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Emotion Enhances the Subjective Feeling of Remembering, Despite Lower Accuracy for Contextual Details

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Abstract

Emotion strengthens the subjective experience of recollection. However, these vivid and confidently remembered emotional memories may not necessarily be more accurate. We investigated whether the subjective sense of recollection for negative stimuli is coupled with enhanced memory accuracy for contextual details using the remember/know paradigm. Our results indicate a double-dissociation between the subjective feeling of remembering, and the objective memory accuracy for details of negative and neutral scenes. "Remember" judgments were boosted for negative relative to neutral scenes. In contrast, memory for contextual details and associative binding was worse for negative compared to neutral scenes given a "remember" response. These findings show that the enhanced subjective recollective experience for negative stimuli does not reliably indicate greater objective recollection, at least of the details tested, and thus may be driven by a different mechanism than the subjective recollective experience for neutral stimuli.

Keywords

emotion; memory; subjective sense of remembering; remember/know; confidence

Emotion enhances the subjective sense of remembering—that is, the subjective vividness of the memory, the sense of reliving the emotional event, and confidence in the accuracy of the memory (Sharot, Martorella, Delgado, & Phelps, 2007; Talarico & Rubin, 2003). For instance, studies of flashbulb memories indicate that emotional real-life events compared to mundane events are reexperienced with a greater sense of recollection, vividness, confidence, and a greater belief in accuracy (Neisser & Harsch, 1992; Neisser et al., 1996; Sharot, Martorella et al., 2007; Talarico & Rubin, 2003). Surprisingly, however, the enhanced recollective experience for emotional events is often not accompanied by enhanced accuracy of these memories (Christianson & Engelberg, 1999; Hirst et al., 2009;

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Neisser & Harsch, 1992; Schmolck, Buffalo, & Squire, 2000; Talarico & Rubin, 2003). For example, in a study investigating recollection of the terrorist attacks of September 11, 2001, the participants reported higher levels of confidence, vividness, recollection, and belief of accuracy in their 9/11 memories compared to memories of an everyday event. Yet, the accuracy for details did not differ between these memories, both declining over time (Talarico & Rubin, 2003).

This discrepancy is particularly striking given evidence that a rich and vivid recollective experience (i.e., the recollection component of recognition) is thought to be associated with accurate recovery of contextual details from the previous encounter (Yonelinas, 2002). It is hypothesized that during recollection, specific qualitative information about the context of the encoding episode, for example, the spatial, temporal, or social context of the event that was encoded is brought back to mind (Johnson et al., 1993; Awipi & Davachi, 2008). The accessibility of these contextual details can drive the subjective recollective experience (Johnson & Raye, 1981). Perfect, Mayes, Downes, & Van Eijk (1996) directly examined the relation between the subjective recollective experience and the recovery of contextual details using the remember/know paradigm and an additional judgment for specific contextual details. In the remember/know paradigm, participants are instructed to provide a “remember” judgment when the stimulus brings to mind a vivid memory accompanied by details of the encoding episode (i.e., recollection). A “know” response indicates that the stimulus was recognized, but that the memory is not accompanied by episodic details (i.e., often referred to as item familiarity; Yonelinas, 2002; Tulving, 1985; Rajaram, 1993). Perfect et al. (1996) found that, for neutral events, “remember” responses were accompanied by enhanced accurate recovery of contextual details. In addition, the type of contextual detail did not matter. For stimuli judged as “remembered”, participants showed greater memory accuracy over a range of contextual details, such as temporal order, spatial location, visual appearance, or internal and external associations. Besides remember/know judgments, in one experiment, Perfect et al. (1996) also assessed high and low confidence judgments for each recognized item. Similar to the pattern observed for remember/know judgments, high confidence judgments were associated with enhanced recovery of contextual details.

Whether the heightened recollective experience of emotional stimuli may likewise be coupled with improved memory accuracy for contextual details has not yet been investigated. Findings from studies with real-life emotional events point toward a dissociation between the subjective recollective experience for emotional stimuli and memory accuracy for contextual details (Talarico & Rubin, 2003). Laboratory evidence likewise hints toward this dissociation. It has been consistently shown that the subjective sense of remembering is higher for emotional relative to neutral stimuli (Dolcos, LaBar, & Cabeza, 2005; Dougal, Phelps, & Davachi, 2007; Kensinger & Corkin, 2003; Ochsner, 2000; Sharot, Delgado, & Phelps, 2004; Sharot, Verfaellie, & Yonelinas, 2007; Sharot & Yonelinas, 2008). However, studies investigating the effects of emotion on memory for contextual details have yielded mixed results. Some studies find emotion to enhance memory for contextual details, while others fail to show this effect, or even report emotion to impair memory for contextual details (see Mather, 2007 for review). Previous findings indicate that the emotional memory enhancement is specific for central details of the emotional stimulus at the expense of memory for peripheral details (Heuer & Reisberg, 1992; Reisberg & Heuer, 2004). This phenomenon has been referred to as tunnel memory and found to be specific for negative emotions (Safer, Christianson, Autry, & Österlund, 1998; Talarico, Berntsen, & Rubin, 2009). Extending the tunnel memory concept, it has been hypothesized that the mixed effects of emotion on memory for contextual details may be due to emotion-induced enhanced binding between an emotional item and its constituent features, but ineffective or even impaired binding between the emotional items and other distinct contextual details (Mather, 2007). Another conceptually related hypothesis states that rather than arousal it is negative valence that enhances binding of intrinsic but not extrinsic memory features (Kensinger, 2007; Kensinger, 2009; Mather & Sutherland, 2009). Consistent with both the “object-based framework” and the “intrinsic versus extrinsic dissociation” hypotheses, it has been shown that emotion enhances memory for features inherent to the emotional stimulus (e.g., the font color, specific visual details, or spatial location; D’Argembeau & Van der Linden, 2004; Doerksen & Shimamura, 2001; Dougal et al., 2007; Kensinger & Corkin, 2003; Kensinger, Garoff-Eaton, & Schacter, 2006, 2007a, 2007b; MacKay & Ahmetzanov, 2005; MacKay et al., 2004; Mather et al., 2006; Mather & Nesmith, 2008). In addition, consistent with these hypotheses, emotion has been found to have no effect or impair memory of features not inherent to the emotional stimulus, such as the type of encoding task or a contextual item (Burke, Heuer, & Reisberg, 1992; Cook, Hicks, & Marsh, 2007; Kensinger & Schacter, 2006; Sharot & Yonelinas, 2008; Touryan, Marian, & Shimamura, 2007). Critically two recent studies showed that emotion particularly disrupts the associative binding of a contextual neutral item to an emotional event (Mather & Knight, 2008; Touryan et al., 2007).

