1 for color). For each dimension, the scores from the two raters were averaged and these averages were compared for the emotional and neutral object pairs. For the pairs of objects used in the experiment, there was no significant effect of emotion on the ratings for color change (mean for emotional = .48, mean for neutral = .54), size change (mean for emotional = .23, mean for neutral = .28), shape change (mean for emotional = .44, mean for neutral = .42), or orientation change (mean for emotional = .71, mean for neutral = .67). There also was no difference in the sum of change scores across all of the different dimensions (sum for emotional = 2.46, sum for neutral = 2.56, all $t < 1.3$, $p > .2$).

[1] There were no effects of gender, so data from men and women are combined in all analyses. While some studies have reported effects of gender on memory for emotional information (e.g., Bremner et al., 2001; Burton et al., 2004; Cahill, Gorski, Belcher, & Huynh, 2004; reviewed by Hamann & Canli, 2004), others have not. It may be that sex-related traits, rather than sex per se influence memory (e.g., Cahill et al., 2004) or that only particular paradigms elicit robust effects of sex on emotional memory.

*Size judgments*

Size was rated by one Harvard University student. For the pairs of objects used in the experiment, roughly half fit inside of a shoebox, and there was no difference in size ratings between the emotional and neutral objects.

*Frequency and familiarity*

To assure that the emotional and neutral objects were of similar familiarity, we calculated the word frequency and word familiarity for the verbal labels of the objects (Coltheart, 1981) and selected stimuli such that the emotional and neutral objects did not differ in these dimensions. We also asked a Harvard University student to rate the stimuli for familiarity on a scale of 1 (highly unfamiliar) to 10 (highly familiar). The ratings were comparable for the emotional objects (mean = 6.75) and the neutral objects (mean = 6.67, $t < 1$, $p > .2$).

*Study procedure*

Participants were presented with 304 nameable, colored objects. These objects were presented across four lists, with each list containing 76 items. In each list, half of the objects had been rated as negative and arousing and the other objects were neutral.

In each list, half of the objects from each emotion condition were shown for 250 ms, and half were shown for 500 ms. The presentation length of the items was counterbalanced across participants. Following the item's presentation, a fixation cross (+) was presented for a variable duration (range of 6–14 s). The order of items was pseudorandomized for each participant, such that no more than four items from an emotion or presentation condition were presented sequentially.

Participants were instructed to indicate by key press whether each object, in the real world, would fit inside of a shoebox. Participants were shown the shoebox prior to the start of the study.

*Test procedure*

Two days later, an object recognition task was administered. This delay was chosen because pilot data indicated that neither ceiling nor floor effects occurred at this delay interval. Participants had not been instructed that there would be a memory test, and debriefing indicated that no participant expected that his or her memory would be assessed. (Incidental encoding was used to minimize the likelihood that participants initiated any mnemonic strategies to help them encode the visual details of the presented items.) On the recognition task, participants were presented with three different types of objects: (1) objects identical to those that had been studied (*same* objects), (2) objects that were similar (i.e., shared the same verbal label) but not identical to studied objects (*similar* objects), and (3) *new* objects (Fig. 1).

At test, each object appeared in the center of the screen, with a prompt below indicating that participants should indicate, by key press, whether the item was *same*, *similar*, or *new*. After the participant made his or her response, a new prompt appeared asking the participant to make a confidence rating (high or low confidence). The emotional content of items did not affect the distribution of confidence ratings, and all analyses conducted using only the high confidence scores showed the same pattern of results (i.e., the same main effects and interactions in the ANOVAs) as the analyses conducted on all of the responses collapsing across confidence. Therefore, we will not discuss confidence ratings further. The same object within the object pair was tested across all participants; the items presented at study were counterbalanced between subjects to manipulate the condition of each object shown at recognition (*same, similar*, or *new*).

Thus, for items studied at each presentation rate, 38 from each emotion condition were tested as *same* items and 38 were tested as *similar* items. An additional 38 items of each emotion condition were presented as *new* items, bringing the total number of items on the recognition test to 380.

*Results*

The data from Experiment 1 are presented in Table 1: The proportion of items given a ''same,'' ''similar,'' or ''new'' response are reported as a function of item type (*same, similar*, or *new*), exposure duration (250 or 500 ms) and emotion type (neutral, negative arousing). We were interested in examining the effects of emotional content on the three different types of items presented at recognition (*new* items, items that were *similar* to studied items, and items that were the *same* as studied items; Fig. 1). For the *similar* and *same* items, we were also interested in the effects of exposure duration on memory performance: Would items that had been presented for a longer duration at study be more likely to be accurately recognized as ''same'' or ''similar''? How would the effects of emotion interact with effects of exposure duration? We were most interested in the effect of emotion and presentation rate on ''same'' responses to *same* and *similar* items and on ''similar'' responses to *same* items. ''Similar'' responses to *similar* items are ambiguous because they could reflect either specific recognition (i.e., someone may remember the exact object that was studied, and know that the object they are viewing is not identical) or nonspecific recognition (i.e., someone may remember the type of object studied [''I saw a teapot''] but not the exact visual features and therefore assign a ''similar'' response).

