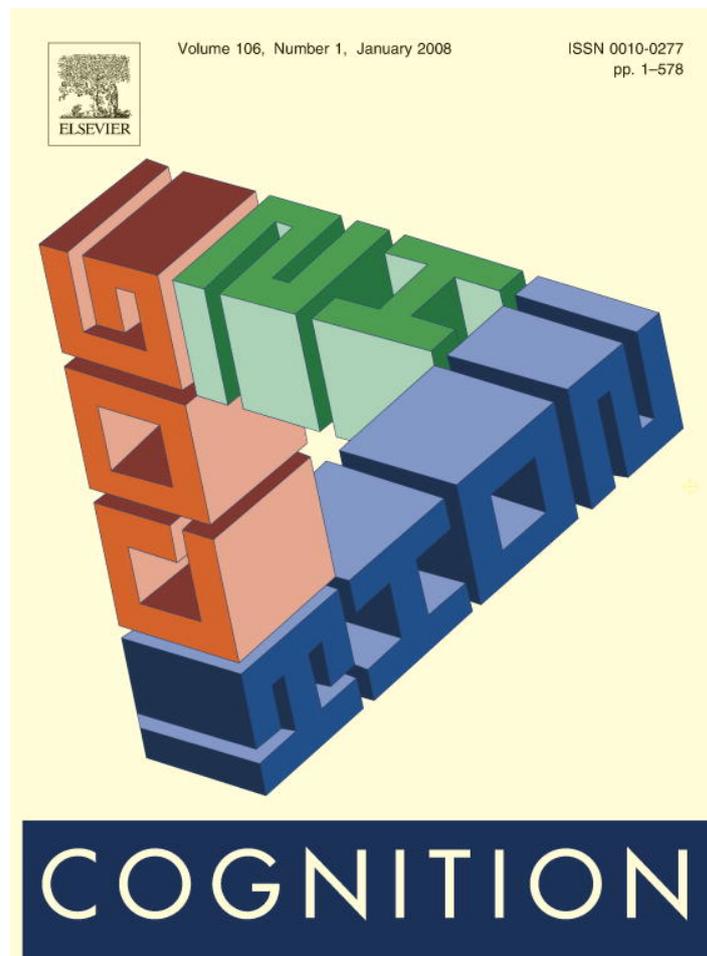


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Brief article

Differential time-dependent effects of emotion on recollective experience and memory for contextual information

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Abstract

Emotion has been suggested to slow forgetting via a mechanism that enhances memory consolidation. Here, we investigate whether this time dependent process influences the subjective experience of recollection as well as the ability to retrieve specific contextual details of the study event. To do so we examined recognition for emotional and neutral pictures at two retention intervals and collected remember/know reports and reports about the task that had been performed with the item during encoding. Recollective experience was enhanced for emotional compared to neutral photos after a 24-h delay, but not immediately after encoding. In contrast, memory for the task performed during encoding did not differ between emotional and neutral photos at either time point. The findings indicate that emotion slows the effects of forgetting on the recollective experience associated with studied events, without necessarily slowing the forgetting of specific contextual details of those events.

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1. Introduction

When recalling an event from our past we often do not just bring to mind the details of that incident (such as when and where), rather – we mentally re-experience the event (Tulving, 1985). The recollective experience can indicate the authenticity of the memory content. For neutral stimuli, a rich and vivid recollective experience is usually coupled with improved memory for the episodic context in which the stimuli was presented (Perfect, Mayes, Downes, & Van Eijk, 1996). It is unclear, however, if this is the case for emotional stimuli. While emotion has consistently been reported to boost the recollective experience (Dolcos, LaBar, & Cabeza, 2004, 2005; Dougal & Rotello, *in press*; Kensinger & Corkin, 2003; Ochsner, 2000; Sharot, Delgado, & Phelps, 2004; Sharot, Martorella, Delgado, & Phelps, 2006), the results from studies examining the modulation of memory for contextual information by emotion have been mixed. For example, emotion has been shown to enhance the ability to distinguish seen from imagined items (Kensinger & Schacter, 2005a, 2005b, 2006a), visually presented words from heard words (Kensinger & Schacter, 2006b), and in some cases, but not all (see D'Argembeau & Van der Linden, 2004), to determine the color of fonts in which words were presented during encoding (Doerksen & Shimamura, 2001; Kensinger & Corkin, 2003). Emotion did not, however, enhance memory for a task performed during encoding (Kensinger & Schacter, 2006b), or increase memory for color-location associations (Mackay, Hadley, & Schwartz, 2005). Thus, emotion seems to enhance memory for contextual information in some cases but not others.