Interestingly, none of the above-mentioned studies have examined the relationship between the enhanced subjective sense of recollection consistently observed for emotional stimuli and recollection of contextual details or the binding between emotional stimuli and contextual details. Thus it remains unclear whether emotional memories that are vividly reexperienced are actually accurate in their details and features bound to them. Given that previous studies on the one hand find that emotion enhances the subjective feeling of remembering, but on the other hand that emotion disrupts memory for contextual detail and memory binding, it is possible that the heightened subjective sense of recollection for emotional stimuli is dissociated from the accurate recollection of contextual details and memory binding. In the present study we set out to investigate these two phenomena concurrently. Specifically we examined whether there is a dissociation between “remember” judgments for neutral and negative stimuli and the recovery of episodic contextual details and contextual detail binding. We hypothesized that emotional scenes are remembered with an enhanced feeling of remembering, but that recovery of contextual details, and the recovery of the association between contextual details and the scene contribute more to the subjective sense of recollection for neutral than emotional scenes.

Experiment 1

Method

Participants—The study sample consisted of 25 subjects (M = 22.58, SD = 4.46 years, 13 female). All participants provided written informed consent and were paid for their participation. The study was approved by the University Committee on Activities Involving Human Subjects (UCAIHS) at New York University.

Stimuli—During the encoding stage, 60 scenes (30 neutral, 30 negative) were presented. At test, the studied scenes were intermixed with a set of 60 novel scenes (30 neutral, 30 negative). The scene sets presented at encoding and test were counterbalanced across subjects. All scenes had been selected from the International Affective Picture Set based on their normative ratings provided for emotional arousal and valence assessed with the Self-Assessment Manikin (SAM) scale (1 = *unhappy*, 9 = *happy*; 1 = *calm*, 9 = *excited*; Lang, 1999). Based on their normative ratings the scenes were divided into an emotional (arousal: M = 5.62 SD = .63, valence: M = 2.88 SD = .74) and a neutral set (arousal: M = 3.87 SD = .94, valence: M = 5.58 SD .60). To confirm the normative ratings the participants (N = 28) of Experiment 2 rated the scenes on arousal and valence at the end of the study using the identical SAM rating scale. The ratings of our subjects confirmed, as expected, higher arousal and lower valence for the scenes grouped into the emotional set (arousal: M = 6.12

SEM = .28; valence: *M* = 2.45 *SEM* = .11) than for the scenes grouped into the neutral set (arousal: *M* = 4.01 *SEM* = .24, $t(27) = 6.14$, $p < .001$; valence: *M* = 5.70 *SEM* = .10, $t(27) = 19.19$, $p < .001$). Negative and neutral scenes were matched on visual complexity. Visual complexity was rated by a separate group of participants (*N* = 5) on a scale from 1 (*not at all complex*) to 9 (*highly complex*). Neutral (*M* = 4.77, *SD* = 1.53) and emotional (*M* = 5.24, *SD* = 1.40) scenes did not differ in their visual complexity ($p > .26$). For both the emotional and neutral scene sets, approximately 2/3 depicted humans, the remaining 1/3 depicted animals and inanimate scenes to an equal degree. The scene set used as foils also depicted about 2/3 humans and 1/3 of animals and inanimate objects. However target scenes and foil scenes did not share the same semantic content (e.g., a snake was only on a target scene or a foil scene).

Each scene was presented inside a colored frame (either yellow, red, blue or green). Colors were counterbalanced across neutral and negative scenes and across the sets for encoding and test. The stimuli were created using Adobe Photoshop CS® and were presented using E-Prime® software. The framed stimuli were shown on a 19-inch computer monitor, scaled to screen size.

Design and Procedure—The experiment consisted of an incidental encoding task followed one hour later by a surprise memory test that assessed (a) recognition and subjective recollection for the presented scenes, and (b) recognition of the frame color for correctly recognized scenes. At encoding, each trial consisted of a 4000 ms presentation of a scene surrounded by a colored frame. For each trial, participants were instructed to judge whether the frame color appeared in the scene or not by pressing one of two response keys. After each scene presentation, a white fixation cross was shown for 1000 ms. The stimuli were presented pseudorandomly in three blocks of 20 scenes with no more than three consecutive negative or neutral scenes. A practice version of the task was administered to each participant beforehand to ensure that he or she understood the task.

After presentation of the stimuli, participants were shown a neutral nonarousing movie (documentary “Great Planes–Boeing 747” from Discovery Channel). One hour after encoding, a self-paced memory test was administered to assess recognition memory and subjective recollection for scenes and frame color.