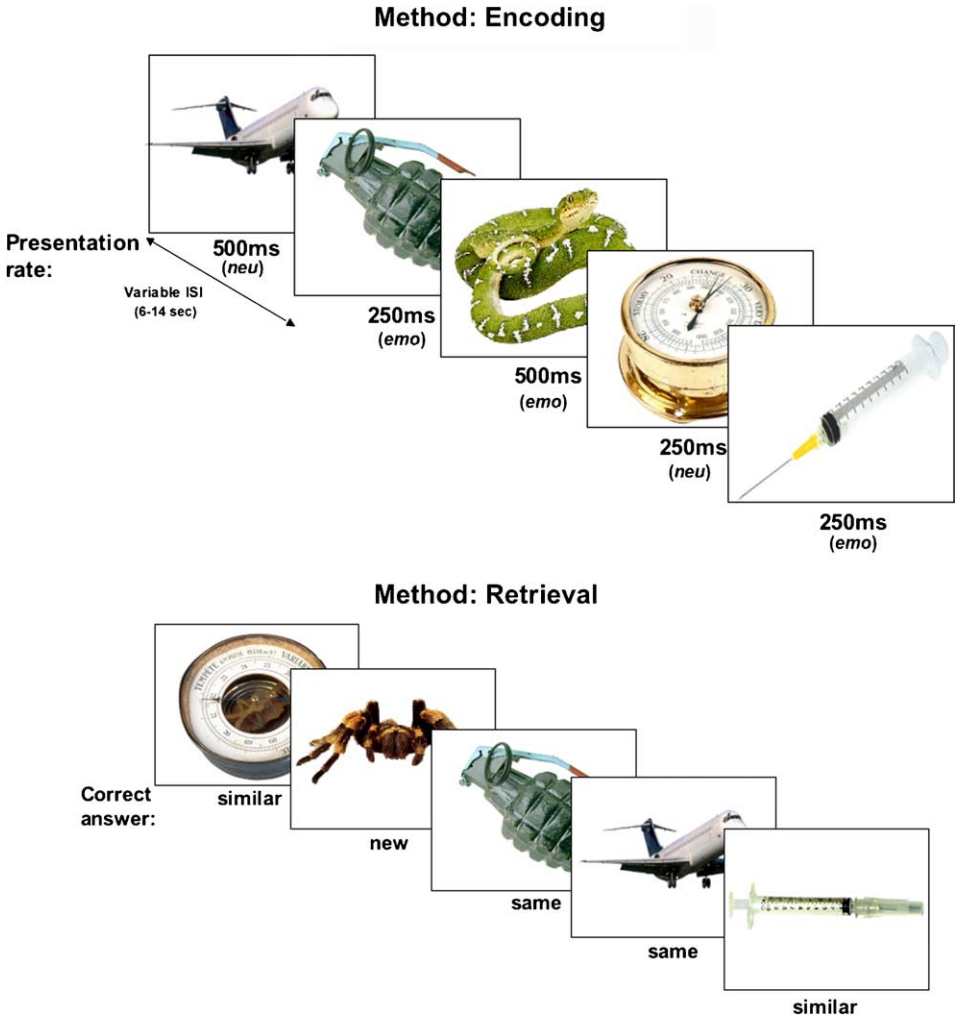


Fig. 1. Task design: At study, participants viewed objects for 250 or 500 ms. Half of the objects were negative and arousing (e.g., grenade), and the other half were neutral (e.g., barometer). At test, participants were presented with emotional and neutral objects that were either the *same* as a studied item, *similar* to a studied item, or *new*. Half of the *same* and *similar* items of each emotion type had been studied for 250 ms and half for 500 ms. Participants indicated whether the item was "same," "similar," or "new."

Table 1
Experiment 1: Mean responses (*SE*) for neutral and emotional objects as a function of item type (*same*, *similar*, or *new*), exposure duration (250 or 500 ms), response type ("same," "similar," or "new") and emotion type (neutral or negative arousing)

| Response | Same 250 ms | Similar 250 ms | Same 500 ms | Similar 500 ms | New |
|---|---|---|---|---|---|
| *Neutral* | | | | | |
| "Same" | .40 (.04) | 0.22 (.03) | 0.46 (.04) | 0.23 (.02) | 0.09(.02) |
| "Similar" | 0.31 (.02) | 0.42 (.03) | 0.32 (.02) | 0.44 (.03) | 0.27 (.03) |
| "New" | 0.29 (.04) | 0.36 (.04) | 0.23 (.03) | 0.33 (.03) | 0.64 (.03) |
| *Negative arousing* | | | | | |
| "Same" | 0.41 (.04) | 0.21 (.03) | 0.52 (.03) | 0.25 (.02) | 0.09 (.02) |
| "Similar" | 0.29 (.02) | 0.43 (.03) | 0.26 (.02) | 0.40 (.02) | 0.25 (.03) |
| "New" | 0.30 (.03) | 0.37 (.04) | 0.22 (.02) | 0.35 (.03) | 0.66 (.03) |