The mixed effects of emotion on contextual memory observed in the existing literature may be related in part to the way in which emotion interacts with memory retention to slow the process of forgetting. A substantial body of research indicates that emotion alters memory storage (Cahill, Babinsky, Markowitsch, & McGaugh, 1995; Hamann, Ely, Grafton, & Kilts, 1999; McGaugh, 1992; Packard & Teather, 1998). It has been suggested that neurohormonal changes in response to emotional events activate β -adrenergic receptors in the amygdala, which in turn enhances hippocampal-dependent memory consolidation (McGaugh, 2000). Because consolidation of memory occurs over a period of time, the beneficial effects of arousal on memory should be most apparent following a delay. Consistent with this hypothesis, studies have shown that while recognition accuracy for neutral items decreases over time, recognition accuracy for arousing items remains relatively constant, and in some cases even improves over time (LaBar & Phelps, 1998; Sharot & Phelps, 2004). The same pattern of results was also found for memory accuracy for neutral items previously paired with arousing items (e.g. Baddeley, 1982; Kleinsmith & Kaplan, 1963; Levonian, 1966; Walker & Tarte, 1963).

The documented effect of emotion on consolidation of memory for items raises the possibility that it might also modulate the consolidation of memory for contextual information. Thus far, all studies examining the influence of emotion on memory for contextual details have tested memory at only one point in time, usually a short while after encoding (e.g., Anderson & Shimamura, 2005; Kensinger & Schacter, 2006a, 2006b; May, Rahhal, Berry, & Leighton, 2005). These studies were unable to fully examine the modulation of memory for contextual information by emotion,

which may be apparent or enhanced only after a delay. The same holds for studies examining the recollective experience for emotional stimuli. They too have only tested memory at one point in time (e.g., Dolcos, LaBar, & Cabeza, 2005; Ochsner, 2000; Sharot et al., 2004), and thus were unable to determine if slower forgetting contributes to the effect of emotion on the recollective experience, consistent with modulation of consolidation or retention.

Here we investigate how time dependent effects of emotion influence recollective experience and memory for contextual details. To date, the influence of emotion on the recollective experience has not been studied together with its influence on memory for contextual details in a single experiment (but see Kensinger & Corkin, 2003, for separate experiments), and neither factor has been examined at different retention intervals. In the current study, participants made judgments about the encoding context (i.e., indicating which task they were performing during incidental encoding of the stimulus) as well as “remember/know” judgments for emotional and neutral photos encountered either 5 min or 24 h prior to the recognition test. In the “remember/know” recognition test (Tulving, 1985) subjects are asked to classify previously experienced stimuli as either (i) vividly “remembered” stimuli that evoke a specific memory for the episodic context in which the stimuli was experienced, such as a thought, feeling, or sensory detail, or as (ii) a stimuli that is “known” to have been experienced earlier but does not bring to mind a recollection of a specific episode.

Two possible patterns of results seem quite plausible. First, since recollection has been suggested to underlie both subjective “remember” judgments and memory for contextual details (Yonelinas, 2002), emotion’s modulation of recollection may concurrently improve memory for context and the subjective sense of remembering over time. Alternately, given that the increase in the recollective experience with emotion is not always accompanied by better recognition accuracy (Ochsner, 2000; Sharot et al., 2004) or memory consistency (Talarico & Rubin, 2003), emotion may enhance recollective experience without necessarily enhancing memory for contextual information.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Twenty four undergraduate students at the University of California Davis (age range 18–22) participated in the study. All participants gave informed consent and received course credit for their participation.

2.1.2. Stimuli

Stimuli consisted of 180 negatively arousing photos, and 180 neutral photos, selected from the International Affective Photo Series (IAPS), based on their standard scores for emotional arousal and emotional valence (Lang et al., 1999), and from our own set of neutral pictures to equate the two sets for the presence of humans and visual complexity (Sharot et al., 2004). Photos were rated in a previous

study for valence and arousal (Sharot et al., 2004). Valence was rated on a scale from 1 (positive) to 9 (negative). Neutral photos were rated as neutral ($M = 3.75$, $SD = 1.07$) and emotional photos as negative ($M = 7.69$, $SD = 0.52$); $t(10) = 14.23$, $P < .0001$. Arousal was rated on a scale from 1 (not at all arousing) to 9 (very much arousing). Neutral photos had lower arousal ratings ($M = 3.03$, $SD = 0.83$), than emotional photos ($M = 6.79$, $SD = 1.15$); $t(11) = 10.67$, $P < .0001$.