Scene recognition: For each scene, the subjective experience of recollection was assessed by both recognition confidence and remember/know judgments. Before the recognition test, participants were trained to make confidence and remember/know judgments (Rajaram, 1993). After reading the detailed instructions participants explained the meaning of “remember” and “know” judgments in their own words. During the practice trials subjects indicated why they judged a scene as “remembered” or “known”. The recognition test was administered once the participants had correctly understood the instructions, that is, they judged a scene as “remembered” when it brought back to mind a specific detail from the episodic context in which the scene had been experienced, such as a sensory detail, a thought, or a feeling.

During the recognition test, the 60 previously presented scenes were shown again, without the frame color, intermixed with an equal number of novel scenes. Scenes were presented pseudorandomly in six blocks of 20 scenes each with no more than three consecutive negative or neutral scenes. After presentation of each scene (2000 ms), subjects had to make a self-paced confidence and a remember/know judgment of their recognition memory. Participants indicated their confidence in having seen or not seen the presented scene by pressing one of six response keys. A “6” response indicated that they were sure that they had seen the scene, a “5” indicated that they were unsure they had seen the scene before, a “4” indicated that they were guessing that they had seen the scene before. A “1” response indicated that they were sure they had not seen the scene, a "2" indicated that they were unsure that they had not seen it, a "3" indicated that they were guessing that they had not seen it. After the confidence judgments, subjects indicated whether they "remembered" or "knew" a scene or whether the scene was "new" (not seen at encoding) by pressing one of three response keys.

Frame color recognition: For each scene that was given a "remember" or a "know" response, participants had to chose the frame color (out of the four) that had surrounded the scene during study or indicate that they did not know the frame color (this option was given to minimize guessing). All five options appeared underneath the scene, labeled numerically (1–5) to indicate the corresponding keystroke.

Data Analysis—Statistical analyses relied on dependent sample *t* tests. Data are presented as mean ± *SEM.* All tests were two-tailed and the level of significance was set at $p < .05$.

Results

Encoding—Participants took significantly longer to judge whether the color of the frame appeared in negative scenes ($M = 2196$, $SEM = 68$ ms) than in neutral scenes ($M = 1944$ ms, $SEM = 60$ ms; $t(24) = 8.91$, $p < .001$).

Memory for Scenes

Recognition memory for scenes: A 2 (RK_{hits} vs. $RK_{false\ alarms}$) by 2 (negative vs. neutral) repeated measures ANOVA for scene memory showed a main effect of response type, $F(1, 24) = 446.03$, $p < .001$ indicating a higher hit rate ($M = .82$, $SEM = .02$) than false alarm rate ($M = .14$, $SEM = .03$). Most importantly, the ANOVA revealed a main effect of emotion, $F(1, 24) = 17.04$, $p < .001$ and a response type by emotion interaction, $F(1, 24) = 4.86$, $p < .05$, reflecting that total hit rate was higher for negative ($M = .85$, $SEM = .02$) versus neutral scenes ($M = .78$, $SEM = .03$; $t(24) = 5.13$, $p < .001$), whereas false alarm rates did not differ between negative and neutral scenes ($p > .20$).

Subjective sense of remembering for scenes: A 2 (R_{hits} vs. $R_{false\ alarms}$) by 2 (negative vs. neutral) ANOVA for scene memory revealed a significant main effects of response type ($R_{hits:}$ $M = .57$, $SEM = .04$, $R_{false\ alarms:}$ $M = .02$, $SEM = .01$, $F(1, 24) = 175.48$, $p < .001$) and of emotion, $F(1, 24) = 26.40$, $p < .001$, as well as an interaction between response type and emotion, $F(1, 24) = 28.42$, $p < .001$. Planned comparisons indicated that participants responded more with R_{hits} for negative scenes ($M = .64$, $SEM = .04$) compared to neutral scenes ($M = .50$, $SEM = .04$), $t(24) = 5.36$, $p < .001$, whereas $R_{false\ alarms}$ did not differ between negative and neutral scenes ($p > .82$). Emotion had no influence on the subjective sense of knowing ($p > .80$) as assessed by familiarity responses, that is, the probability for responding "know" to a stimulus, given that the stimulus was not "remembered", corrected for false alarms, that is, $K_{hit\ rate}/(1 - R_{hit\ rate}) - K_{false\ alarm\ rate}/(1 - R_{false\ alarm\ rate})$. An analysis of high confidence judgments, that is, scenes recognized with a "6" response, revealed a similar pattern. Participants provided on average more high confidence recognition judgment ("6" response) for negative ($M = .67$, $SEM = .04$) compared to neutral scenes ($M = .51$, $SEM = .04$) judged as old, $t(24) = 5.77$, $p < .001$.

Memory for the Colored Frame-Scene Association—Memory for the colored frame-scene association was assessed using two measures. First we assessed the objective associative memory between color frames and scenes independent of the recollection measure recollection. Second, we assessed the objective memory for the colored frame-scene association in respect to the subjective "remember" judgments for scenes.

Objective memory for the color frame-scene association: Given previous evidence of impaired associative memory between negative scenes and peripheral information (Touryan et al., 2007) we hypothesized that emotion would impair the associative binding between the color frames and scenes. Indeed, correct identification of which of the four colors had framed the scene during encoding (indexed by hit rate for correct colored frame-scene association), was significantly better for colors that had framed neutral scenes ($M = .49$, $SEM = .03$) than for colors that had framed negative scenes during encoding ($M = .39$, $SEM = .03$; $t(24) = 3.94$, $p = .001$).