*New items*

For the *new* items, we conducted an ANOVA with response type (''same,'' ''similar,'' and ''new''), and emotion (negative arousing, neutral) as within-subject factors. This ANOVA indicated a significant effect of response type ($F(2,46) = 97.71$, $p < .0001$, partial eta-squared = .92) but no main effect of emotion or interaction between emotion and response type. The effect of response type emerged because individuals were more likely to call a *new* item ''new'' than they were to call it ''same'' or ''similar.'' This pattern of results was identical for the emotional and the neutral items (i.e., individuals were equally likely to correctly reject new emotional and new neutral items). Moreover, when an item was falsely endorsed as a studied item, it was called ''similar'' more often than it was called ''same'' (all $t(23) > 5.2$, $p < .0001$; Table 1).

*Similar items*

For the *similar* items, we conducted an ANOVA with response type, emotion, and presentation rate (250 ms, 500 ms) as within-subject factors. This ANOVA revealed only a significant main effect of response type ($F(2,46) = 8.75$, $p < .001$, partial eta-squared = .28). Separate ANOVAs conducted for the items studied for 250 ms and for the items studied for 500 ms confirmed that, for both exposure durations, there was a main effect of response type ($F(2,46) = 7.84$, $p < .001$, partial eta-squared = .25 for the *similar* items studied at 250 ms; $F(2,46) = 8.31$, $p < .001$, partial eta-squared = .26 for the *similar* items studied at 500 ms) but no interaction between response type and emotion type (partial eta-squared < .06). Thus, while individuals were most likely to call *similar* items ''similar'' (and less likely to call them ''same'' or ''new''), this effect was not modulated by emotional content (Table 1).

*Same items*

For the *same* items, an ANOVA indicated a significant main effect of response type ($F(2,46) = 8.9$, $p < .001$, partial eta-squared = .28), an interaction between response type and exposure duration ($F(2,46) = 11.12$, $p < .0001$, partial eta-squared = .33), between response type and emotion type ($F(2,46) = 3.24$, $p < .05$, partial eta-squared = .12), and a marginal three-way interaction between response type, exposure duration, and emotion type ($F(2,46) = 3.01$, $p < .1$, partial eta-squared = .10). These results suggested that the interaction between response type and emotion type was modulated by the exposure duration of the items.

Separate ANOVAs were conducted for the items studied at each presentation rate. These ANOVAs clarified that for *same* items studied for 250 ms, there was a marginal effect of response type ($F(2,46) = 2.52$, $p < .1$, partial eta-squared = .10) but no interaction between response type and emotion type (partial eta-squared = .02). Thus, at this faster presentation rate, individuals were more likely to indicate that a *same* item was ''same'' than they were to indicate that it was ''similar'' or ''new,'' but the magnitude of this effect was not modulated by emotion (Table 1). In contrast, for *same* items studied for 500 ms, there was a significant effect of response type (partial eta-squared = .44) and also a significant interaction between response type and emotion type ($F(2,46) = 4.12$, $p < .05$, partial eta-squared = .15). At this slower presentation rate, individuals' specific recognition responses (i.e., saying ''same'' to *same* items) were enhanced for the emotional items ($t(23) = 2.36$, $p < .05$) while their general recognition responses (the sum of ''same'' and ''similar'' responses to *same* items) were comparable for the emotional and neutral items; ($t(23) < 1$).

These results for *same* items provided evidence that emotion can enhance the specificity with which an individual remembers an object. They also provided suggestive but relatively weak evidence (a marginal three-way interaction) that this emotion-mediated effect on memory specificity was enhanced when items were studied for 500 ms compared to 250 ms. A more sensitive way to address this hypothesis is to examine whether presentation rate affected the likelihood that emotion boosted the probability of remembering an item with specific visual detail given that at least some aspects of the item were remembered. This calculation allowed us to examine what proportion of the items for which general recognition occurred (i.e., for which ''same'' or ''similar'' responses were given) also were associated with specific recognition (i.e., a ''same'' response). These proportional scores were calculated as: ''same'' responses/(''same'' + ''similar'' responses). We then conducted an ANOVA on these proportional scores, with presentation rate and emotion as within-subject factors. This ANOVA revealed a main effect of presentation rate ($F(1,23) = 7.31$, $p < .05$, partial eta-squared = .24) and an interaction between presentation rate and emotion type ($F(1,23) = 4.88$, $p < .05$, partial eta-squared = .17). This interaction emerged because the specific recognition proportion was greater for emotional items than for neutral items when the corresponding items had been studied for 500 ms ($t(23) = 2.63$, $p < .05$), whereas there was no effect of emotional content on the specific recognition proportion when the corresponding items had been studied for 250 ms[2] ($t(23) < 1$; Fig. 2).