2.1.3. Paradigm

Participants were given an incidental encoding task in two sessions separated by approximately 24 h. In each session the encoding task consisted of 120 trials, which included the presentation of 60 neutral photos and 60 emotional photos. The lists of photos presented on each day were different from each other, and counterbalanced between subjects. On each trial a photo was presented for 1s, after which the participant had 2s to rate the photo for visual complexity. Then a fixation cross appeared for 6s. The trials were separated into four blocks of 30 trials each. In two of the blocks the participants were instructed to take into consideration the colors of the photo when rating its visual complexity (we will refer to these as the “color task” trials), in the other two blocks they were instructed to consider the amount of visual detail when rating the visual complexity of the photo (we will refer to these as the “detail task” trials). For half of the participants, the “color task” blocks preceded the “detail task” blocks on day 1, and vice-versa on day 2. For the other half of participants, the order was reversed.

Immediately after the encoding session on day two participants were trained at making a “remember”/“know” judgment (Rajaram, 1993); after reading the detailed instructions they were asked to explain the difference between “remember” and “know” judgments in their own words, and were then given practice trials in which they verbally justified their “remember” responses. The recognition test included the presentation of 360 photos; 60 old negatively arousing photos presented the previous day, 60 old negatively arousing photos presented that day, 60 old neutral photos presented the previous day, 60 old neutral photos presented that day, 60 new negatively arousing photos, and 60 new neutral photos. Stimuli were presented in a random order on a computer screen. Each trial consisted of the presentation of a photo for 2s, followed by 3s to indicate whether the photo was new, “remembered”, or “known”, by pressing the appropriate key. Then the participants had 3s to indicate whether the photo was presented during the “color task” blocks, “detail task” blocks, was old but the participant could not remember in which type of block it was presented, or if the photo was new. Finally a fixation cross appeared for 4s. The trials were separated into six blocks of 25 trials each.

3. Results

3.1. Overall item recognition

Item recognition accuracy was examined by subtracting the overall false alarm rate from the overall hit rate in each experimental condition (Fig. 1). A 2 (type of

photo:emotional/neutral) by 2 (retention interval:immediate/24 h) repeated measures ANOVA indicated that there was an interaction, $F(1, 23) = 27.37$, $P < .0001$, reflecting that recognition was better for emotional photos than neutral photos after a retention interval of 24 h ($t(23) = 3.82$, $P < .001$), but not immediately after encoding. In addition, recognition for neutral photos was greater immediately after encoding than after a retention interval of 24 h, ($t(23) = 6.69$, $P < .0001$), whereas recognition for emotional items did not differ significantly across the delay conditions.

3.2. “Remember” responses

Remember responses (R) were measured as the proportion of old items receiving a remember response minus the proportion of new items receiving this response (see Table 1 for *uncorrected* proportion of remember responses for old and new emotional and neutral items). This correction for false alarms was necessary because the false remember rate for new items was greater for emotional (mean = 0.06) than neutral (mean = 0.04) photos; $t(23) = 2.3$ $P < .05$. These R scores were then subjected to a 2 (type of photo:emotional/neutral) by 2 (retention interval:immediate/24 h) repeated measures ANOVA. The analysis revealed a significant interaction $F(1, 23) = 4.35$, $P < .05$, indicating that the retention interval modulated the effects of emotion on remembering. The results of a within subjects t -test indicate that the interaction was due to an increase in R responses for emotional compared to neutral stimuli after a 24 h retention interval ($t(23) = 3.96$, $P < .001$), but not after the short retention interval (5 min) (Fig. 1).

3.3. “Know” responses

Table 1 presents the proportions of know responses for old and new items, and indicates that these responses were not noticeably affected by emotion or delay. Because know responses are mathematically constrained by remember responses the raw scores were not statistically analyzed. Rather, know responses were used to derive estimates of familiarity (e.g., $K = K_{hit}/(1 - R_{hit}) - (K_{fa}/(1 - R_{fa}))$, (Yonelinas & Jacoby, 1994), and these estimates were submitted to an analysis of variance. There was a significant interaction $F(1, 23) = 22.79$, $P < .0001$, indicating that retention interval modulated the effects of emotion on K responses. The results of a within subjects t -test indicate that the interaction reflected the fact that K responses were greater for emotional stimuli relative to neutral stimuli after a 24 h retention interval ($t(23) = 3.96$, $P < .001$), but not after only a short retention interval. False alarms were greater for emotional (mean = 0.16) than neutral photos (mean = 0.12); $t(23) = 2.23$ $P < .05$.