Objective memory for the color frame-scene association in respect to the subjective measures of recollection for scenes: A 2 (%R with correctly identified colored frame-scene association vs. %K with correctly identified colored frame-scene association) × 2 (negative vs. neutral) repeated measures ANOVA for scene memory showed a main effect of response type, $F(1, 24) = 10.96$, $p < .01$ indicating that the color that framed the scenes during encoding, was more often correctly identified for scenes given an R response than for scenes given a K response. Most importantly, the ANOVA revealed a main effect of emotion, $F(1, 24) = 7.02$, $p < .01$ and a response type by emotion interaction, $F(1, 24) = 5.11$, $p < .05$, reflecting that on average only 44.61% ($SEM = 3.20\%$) of negative scenes compared to 66.36% ($SEM = 3.70\%$) of the neutral scenes given an R response were accompanied with correct frame-color attribution attribution, $t(24) = 6.77$, $p < .001$, whereas the %K with correctly identified colored frame-scene association did not differ between negative and neutral scenes ($p > .46$) (Figure 1B).

Discussion

In Experiment 1, we show that emotion enhances overall recognition accuracy and the subjective recollective experience, replicating previous findings (Dolcos et al., 2005; Kensinger & Corkin, 2003; Ochsner, 2000; Sharot et al., 2004; Sharot, Verfaellie et al., 2007; Sharot & Yonelinas, 2008). In a cued association test, we additionally investigated associative memory between the scene and the colored frame that surrounded it during encoding. In contrast to the emotion-enhancing effect for scene memory, we found the reverse pattern for the associative binding of the scene and the colored frame: binding was better for neutral scenes compared to negative scenes. This finding is consistent with a recent study that showed impaired associative memory between negative, but not neutral scenes, and contextual information (Touryan et al., 2007). Interestingly though, this finding does not concur with the results of a previous study that also employed colored frames as contextual details (Doerksen & Shimamura, 2001). In their study Doerksen and Shimamura (2001) found heightened memory for frame colors associated with emotional words relative to frame colors associated with neutral words. This discrepancy might reflect differences in the materials. Compared to emotional scenes typically used in studies of memory and emotion (e.g., scenes from the IAPS), emotional words typically used in these kinds of studies do not elicit as strong an emotional arousal response (Phelps, LaBar, & Spencer, 1997), which consequently may impact source memory differentially.

Most strikingly, we found a double dissociation between the subjective and the objective measures of recollection for negative and neutral scenes. Although the subjective sense of “remembering” was higher for negative than neutral scenes, objective memory accuracy of the colored frame-scene association was lower for negative than neutral scenes given a “remember” response. However, since we did not measure the memory for the contextual detail per se, it is unclear whether the dissociation of the subjective sense of remembering and objective memory accuracy of the colored frame-scene association is specific for the associative binding between the negative scene and the contextual detail or for objective memory for the contextual details per se. To address this concern, in a second experiment, we additionally measured objective memory for the contextual details themselves by introducing one distinct contextual detail for each scene.

Experiment 2

Method

Participants—The study sample consisted of 30 subjects (*M* = 22.95, *SEM* = 5.07 years, 15 female). All participants provided written informed consent and were paid for their participation. The study was approved by the University Committee on Activities Involving Human Subjects (UCAIHS) at New York University. Two participants were excluded from analysis, due to below chance scene recognition (*N* = 1, female) or object recognition (*N* = 1, male).

Stimuli—The same scenes as in Experiment 1 were used. For each scene, we placed a conceptually unrelated single object (e.g., a kettle, a stapler etc.) in one corner, so that each scene contained one distinct object. Each object was scaled to fit in a 1.5 × 1.5 in. white box. We attempted to match the objects on visual complexity and semantic categories (e.g., office supplies, toys) across negative and neutral scenes. Each object was randomly assigned to a corner, with the requirement that objects were equally distributed among the four corners across negative and neutral scenes. We further counterbalanced the objects such that each object was paired with neutral and negative scenes used at encoding and at test with equal frequency. At the end of the study, participants rated the objects to be nonemotional in nature (valence rating: *M* = 5.42, *SEM* = .07; arousal rating: *M* = 3.68, *SEM* = .30). The arousal and valence ratings did not differ between objects that had been presented on negative scenes and objects that had been presented on neutral scenes (all $p > .23$). The stimuli were created using Adobe Photoshop CS® and were presented on a 19 in. computer monitor, scaled to the screen size using E-Prime® software.

Design and Procedure—The experimental procedure was identical to Experiment 1 with a few modifications. First, instead of an incidental encoding task, we used an intentional encoding task to ensure that participants encoded each distinct embedded object with its respective scene. For each trial, participants were instructed to (a) memorize as much as possible of every stimulus on the screen, (b) form an association between the embedded object and the scene, and (c) to indicate which of the four corners the object was embedded in by pressing one of four response keys. Second, for encoding, we increased the presentation time of each stimulus from 4000 ms to 6000 ms. Third, we administered additional memory tests in order to assess recognition memory for the objects and for the association between the object and the scenes in which they had been embedded.

As in Experiment 1, we first administered a scene recognition test. In this test, the 60 previously presented scenes were shown again, without the previously embedded object, intermixed with an equal number of novel scenes. Scenes were presented pseudorandomly in six blocks of 20 scenes each with no more than three consecutive negative or neutral scenes. After presentation of each scene (2000 ms), subjects had to make a self-paced confidence and a remember/know judgment of their recognition memory for the scenes. After participants had completed the scene recognition test an object recognition test was administered. In the object recognition test, the 60 objects previously presented in the corner of the 60 studied scenes were presented again in isolation, that is, without the scenes. We randomly intermixed 60 novel objects and presented the total of 120 objects in six blocks of 20 stimuli. Each object was shown for 2000 ms. Following the presentation for each object subjects first indicated their confidence in having seen or not seen the presented object in the corner of a studied scene, and then provided “remember”/“know”/”new” judgments. Participants’ responses were self-paced. After the object recognition test, we tested the associative memory between the studied scene and its previously embedded object. Participants had to choose one out of three objects, which appeared underneath the scene, labeled numerically (1–3). If they were unsure about which object to choose, participants were asked to provide a “guess” judgment (this option was given to minimize guessing). Following their choice subjects provided remember/know judgments of their associative memory. Importantly, all three objects had been seen during encoding but only one of them had been embedded in the particular studied scene. Of the other two objects, one had been embedded in a negative scene and one in a neutral scene during encoding. The presentation of the objects was counterbalanced so that each subject saw every object three times during the association test. The position of the target object (1, 2 or 3) was also counterbalanced across trials and between negative and neutral scenes.