[2] These effects did not reflect a general bias for participants to assign ''same'' responses to emotional objects. There was no effect of emotional content on the proportion of *same* responses given to similar items, regardless of whether the corresponding items had been studied for 250 ms ($t(23) < 1$) or 500 ms ($t(23) < 1.3$).

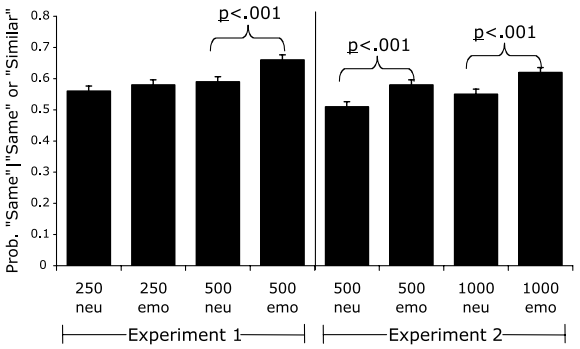


Fig. 2. The probability that participants gave a correct response of "same" to a *same* item, given that they recognized the item as either a "same" or a "similar" item (i.e., the probability that participants showed specific recognition of a *same* item, given that they had any recognition for the item). This probability was equal for the neutral and emotional items with a 250 ms exposure duration, but was enhanced for the emotional items shown at 500 or 1000 ms.

### *Discussion*

The goal of this experiment was to examine the effects of negative arousing content on the likelihood of remembering the visual details of an object, and whether the study duration altered these effects of emotional content. The primary conclusion to emerge from this experiment was that items with emotional content were more likely to be remembered with specific visual detail than items lacking in emotional relevance. In particular, emotion enhanced an individual's ability to recognize a *same* object on the recognition test as being the "same" as a studied object. There was no effect of emotion on responses to the *new* or *similar* items.

While the central message from Experiment 1 is that emotion can enhance the specificity of memory, two other patterns in the data merit discussion. First, there was suggestive evidence that presentation rate may influence these effects on memory specificity. When items were studied for only 250 ms, memory specificity did not differ significantly for the emotional and the neutral items, whereas robust effects of emotion on memory specificity arose when items were studied for 500 ms. An effect of presentation rate on memory for emotional information also was demonstrated in a recent investigation of visual short-term memory, using the rapid serial visual presentation task (Maljkovic & Martini, 2005). In that study, encoding of negative information was found to accelerate more rapidly than the encoding of neutral information during the first 500 ms of exposure. Thus, negative stimuli were better remembered than neutral or positive stimuli when exposure was around 400 ms or greater, but not with faster exposure durations. The results of Experiment 1 are consistent with these findings, suggesting that sufficient study time may be required to maximize the benefits of negative emotional content on memory.

Second, for the items studied for 500 ms, the enhancement in specific recognition was robust but there was not a significant alteration in general recognition. Individuals were equally likely to remember at least some aspects of neutral items and emotional items. These results parallel the self-report data of Ochsner (2000) and Sharot et al. (2004): Both studies found that negative emotional content enhanced the likelihood that individuals claimed to remember studied items vividly but had no effect on the likelihood of calling a previously studied item "old." The results of Experiment 1 suggest that these prior data may not merely reflect individuals' biases to believe that they vividly remember an emotional item (see Sharot et al., 2004 for discussion). Rather, the results of the present study suggest that, at least in some instances, emotional content can enhance the likelihood that specific visual details are remembered while not altering the general recognition (i.e., memory for any features) of studied items. In other words, emotion can increase the proportion of remembered items that are associated with vivid detail while not affecting the overall proportion of items remembered.

In sum, the results of Experiment 1 provided strong evidence that emotion can enhance the likelihood that specific details are remembered about items. These results confirm those of a prior investigation (Burke et al., 1992) using a very different paradigm and stimulus set, suggesting that this emotion-mediated enhancement in memory specificity is likely to occur across a range of settings. The results, however, also suggest that the effects of emotion on memory may be somewhat focal: Effects were strongest when items were studied for 500 ms, and they exerted the strongest influence on specific recognition rather than general recognition. This set of results led to the question of whether, with a longer presentation rate, the effects of emotion might become less focal, influencing not only the rates of specific recognition, but also the likelihood of general recognition. To examine this issue, Experiment 2 assessed memory for items presented at 500 and 1000 ms.