3.4. Source memory

A 2 (type of photo:emotional/neutral) by 2 (retention interval:immediate/24 h) repeated measures ANOVA was conducted on source accuracy (as indexed by

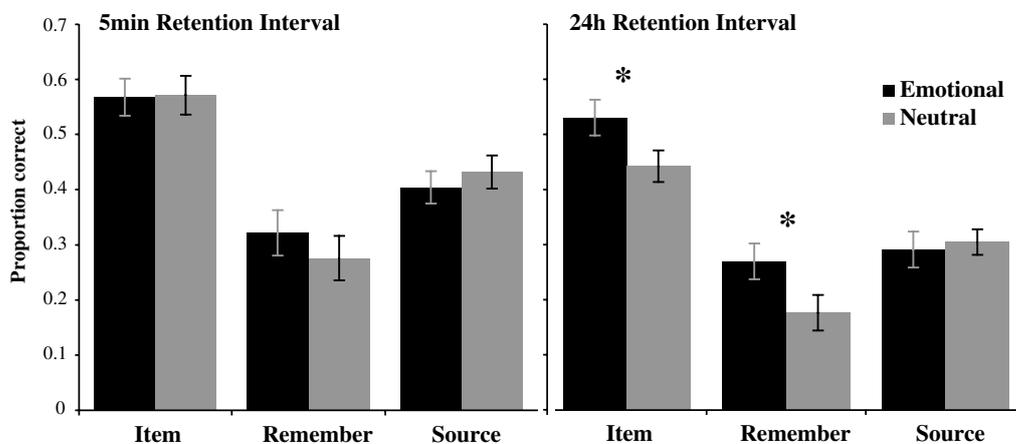


Fig. 1. Emotion enhances subjective recognition judgments over time without effecting source memory. Remember = (“remember”/old) – (“remember”/new). Source = correct source/overall hits. Item = Hits – False alarms. * $P < .001$ (Error bars = sem).

photos for which source was correctly identified/photos correctly identified as old). In contrast to the results of the recognition and remember/know results, source memory was not significantly influenced by emotion, at either the short or long delay periods (Fig. 1). Source memory was characterized by a reliable main effect of time $F(1, 23) = 12.52$, $P < .005$, with better source memory for photos tested immediately after encoding than 24 h after encoding. The results of a within subjects t -test indicate that source memory was greater immediately after encoding than after a retention of 24 h for both neutral photos ($t(23) = 4.61$, $P < .001$), and emotional photos ($t(23) = 4.4$, $P < .001$). All other comparisons and interaction were not found to be significant.

4. Discussion

The results suggest that the time-dependent effects of emotion on memory influence recollective experience, but do not necessarily benefit memory for specific contextual information. While an enhancement in the recollective experience is usually accompanied by better memory for contextual details related to the stimulus presentation (Perfect et al., 1996), our findings indicate that this is not always the case when the source of the enhancement is emotion. We found a boost in “remember” judgments for emotional photos relative to neutral photos after a 24 h retention interval. However, a parallel boost in memory for the type of task performed during encoding was not observed. This is surprising given that the recollection component of recognition is thought to underlie both “remembering” and memory for context (Yonelinas, 2002). The results suggest that emotion does not provide a general enhancement of recollection, rather it boosts particular aspects of recollection in a selective manner. Emotion may enhance the recollective experience, as well as memory for some

Table 1
Proportion of remember and know responses for old and new emotional and neutral items

	Remember responses				Know responses			
	Emotional		Neutral		Emotional		Neutral	
	Old	New	Old	New	Old	New	Old	New
5 min	.38	.06	.31	.04	.41	.16	.44	.12
24 h	.37		.21		.44		.40	

aspects of the event that may be of adaptive value (e.g., the ability to distinguish seen from imagined items – [Kensinger & Schacter, 2005a, 2005b, 2006a](#)), without boosting memory for other, possibly less significant, contextual details.