Data Analysis—The data analysis was identical to Experiment 1. Additional analyses were performed to assess recognition memory for the objects and the association between the objects and the studied scenes.

Results

Encoding—Participants took significantly longer to indicate the corner of objects on negative scenes (*M* = 2697 ms, *SEM* = 202 ms) compared to objects on neutral scenes (*M* = 2482 ms, *SEM* = 192 ms; $t(27) = 4.07$, $p < .001$).

Memory for Scenes

Recognition memory for scenes: A 2 (RK_{hits} vs. $RK_{false\ alarms}$) by 2 (negative vs. neutral) repeated measures ANOVA for scene memory showed a main effect of response type, $F(1, 27) = 871.73$, $p < .001$ indicating a higher hit rate (*M* = .89, *SEM* = .02) than false alarm rate (*M* = .08, *SEM* = .02). Most importantly, the ANOVA revealed a main effect of emotion, $F(1, 27) = 17.38$, $p < .001$ and a response type by emotion interaction, $F(1, 27) = 17.89$, $p < .001$, reflecting that total hit rate was higher for negative (*M* = .94, *SEM* = .02) versus neutral scenes (*M* = .83, *SEM* = .03; $t(27) = 4.70$, $p < .001$), whereas false alarm rates did not differ between negative and neutral scenes ($p > .67$).

Subjective sense of remembering for scenes: A 2 (R_{hits} vs. $R_{false\ alarms}$) by 2 (negative vs. neutral) ANOVA for scene memory revealed significant main effects of response type ($R_{hits:}$ *M* = .74, *SEM* = .03, $R_{false\ alarms:}$ *M* = .03, *SEM* = .01, $F(1, 27) = 357.56$, $p < .001$) and emotion, $F(1, 27) = 21.22$, $p < .001$, as well as an interaction between response type and emotion, $F(1, 27) = 12.60$, $p = .001$. Planned comparisons indicated that participants responded more with R_{hits} for negative scenes (*M* = .80, *SEM* = .03) compared to neutral scenes (*M* = .69, SEM = .04; $t(27) = 4.11$, $p < .001$), whereas $R_{false\ alarms}$ did not differ between negative and neutral scenes ($p > .16$). The subjective sense of knowing was also higher for negative (*M* = .62, *SEM* = .06) compared to neutral scenes (*M* = .45, *SEM* = .05; $t(27) = 2.08$, $p < .05$) as assessed by familiarity responses, that is, the probability for responding “know” to a stimulus, given that the stimulus was not “remembered”, corrected for false alarms, that is, $K_{hit\ rate}/(1 - R_{hit\ rate}) - K_{false\ alarm\ rate}/(1 - R_{false\ alarm\ rate})$.

An analysis of high confidence judgments, that is, scenes recognized with a “6” response, revealed a similar pattern. Participants provided on average more high confidence recognition judgment (“6” response) for negative (*M* = .84, *SEM* = .03) compared to neutral scenes (*M* = .72, *SEM* = .04) judged as old, $t(27) = 4.54$, $p < .001$.

Memory for the Contextual Objects

Recognition memory for objects: Objective memory for the objects was assessed with the object recognition test. Object recognition (indexed as the proportion of hits) marginally differed between objects that were studied with negative scenes (hit rate: M = .73, SEM = .03) and objects that were studied with neutral scenes (hit rate M = .77, SEM = .03; $t(27) = 1.84$; $p = .08$). Corrected recognition rates (hit rate minus false alarm rate) were not calculated, as the nonstudied objects had not been embedded in neutral or negative scenes (Touryan et al., 2007). Thus, false alarm rates could not be parsed into neutral and negative categories.

Subjective sense of remembering the objects: The subjective sense of object recognition (indexed as R_{hits} for objects/total hits for objects) did not differ between objects that had been encoded on negative scenes (M = .63, SEM = .04) versus objects that had been encoded on neutral scenes (M = .64, SEM = .04, $p > .63$). Likewise, the proportion of high confidence recognition judgment ("6" response) did not differ for objects that had been encoded on negative scenes (M = .70, SEM = .04) versus objects that had been encoded on neutral scenes (M = .71, SEM = .04, $p > .95$).

Objective memory for the objects with respect to the subjective measures of recollection for scenes: A 2 (%R for scenes with correctly recognized objects in the object recognition test vs. %K for scenes with correctly recognized objects in the object recognition test) × 2 (negative vs. neutral) repeated measures ANOVA for scene memory showed a main effect of response type, $F(1, 27) = 4.42$, $p < .05$ indicating that the object, that had been embedded in the corner of the scenes during encoding, was more often correctly identified for scenes given a R judgment than for scenes given a K judgment, $t(27) = 5.58$; $p < .001$. The response type by emotion interaction failed to reach significance, $F(1, 27) = 2.22$, $p = .14$. Yet, subsequent t tests showed that on average, less negative (M = 73.54%, SEM = 2.98%) than neutral scenes (M = 80.95%, SEM = 2.78%) given an R response were accompanied with correct object recognition, $t(27) = 3.50$, $p = .002$, whereas the %K with for scenes with correctly identified object did not differ between negative and neutral scenes ($p > .70$) (Figure 2C).