## Experiment 2

In Experiment 1, emotional content enhanced specific recognition (saying "same" to a *same* object), with the effect being particularly robust when items were presented at the slower (500 ms) presentation rate. In Experiment 2, we examined whether with even slower presentation (1000 ms), the effects of emotional content would be altered. A few possibilities seemed plausible. At the slower exposure duration, the effect of emotional content might extend to general recognition as well as to

specific recognition: Individuals might be less likely to forget an emotional item, and also more likely to remember the specific visual details of those items for which they had some memory (see Burke et al., 1992). Another alternative, however, was that the effects of emotion on memory might be less pronounced at 1000 ms than at 500 ms. Perhaps with the additional exposure to the neutral items, participants' memories for those objects would be just as good as their memories for the emotional objects (i.e., emotional content might enhance memory for specific visual details only at intermediate presentation rates). A final possibility was that the effects of emotion on memory could be comparable at the 500 and 1000 ms presentation rates; perhaps at both presentation lengths, emotion would enhance the likelihood of specific recognition, but would not influence the likelihood that at least some aspects of items were remembered (i.e., would not influence general recognition).

## Method

### Participants

Participants were 24 Harvard University undergraduate students (8 men and 16 women, mean age = 20.1, age range = 18–28), who met the same criteria as outlined in Experiment 1.

### Materials and procedure

The materials were identical to those of Experiment 1. The procedure was identical, except that the two presentation rates used at study were 500 and 1000 ms, rather than 250 and 500 ms as in Experiment 1.

## Results

The data from Experiment 2 are presented in Table 2: The proportion of items given a "same," "similar," or "new" response are listed as a function of item type (*same, similar*, or *new*), exposure duration (500 or 1000 ms) and emotion type (neutral or negative arousing). To examine the effects of emotion on memory for items studied for 500 and 1000 ms, we conducted ANOVAs for the three different types of items presented on the recognition task: *new* items, items that were *similar* to studied items, and items that were the *same* as studied items.

### New items

For the *new* items, an ANOVA indicated a main effect of response type ($F(2,46) = 131.40$, $p < .0001$, partial eta-squared = .85), and an interaction between emotion and response type ($F(2,46) = 7.48$, $p < .01$, partial eta-squared = .25). This interaction resulted because individuals were more likely to call a *new* item "new" if it was emotional than if it was neutral ($t(23) = 3.24$, $p < .01$), less likely to call a *new* item "similar" if it was emotional ($t(23) = 2.34$, $p < .05$), and marginally less likely to call a *new* item "same" if it was emotional ($t(23) = 1.87$, $p < .08$).

### Similar items

For the *similar* items, an ANOVA revealed only a significant main effect of response type ($F(2,46) = 20.36$, $p < .0001$, partial eta-squared = .47), but no effect of presentation rate or emotion, nor any significant interactions. As expected, when separate ANOVAs were conducted on the items with a 500 or 1000 ms exposure duration, the analyses indicated only a main effect of response type ($F(2,46) = 17.08$, $p < .001$, partial eta-squared = .43 for the items presented for 500 ms; $F(2,46) = 17.78$, $p < .001$, partial eta-squared = .44 for the items presented for 1000 ms), but no interaction between response type and emotion (partial eta-squared < .07). Thus, just as in Experiment 1, individuals were more likely to label a *similar* item "similar" than they were to label it "same" or "new," and this pattern of responses to the *similar* items was not affected by the emotional content of the items.

### Same items

An ANOVA conducted on the *same* items indicated a significant effect of response type ($F(2,46) = 13.56$, $p < .0001$, partial eta-squared = .37), as well as interac-

Table 2
Experiment 2: Responses (mean, *SE*) for neutral and emotional objects as a function of item type (*same*, *similar*, or *new*), exposure duration (500 or 1000 ms), response type ("same," "similar," or "new") and emotion type (neutral or negative arousing)

| Response | Same 500 ms | Similar 500 ms | Same 1000 ms | Similar 1000 ms | New |
|---|---|---|---|---|---|
| *Neutral* | | | | | |
| "Same" | 0.38 (.03) | 0.14 (.02) | 0.42 (.03) | 0.19 (.02) | 0.07 (.01) |
| "Similar" | 0.36 (.03) | 0.49 (.04) | 0.34 (.03) | 0.49 (.04) | 0.34 (.03) |
| "New" | 0.26 (.04) | 0.36 (.05) | 0.24 (.03) | 0.31 (.04) | 0.59 (.03) |
| *Negative arousing* | | | | | |
| "Same" | 0.44 (.03) | 0.15 (.02) | 0.53 (.03) | 0.17 (.02) | 0.06 (.01) |
| "Similar" | 0.33 (.02) | 0.52 (.04) | 0.33 (.02) | 0.49 (.04) | 0.29 (.02) |
| "New" | 0.23 (.03) | 0.32 (.04) | 0.15 (.02) | 0.34 (.03) | 0.66 (.02) |

tions between response type and presentation rate ($F(2,46) = 3.78$, $p < .05$, partial eta-squared = .14), response type and emotion type ($F(2,46) = 8.71$, $p < .001$, partial eta-squared = .28), and among response type, presentation rate, and emotion type ($F(2,46) = 3.49$, $p < .05$, partial eta-squared = .13).