Strikingly, emotion had no effect on memory immediately after encoding, but notably modulated memory after a delay. There was a significant time by stimuli interaction for overall recognition as well as both “remember” and “know” judgments, but not for source memory judgments. The findings may be understood in light of recent brain imaging studies showing that amygdala activation at encoding is related to subsequent memory for emotional items ([Kensinger & Schacter, 2006b](#)) and “remember” judgments for those items ([Dolcos et al., 2004](#)), but not to subsequent memory for the task performed during encoding ([Kensinger & Schacter, 2006b](#)). Non-human studies show that the amygdala is essential in activating the process by which emotion enhances memory consolidation ([McGaugh, Cahill, & Roozendaal, 1996](#)). Thus, we speculate that our behavioral results reflect a mechanism by which amygdala activation at encoding related to the presentation of an emotional item triggers a mechanism that modulates memory storage of that item, thereby also enhancing the subjective qualities of that memory. Amygdala activity does not seem to be related to the formation of a memory trace corresponding to contextual information during encoding of the emotional item ([Kensinger & Schacter, 2006b](#)), and thus that information does not benefit from slower forgetting.

In the current study emotional stimuli differed from neutral stimuli on both the dimensions of valance and arousal. Thus, on the basis of the current results alone it is not clear whether the effects of emotion on recognition were related to valance or arousal. However, given behavioral and neuroimaging evidence ([Dolcos et al., 2004; Kensinger & Schacter, 2006b](#)) that arousal rather than valance is the key feature underlying the modulation of memory by emotion, and that arousal is specifically related to the boost in “remember” responses ([Dolcos et al., 2005](#)), it is most likely that the emotion effects we observed were due to the differences in arousal rather than valance per se. Nevertheless, future research is needed to determine whether the same effects of emotion on memory would be observed for stimuli that are equated on arousal but differ on valance and vice-versa.

The results of the current study converge with previous remember/know studies in showing that emotion enhances remembering (e.g., [Ochsner, 2000; Sharot et al., 2004](#)). However, unlike those previous studies, knowing was also found to be enhanced by emotion. The reason for this discrepancy may be related to the inclusion of the source judgment task in the current experiment. When memory for source

was not available, participants' confidence may have been undermined, potentially making them less inclined to respond "remember". Thus, they may have responded "know" when otherwise they would have given a "remember" response, so that the emotional advantage began to affect knowing responses. To examine this hypothesis we compared "know" judgments for emotional and neutral stimuli at the delay condition while controlling for source judgments for emotional stimuli.¹ As predicted, after controlling for source judgments the emotional advantage for knowing was no longer significant.

In sum, the results suggest that the enhancement in the recollective experience with emotion reflects the operation of a time-dependent process that acts to preferentially protect emotional memories from forgetting. This finding is consistent with previous studies showing better recognition accuracy for emotional items only after a delay (e.g., Sharot & Phelps, 2004), and with the notion that emotion triggers a mechanism that enhances consolidation (McGaugh et al., 1996) thus making emotional memories more accessible after a delay, compared to neutral memories. Although we did not observe a significant emotion advantage in the immediate test, emotion may have beneficial effects on recognition even without a delay, perhaps after different encoding conditions or with different materials. That is, emotion's effects on attention and perception during encoding (Anderson & Phelps, 2001; Fox, Russo, Bowles, & Dutton, 2001) may boost the recollective experience immediately (Dougal & Rotello, in press; Kensinger & Corkin, 2003, 2004). However, the present findings suggest that the emotional advantage is greater over time due to enhanced consolidation.

The results indicate that emotion selectively facilitates the retention of only some aspects of the memory. Although at first glance counterintuitive, the modulation of the recollective experience by emotion independent of absolute accuracy of contextual information can be of adaptive value. Most peripheral details of emotional memories are not important for predicting future events, and thus may not promote survival. However, accessibility to a vivid representation of a significant, emotional event, as well as memory for some of its core features, may be critical for ensuring that it guides behavior.

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¹ An ANCOVA comparing know judgments for emotional and neutral stimuli at time 2, with source memory judgments for emotional stimuli at time 2 as a covariate, did not reveal a significant difference between know judgments for emotional and neutral stimuli $F(2,2) = 2.52$ $P > .1$. Note, that conducting the same analysis on remember judgments did not change the initial finding; remember judgments for emotional stimuli were still greater than for neutral stimuli regardless of source judgments $F(2,2) = 12.95$, $P < .002$.

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