Associative Object-Scene Memory

Objective memory for the object-scene association: The associative memory between the objects and the scenes was tested with the presentation of a studied scene (smaller and without an object embedded in it) with a selection of three objects underneath. For this analysis only trials were included for which participants (a) correctly identified the object that had been embedded in the presented scene during encoding, and (b) correctly identified the scene and the object separately in the scene and object recognition test. Thus, this analysis controlled for accurate scene and object memory. Associative memory was significantly better for objects that had been encoded with neutral scenes (M = .48, SEM = .05) compared to objects that had been encoded with negative scenes (M = .40, SEM = .05; $t(27) = 2.69$, $p = .012$).

Subjective sense of remembering the object-scene association: Similar to the objective associative memory, the subjective sense of associative memory (indexed as R_{hits} for object-scene association including only trials with correct object and scene recognition divided by total hits for object-scene association including only trials with correct object and scene recognition) was significantly better for object-neutral scenes (M = .73, SEM = .05) compared to object-negative scenes (M = .60, SEM = .06; $t(27) = 2.11$, $p < .05$). An analysis of the proportion of high confidence judgments ("6" response) for associative memory including only trials with correct object and scene recognition revealed a similar pattern.

Participants provided on average more high confidence recognition judgment for object-neutral scene associative memory (M = .62, SEM = .05) compared to object-negative scene associative memory (M = .49, SEM = .06, $t(27) = 2.04$, $p = .05$).

Objective memory for the object-scene association with respect to the subjective measures of recollection for scenes: A 2 (%R vs. %K for scenes with correctly made object-scene attribution in the associative memory test including only trials for which objects had been separately recognized in the object recognition test) × 2 (negative vs. neutral) repeated measures ANOVA for scene memory showed a main effect of response type, $F(1, 27) = 7.34$, $p = .01$ indicating that participants showed better object-scene association memory for scenes given an R response than for scenes given a K response, $t(27) = 3.67$; $p = .001$. Most importantly, the ANOVA revealed a main effect of emotion, $F(1, 27) = 3.74$, $p = .06$ and a marginal response type by emotion interaction, $F(1, 27) = 3.16$, $p = .08$, reflecting that on average only 43.36% (SEM = 5.10%) of negative scenes compared to 58.73% (SEM = 4.58%) of the neutral scenes given an R response were accompanied with correct memory binding, $t(27) = 5.56$; $p < .001$ (Figure 2B).

Discussion

In Experiment 2, we examined two features of contextual details possibly contributing to the dissociation between subjective and objective measures of recollection for negative and neutral stimuli: memory for the contextual detail itself and contextual detail-scene binding. Instead of using repeating colored frames as contextual details as in Experiment 1, we embedded one distinct object into one corner of each scene, for which we additionally assessed objective memory in an object recognition test. We further obtained a more conservative measure of associative memory binding, as the experimental design allowed us to exclude the trials for which participants did not exhibit correct memory for the object or the scene itself in the object or scene recognition tests.

Replicating Experiment 1, emotion enhanced overall recognition and the subjective recollective experience for the scenes. In contrast to the emotion-enhancing effect for scene memory we found marginally lower memory for objects that had been presented on negative scenes versus objects that had been presented on neutral scenes, although for those objects correctly recognized the subjective recollective experience did not differ. This finding of impaired recognition for objects presented on negative scenes is consistent with previous studies that show that emotion benefits memory for gist or central details of a stimulus with a corresponding deficit in memory for contextual items (Burke et al., 1992; Kensinger et al., 2007a; Kensinger, Piguet, Krendl, & Corkin, 2005; Touryan et al., 2007).

In addition, we found that memory binding between contextual objects and scenes was impaired for negative scenes. Consistent with this difference in memory binding accuracy, the subjective recollective experience was lower for object-negative versus object-neutral scene associations. This finding confirms and extends the findings from Experiment 1 as well as a recent study (Touryan et al., 2007) by showing that emotion also disrupts contextual object-negative scene binding under intentional encoding instructions that specifically emphasize the formation of an association between the contextual detail and the scene. Importantly by using only trials for which subjects exhibited correct object recognition for the analysis of memory binding, we ruled out that the specific impairment in memory binding for the negative scenes in the cued association test was due to a lack of memory for the objects per se rather than to a disruption in memory binding. Our results, therefore, suggest that the contextual detail-negative scene memory binding is impaired even if memory for the contextual detail itself is intact.

We further investigated whether the enhanced subjective recollective experience for negative scenes is not only accompanied by lower associative memory between the contextual detail and the negative scene, as shown in Experiment 1, but also by lower objective memory for the contextual detail per se. Our results confirm and extend the double dissociation between the subjective and the objective measures of recollection for negative and neutral scenes, which we found in Experiment 1. Negative scenes were more often judged as “remembered” indicating a higher subjective recollective experience for negative scenes. Yet, replicating Experiment 1, for negative compared to neutral scenes judged as “remembered”, participants showed lower associative memory between the contextual detail and the scenes. In addition, participants also showed lower memory of the contextual objects themselves in relation to negative compared to neutral scenes which were given a “remember” response. This finding indicates that the enhancement for the subjective recollective experience for negative scenes is less often associated with accurate recollection of both the tested contextual detail and the association between the tested contextual detail and negative stimuli.

General Discussion

In two experiments, we explored whether the relationship between subjective reports of recollection, memory for contextual details and the binding between contextual details and scenes is consistent across negative and neutral stimuli. The main findings are a double dissociation between subjective and objective measures of recollection for negative compared to neutral stimuli: Specifically, the enhanced subjective recollective experience for negative scenes compared to neutral scenes was less often accompanied by memory for contextual details and contextual detail-scene binding.