We conducted separate ANOVAs for the items studied at 500 and 1000 ms. For the items with a 500 ms presentation rate, the ANOVA indicated a significant main effect of response type ($F(2,46) = 5.53$, $p < .01$, partial eta-squared = .19) and an interaction between response type and emotion ($F(2,46) = 4.13$, $p < .02$, partial eta-squared = .15). For the items with a 1000 ms presentation rate, the ANOVA also indicated a significant main effect of response type ($F(2,46) = 20.57$, $p < .001$, partial eta-squared = .47) and an interaction between response type and emotion type ($F(2,46) = 9.77$, $p < .001$, partial eta-squared = .30). Post hoc $t$ tests confirmed that for items studied at both the 500 and 1000 ms presentation rates, individuals were more likely to later correctly recognize the *same* items as "same" if they were emotional than if they were neutral ($t(23) = 2.82$, $p < .01$ for 500 ms presentation; $t(23) = 3.71$, $p < .001$ for 1000 ms presentation).

For the 500 ms presentation rate, the results replicated those of Experiment 1, in that the interaction between response type and emotion type was driven by the change in the specific recognition responses, and not in the general recognition of the objects: Sums of "same" and "similar" responses to *same* items did not differ based on the emotion type ($t(23) < 1.4$). For items studied for 1000 ms, however, not only did emotion enhance specific recognition, it also increased general recognition. The sums of "same" and "similar" responses were greater for *same* emotional items than for *same* neutral items ($t(23) = 3.09$, $p < .01$; Table 2).

The results discussed so far for the *same* items suggested that for items presented for either 500 or 1000 ms, emotional content confers a memory advantage in terms of increasing the specific recognition responses. To further examine the validity of this conclusion, we calculated the probability that participants showed specific recognition of a *same* item, given that they had remembered at least some aspects of the item (i.e., the probability that a same item was labeled "same," given that it was labeled "same" or "similar" [not "new"]). We then conducted an ANOVA on these proportions, with presentation rate and emotion as within-subject factors. This ANOVA revealed main effects of presentation rate ($F(1,23) = 5.65$, $p < .05$, partial eta-squared = .20) and emotion ($F(1,23) = 7.77$, $p < .01$, partial eta-squared = .25) as well as an interaction between the two ($F(1,23) = 7.17$, $p < .05$, partial eta-squared = .24). This interaction reflected the fact that, when individuals showed any recognition of an item (assigning a "same" or "similar" response to a *same* item), a greater proportion of those recognition responses were based on specific recognition for the emotional items than for the neutral items ($t(23) = 2.45$, $p < .05$ for items studied at 500 ms; $t(23) = 2.89$, $p < .01$ for items studied at 1000 ms[3]). There were no interactions with presentation rate. Thus, given that at least some aspects of an item were remembered, presentation rate did not affect the likelihood that specific visual information was available. Following both 500 and 1000 ms presentation durations, emotional items that were remembered were more likely to be recognized with specific visual details than were neutral items that were remembered (Fig. 2).

### *Discussion*

The central question asked in Experiment 2 was whether the effects of emotion that existed when objects were studied for 500 ms (i.e., increased specific recognition) would remain unchanged when items were studied for a longer (1000 ms) duration, or whether the effects of emotion would be altered when items were studied for a longer period of time. The results of Experiment 2 indicate that emotional content continues to enhance specific recognition, even when items are studied for 1000 ms. Moreover, with the longer presentation rate, emotional content also seems to affect general recognition: Individuals were more likely to remember at least some aspects of items (i.e., that they had seen a particular type of item) if it was an emotional object presented for 1000 ms than if it was a neutral object presented for 1000 ms.

Prior research has been mixed with regard to whether or not emotion enhances the likelihood that any information is recognized about an item (e.g., overall recognition scores; Abrisqueta-Gomez, Bueno, Oliveira, & Bertolucci, 2002; Johansson, Mecklinger, & Treese, 2004; Kensinger & Corkin, 2003; Kensinger & Schacter, in press; Windmann & Kutas, 2001) or only the likelihood that information is remembered vividly (e.g., Ochsner, 2000; Sharot et al., 2004). The present results indicate that both types of memory benefits can occur (see also Burke et al., 1992): When items are processed for a longer period of time, emotional content appears to enhance not only the amount of specific information (or visual detail) remembered about an item, but also the likelihood that any information (specific or general) will be remembered.

[3] As in Experiment 1, these effects did not reflect a general bias for participants to assign "same" responses to emotional objects. Emotion did not affect the distribution of "same" responses given to *similar* items ($t(23) < 1$ for items studied at 500 and 1000 ms).

## General discussion

Abundant evidence indicates that individuals believe that they remember emotional information vividly (e.g., Dewhurst & Parry, 2000; Kensinger & Corkin, 2003; Ochsner, 2000; Reisberg et al., 1988). It has been debated to what extent these self-report data reflect accurately on the detail with which emotional information is remembered (e.g., Easterbrook, 1959; Loftus & Burns, 1982; Sharot et al., 2004). While previous studies have demonstrated that negative arousing content can enhance the likelihood that various aspects of an event are remembered (e.g., the spatial location of a word, whether an object was visually presented or mentally imagined; D'Argembeau & Van der Linden, 2004; Doerksen & Shimamura, 2001; Kensinger & Schacter, in press; MacKay & Ahmetzanov, 2005), the results have been ambiguous with regard to whether emotion enhances memory for an item's specific visual details, with some evidence indicating an enhancement (e.g., Burke et al., 1992) and other data suggesting a decrement (e.g., Adolphs et al., 2001).

The present results provide strong evidence that negative arousing content can increase the likelihood that the specific visual details of an emotional object are remembered. A few factors may contribute to this enhancement. For one, emotional arousal has strong effects on attention deployment: Attention appears to be focused automatically and preferentially on emotionally arousing stimuli, increasing the likelihood that emotional items are perceived. For example, individuals are more likely to detect emotional objects in complex arrays than they are to detect nonemotional ones (Ohman, Flykt, & Esteves, 2001), and in cuing paradigms, emotional cues are more effective than neutral ones in directing participants' attention to a particular location on a screen (Armony & Dolan, 2002; Mogg, Bradley, de Bono, & Painter, 1997). Moreover, emotionally arousing items appear privy to prioritized or facilitated processing, such that emotional items can be processed even when attention is limited or divided (reviewed by Dolan & Vuilleumier, 2003). Thus, emotional items are less susceptible to the attentional blink than are nonemotional ones (Anderson & Phelps, 2001), and patients with visual extinction are less likely to ignore an emotional stimulus presented to the contralesional visual field than they are to ignore a nonemotional stimulus (e.g., Vuilleumier & Schwartz, 2001). These attentional effects of emotion may relate to the enhanced memory for visual details demonstrated here. The encoding of visual details may have occurred more automatically for the emotional items than for the neutral items. This hypothesis is consistent with neuroimaging data indicating that visual activity is greater during the processing of emotional information compared to neutral information (Lang et al., 1998; Vuilleumier, Richardson, Armony, Driver, & Dolan, 2004; Wang, McCarthy, Song, & LaBar, 2005) and that these effects can occur even with limited attention (Morris, Ohman, & Dolan, 1999; Vuilleumier, Armony, Driver, & Dolan, 2001; Lane, Chua, & Dolan, 1999).

This attentional focus could have enhanced memory for visual details in another way as well: For emotional items, a greater proportion of time may have been spent attending to the visual stimulus rather than to other types of information (either nonvisual details related to the presented item, or task-irrelevant information). As discussed in the introduction, emotional elements in a scene often appear to be attended at the cost of information present in the periphery (e.g., Brown, 2003; Burke et al., 1992; Kensinger et al., 2005; Safer et al., 1998). This focusing will mean that encoding resources will be more likely to be focused on the visual percept of the emotional item than on other information in the environment. Although the stimuli used in the present experiment were single objects, and therefore attention did not have to be diverted from other visual elements presented on the computer screen, it is still possible that other aspects of the testing environment (including thoughts associated with the types of items presented) were more likely to distract attention from encoding of the visual form of the neutral items compared to the emotional items. It is even possible that these differences in attention deployment could explain why the effects of emotion were most robust with longer presentation durations. At 250 ms, participants' attention may have been focused on the visual form of the neutral or emotional items for their entire presentation duration. With longer durations, in contrast, it is possible that attention began to divert from the visual percept, but that this diversion occurred more frequently for the neutral items than for the emotional items. Such a diversion of attention may also explain why the longer presentation rates boosted specific recognition significantly for the emotional stimuli but had less of an effect on specific recognition for the neutral stimuli: Participants may not have attended to the visual percept of the neutral items for the entire time that they were on the computer screen, whereas such focal attention may have been more successful for the emotional items. Future studies will be required to investigate the generality of this finding; it is currently unclear whether sufficient study time is required principally when encoding of specific visual details is required, or whether insufficient study duration can reduce emotional memory enhancement effects across a range of paradigms.