In both experiments, we assessed the subjective recollective experience by asking for remember/know judgments and by measuring recognition confidence. “Remember” and high confidence judgments are thought to reflect recollection-based judgments, while “know” and low-confidence judgments are thought to be related to familiarity-based recognition judgments (Tulving, 1985; Yonelinas, 2002). Since it has been previously shown that “remember” and high confidence judgments are coupled with better memory for a number of contextual details (Perfect et al., 1996), we first examined the relation between the subjective recollective experience and the objective recollection of the contextual details/contextual detail-scene binding (colored frame of scenes in Experiment 1, distinct object embedded in the corner of each scene in Experiment 2) independent of the emotionality of the scenes. In both studies “Remember” compared to “Know” judgments for neutral and emotional scenes combined were associated with better memory of contextual details and memory binding. This finding confirms previous findings that “Remember” versus “Know” responses are accompanied by better memory for contextual details of neutral stimuli (Perfect et al., 1996) and extends this pattern to emotional stimuli. It further shows that “Remember” versus “Know” responses are not only associated with better memory for contextual details, but also with better memory binding between contextual details and scenes.

However, even though we find memory of contextual details to be associated with “Remember” responses for emotional and neutral scenes combined, this relationship is not equivalent for emotional and neutral scenes. Consistent with previous observations (Dolcos et al., 2005; Kensinger & Corkin, 2003; Ochsner, 2000; Sharot et al., 2004; Sharot, Verfaellie et al., 2007; Sharot & Yonelinas, 2008), participants were more likely to experience a vivid memory for negative than neutral scenes, as indicated by heightened “remember” and high confidence recognition judgments for negative scenes. Given that the recollection component of recognition is thought to be associated with memory for context

(Yonelinas, 2002), one would expect that the heightened subjective sense of recollection for negative stimuli is associated with enhanced memory accuracy for contextual details. However, the boost for “remember” responses for negative scenes did not reflect enhanced memory accuracy for both the contextual detail-scene binding and the contextual details that were presented with the scenes during encoding. Rather, we found that a smaller proportion of negative than neutral scenes given a “remember” judgment was accompanied by accurate recollection of the contextual details and the association between contextual details and scenes.

In terms of the underlying mechanism of the observed double dissociation, the attentional narrowing hypothesis states that heightened emotional arousal produced by the experience of an emotional stimulus focuses attention predominantly on central aspects of the emotional stimulus, at the expense of peripheral information, which does not get encoded in as much detail and, correspondingly, does not leave as stable a memory trace (Christianson, 1992; Easterbrook, 1959; Heuer & Reisberg, 1990). This notion is in accordance with the fact that we show longer reaction times in both experiments for the encoding task for negative scenes, which involved the directing of attention to the contextual details. A narrowing of attention mechanism might further have affected the encoding of the contextual objects in Experiment 2 resulting in subsequent lower memory for objects that had been encoded with negative scenes. Why this lower memory for the contextual objects is not tied to a lower subjective feeling of remembering the emotional scene, as would be expected from findings by Perfect et al. (1996), remains unclear. One explanation may be that there is a distinction between what kinds of contextual details are associated with the subjective feeling of remembering neutral versus negative stimuli. For neutral stimuli, the subjective sense of remembering is associated with a variety of contextual details (Perfect et al., 1996). In contrast, the subjective feeling of remembering negative stimuli may only be associated with certain types of contextual details. Indeed it has previously been demonstrated for objective memory that emotion does not affect memory for various kinds of contextual details equally. Emotion has been shown to only benefit intrinsic or within-item features of objective memory measures, but not for extrinsic contextual details (Kensinger, 2009; Mather, 2007). Likewise the subjective sense of remembering emotional stimuli may not be associated with extrinsic contextual details, as shown in the current studies, but only with intrinsic types of details. Thus it may be that it is specifically the memory for item details of an emotional stimulus that contributes to the subjective sense of remembering this emotional stimulus. Another explanation may be that the subjective feeling of remembering is associated with the quality of the recalled memories rather than the quantity or kind of details recalled. For example, free reports of flashbulb memories have shown that the recall of a few “idiosyncratic details” are associated with an enhanced subjective feeling of vividness and recollection, even if other “canonical details” (e.g., place or interrupted activity when hearing about the event) were not recalled (Brown & Kulik, 1977). Given this evidence, it may be that details of emotional compared to neutral stimuli are recalled much better providing a stronger mnemonic signal that may drive the enhanced subjective feeling of remembering with emotion.

The neural systems underlying the subjective sense of remembering during memory retrieval found in previous studies further corroborate the notion that the subjective sense of remembering emotional stimuli versus neutral stimuli are based on different mechanisms. Neuroimaging studies indicate a double dissociation between regions in the medial temporal lobe that correlate with the subjective sense of remembering neutral versus negative scenes. For neutral items, the subjective sense of remembering is coupled with increased activation in the parahippocampal cortex during retrieval (Eldridge, Knowlton, Furmanski, Bookheimer, & Engel, 2000; Sharot et al., 2004). Interestingly the same region has been shown to be important in processing and recognizing of scenes and their details (Burgess, Maguire, & O'Keefe, 2002; Kohler, Crane, & Milner, 2002). These fMRI findings suggest that "Remember" compared to "Know" judgments for neutral stimuli are coupled with more accurate memory for contextual scene details. In contrast, for emotional scenes or emotional autobiographical memories retrieved with a sense of recollection rather than familiarity, activity in the amygdala is enhanced (Dolcos et al., 2005; Sharot et al., 2004; Sharot, Martorella et al., 2007). In addition to memory strength, amygdala activity is specifically related to the gist of emotional items (Adolphs, Tranel, & Buchanan, 2005; Kensinger & Schacter, 2006), and patients with amygdala lesions not only retrieve remote emotional memories with an impaired subjective feeling of remembering but also exhibit fewer details for these memories (Buchanan, Tranel, & Adolphs, 2005). Given that amygdala activity is related to both a heightened sense of remembering emotional stimuli and memory for gist, it may be that "Remember" compared to "Know" judgments for emotional stimuli are coupled with a strong memory for an emotional item's core features, but not with a memory for other contextual details (Phelps & Sharot, 2008).

One limitation of our study is that even though we used a surrounding detail (colored frame in Experiment 1) versus an embedded detail (object in Experiment 2), one might argue that both types of details are perceptually in the periphery and conceptually unrelated to the scene. Previous studies showed a tunnel memory effect for emotional stimuli, that is, emotion benefits memory for central aspects of a stimulus at the expense of peripheral aspects. Since the contextual details in our study were perceptually peripheral, this tunnel memory effect may underlie the observed lower memory for the contextual details when they were paired with an emotional versus a neutral scene. However, it has been shown that explicit encoding instructions (as the one we used in Experiment 2) work against this effect (Kensinger et al., 2005). Indeed in Experiment 2, we used intentional encoding instructions, which additionally emphasized the formation of an association between the contextual detail and the scenes. As such the contextual detail may be encoded as a part of the memory that may be later be retrieved as an idiosyncratic part of that memory. As such this kind of contextual detail may be analogous in its nature to the idiosyncratic details that are part of flashbulb memories. To resolve these questions, future studies should investigate the association between conceptually and peripherally central details and the subjective sense of remembering.

The findings of our study show that emotion specifically enhances the subjective recollective experience for scenes, but this increased subjective recollective experience is not associated with accurate memory of the same scene details for negative scenes as much as it is for neutral scenes. Interestingly, in Experiment 2, we found that the subjective recollective experience for detail-scene association mirrors objective memory for this association (that is, lower for negative scenes), while the subjective recollective experience for detail itself did not. These findings suggest that although the strong recollective experience of an emotional event may not correspond to a rich and accurate memory of its contextual details, the subjective recollective experience of a more specific, associative mnemonic judgment may reflect memory accuracy. The mechanisms underlying this discrepancy need further investigation and may provide insight into the mechanisms involved in flash-bulb memories, which exhibit a striking contrast between their vivid and confident recollection and their lack of memory accuracy for details (Neisser & Harsch, 1992; Talarico & Rubin, 2003).

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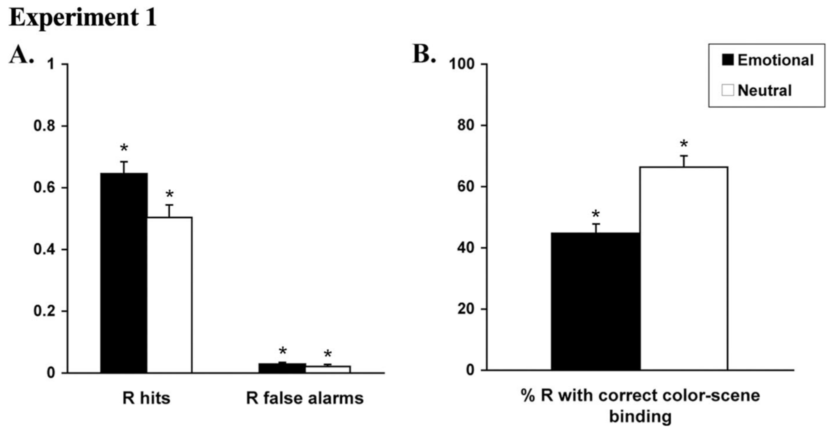

Figure 1.

Emotion enhances the subjective recollective experience of scenes (Panel A), which is accompanied by lower objective accuracy for the associative memory between contextual details and scenes (indexed as % R_{hits} with correct colored frame-scene binding, Panel B. ** $p < 0.01$ for pairwise comparisons. Error bars indicate *SEM*.

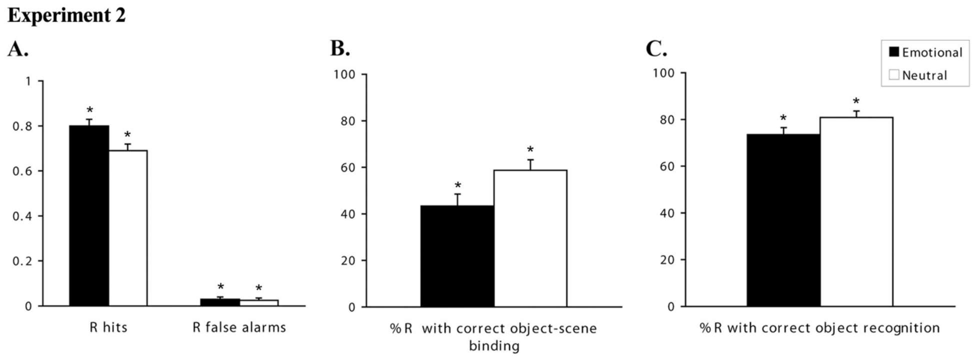

Figure 2.

Emotion enhances the subjective recollective experience of scenes (Panel A). However this enhancement is accompanied by lower objective accuracy for the associative memory between contextual details and emotional scenes (indexed as % R_{hits} for scenes with correct object-scene binding, Panel B). Likewise, the enhanced subjective recollective experience for negative scenes is less often accompanied by correct memory for the contextual objects (Panel C). * $p < 0.05$, ** $p < 0.01$ for pairwise comparisons. Error bars indicate SEM.