This attentional explanation may describe how the emotional content of the items affected specific recognition through effects at encoding. It is well known, however, that the emotional content of information also can influence other stages of memory processing (consolidation and retrieval). For example, memory enhancements

for emotional information increase as delay intervals lengthen (e.g., Sharot & Phelps, 2004), and researchers have postulated that these effects arise because items with emotional content are more likely to be consolidated into a stable memory trace that will accessible after a delay than are items lacking in emotional meaning (reviewed by McGaugh, 2000; Phelps, 2004). Evidence to support this hypothesis has come from both animal and human studies demonstrating interactions between emotion processing regions (particularly the amygdala) and the hippocampus, a region known to be essential for memory consolidation (reviewed by Phelps, 2004). Thus, it is likely that the specific visual details of the emotional stimuli were more likely not only to be encoded but also to be bound into a stable memory trace.

The emotional items also may have benefited from effects at retrieval. Emotional information is thought to be more distinctive than neutral information because of the various additional dimensions associated with the emotional information (e.g., personal relevance and physiological response; Christianson & Engelberg, 1999; LeDoux, 2002). It has been proposed that this enhanced distinctiveness may make it more likely that individuals are able to successfully access the information that has been encoded, thus increasing their ability to remember information vividly (Dewhurst & Parry, 2000; Kensinger & Corkin, 2003; Ochsner, 2000) and accurately (Kensinger & Corkin, 2004; Kensinger & Schacter, in press; Pesta, Murphy, & Sanders, 2001). Therefore, it is plausible that the enhanced distinctiveness of the emotional information contributes to the effects revealed in this study.[4] To summarize, we suggest that attentional modulation at encoding mediates many of the effects of emotion demonstrated here (and may explain some of the effects of presentation duration suggested by the present data), but that effects during consolidation and retrieval also may play an important role. Future studies will be required to tease apart the effects of emotion on these different phases of memory.

[4] It is worth noting that while enhanced distinctiveness often is found to increase accurate recognition and to decrease false recognition, we did not find evidence of a "mirror effect" (Glanzer & Adams, 1990). Although "same" to *same* responses were enhanced by emotion, "same" to *similar* responses were not affected. However, it is important to note that "same" to *similar* responses do not necessarily reflect only inaccurate retrieval: Participants can have accurate recollection of some number of item details and yet still falsely endorse an item if not all critical details are remembered (e.g., participants could remember correctly that a gold-colored, circular barometer was presented at study and yet still make the incorrect decision at retrieval since these features would not accurately distinguish the *same* from the *similar* barometer; Fig. 1).

It is interesting to note that the present results diverge from the findings of a couple of prior studies demonstrating that emotional content enhanced memory for gist, but impaired memory for visual detail (Adolphs et al., 2001; Denburg et al., 2003). This contradiction likely depends on differences in the types of stimuli and tasks used. One likely factor relates to the elements of the scenes for which memory for detail was assessed. It is likely that in complex scenes, memory for the elements central to the source of emotional arousal are remembered with rich visual detail (Burke et al., 1992), while elements more peripheral to the emotional arousal are forgotten altogether or remembered without visual detail (Brown, 2003; Burke et al., 1992; Christianson & Loftus, 1991; Heuer & Reisberg, 1990; Safer et al., 1998). In the present study, memory was boosted for the details of the emotional items themselves; we hypothesize that if these objects were placed into scenes, memory for the details of the scenes would not be enhanced, and in fact might be impaired, by the presence of (and attention focus on) the emotional item.

Another prospective resolution may relate to the encoding task used. In studies that have found impaired memory for visual details of emotional scenes (Adolphs et al., 2001, 2005; Denburg et al., 2003), the incidental encoding tasks have been unconstrained (i.e., passive viewing of the scenes), thus allowing attention to be focused on any element of the scene. In contrast, the present experiments used a controlled and constrained encoding task (making size judgments about the stimuli). Thus, attention was likely directed toward the item features in a specified way that may have prevented an extraction of gist information at the expense of memory for visual detail.

In conclusion, although prior studies had led to mixed conclusions regarding the effects of emotion on the likelihood of remembering visual detail, the present experiments provide strong evidence that negative arousing content can increase the likelihood that visual details of objects are remembered. These effects of emotion were most robust when items were studied for longer than 250 ms. Moreover, with the longest study duration assessed (1000 ms), the benefits of emotional content extend from a targeted effect on specific recognition of visual details to include a benefit in general recognition (i.e., an enhanced ability to remember at least some aspects of emotional compared to neutral items). These results suggest an interplay between encoding duration and memory enhancement for emotional information, and indicate that negative arousing content can influence not only the subjective feeling of vividness associated with a memory (Dewhurst & Parry, 2000; Kensinger & Corkin, 2003; Ochsner, 2000; Reisberg et al., 1988), but also the likelihood that specific visual details are remembered about a previously encountered emotional item.

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