Emotion

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Memory for Time and Place Contributes to Enhanced Confidence in Memories for Emotional Events

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Emotion strengthens the subjective sense of remembering. However, these confidently remembered emotional memories have not been found be more accurate for some types of contextual details. We investigated whether the subjective sense of recollecting negative stimuli is coupled with enhanced memory accuracy for three specific types of central contextual details using the remember/know paradigm and confidence ratings. Our results indicate that the subjective sense of remembering is indeed coupled with better recollection of spatial location and temporal context, but not higher memory accuracy for colored dots placed in the conceptual center of negative and neutral scenes. These findings show that the enhanced subjective recollective experience for negative stimuli reliably indicates objective recollection for spatial location and temporal context, but not for other types of details, whereas for neutral stimuli, the subjective sense of remembering is coupled with all the types of details assessed. Translating this finding to flashbulb memories, we found that, over time, more participants correctly remembered the location where they learned about the terrorist attacks on 9/11 than any other canonical feature. Likewise, participants' confidence was higher in their memory for location versus other canonical features. These findings indicate that the strong recollective experience of a negative event corresponds to an accurate memory for some kinds of contextual details but not for other kinds. This discrepancy provides further evidence that the subjective sense of remembering negative events is driven by a different mechanism than the subjective sense of remembering neutral events.

Keywords: emotion, memory, subjective sense of remembering, remember/know, confidence

Emotion intensifies 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 (Ochsner, 2000; Sharot, Martorella, Delgado, & Phelps, 2007; Talarico & Rubin, 2003). For instance, studies of flashbulb memories indicate that emotional real-life events are reexperienced with a greater sense of recollection, vividness, confidence, and a greater belief in accuracy than more mundane events (Winograd & Neisser, 1992; Neisser et al., 1996; Sharot, Martorella, et al., 2007; Talarico & Rubin, 2003).

However, this enhanced recollective experience is often not accompanied by enhanced accuracy for details concerning the emotional event (Christianson & Engelberg, 1999; Hirst et al., 2009; Winograd & Neisser, 1992; Schmolck, Buffalo, & Squire, 2000; Talarico & Rubin, 2003). In a study investigating flashbulb memories for the terrorist attacks of September 11, 2001, Talarico and Rubin (2003) found that the higher levels of confidence and the greater level of vividness that accompany flashbulb memories, when compared with memories for everyday events, was not accompanied by a higher level of mnemonic consistency. People tend to forget the details associated with their flashbulb memories at the same rate as they forget the details of memories concerning everyday events. Similar results can be found in laboratory studies. Rimmele, Davachi, Petrov, Dougal, and Phelps (2011), for instance, found that even though negative scenes were remembered with a heightened subjective sense of remembering compared with neutral scenes, recollection of peripheral details was lower, rather than higher, for the negative scenes. These findings suggest that for negative events, a strong subjective sense of remembering may not be a reliable indicator of accurate recollection of contextual details, despite the common intuition that a vivid, detailed, and confidently held memory is likely to be highly accurate (Deffenbacher, 1980).

What can account for this discrepancy? Rich and vivid recollective experience is often associated with recovery of contextual details (Yonelinas, 2002). 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, may be brought back to mind (Johnson, Hashtroudi, & Lindsay, 1993; Mitchell & Johnson, 2009). The accessibility of these contextual details has been hypothesized to drive the subjective recollective experience (Johnson & Raye, 1981). For neutral events, empirical evidence indicates that the subjective sense

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of remembering is associated with greater memory accuracy for a variety of contextual details (Gardiner, Ramponi, & Richardson-Klavehn, 1998; Perfect, Mayes, Downes, & Van Eijk, 1996). These studies examine a particular type of subjective experience: the feeling of remembering rather than knowing. They indicate that when people bring to mind a vivid image accompanied by details of the encoding episode, they tend to have the subjective experience of *remembering*, whereas when the stimulus is simply recognized without any recollection of the accompanying episodic details, people tend to report that they do not remember but *know* that the event occur in the past (Rajaram, 1993; Tulving, 1985; Yonelinas, 2002). For example, Gardiner et al. (1998) reported that remember responses for neutral words were accompanied by recollection of a variety of contextual details, such as associations with the list in which they had been presented, an item's physical feature, or some personal memory. In addition, Perfect et al. (1996) tested participants' memory for different kinds of details and found that for stimuli judged as remembered, participants showed greater memory accuracy for a range of contextual details, such as temporal order, spatial location, visual appearance, or internal and external associations.

This work, however, has focused mainly on neutral stimuli. Is it also the case that heightened recollective experience of emotional memories is associated with improved memory accuracy for a variety of contextual details? Findings from studies investigating the effects of emotion on memory for contextual details, using objective measures of memory recovery, point toward an association between the subjective sense of remembering emotional stimuli and accurate recollection of central, but not peripheral types of details. For example, previous findings indicate that the emotional memory enhancement is specific to memory for spatially central details of the emotional stimulus at the expense of memory for spatially peripheral details (Heuer & Reisberg, 1992; Reisberg & Heuer, 2004). This phenomenon has been referred to as *tunnel memory* and has been found to be specific to negative emotions (Safer, Christianson, Autry, & Österlund, 1998; Talarico, Berntsen, & Rubin, 2009). Tunnel memory may be due to an attentional narrowing mechanism, in which heightened emotional arousal, produced by a negative stimulus, focuses attention predominantly on central aspects of the negative stimulus (Easterbrook, 1959). As a result, spatially peripheral information does not get encoded in as much detail, resulting in a weaker memory (Christianson, 1992; Easterbrook, 1959; Heuer & Reisberg, 1990). Another framework suggests that emotion enhances memory for the central meaning or gist of an event at the expense of memory for irrelevant details (Buchanan & Adolphs, 2002).

Extending the tunnel memory and the gist concept, Mather (2007) hypothesized that the mixed effects of emotion on memory may be due to an emotion-induced enhanced binding. Interestingly, she argued that emotion might enhance binding between an emotional item and its constituent features, but be less effective or even impair, binding between the emotional items and other distinct contextual details (Mather, 2007). The former might be viewed as intrinsic features of the stimuli and the latter as extrinsic features. A conceptually related claim states that rather than arousal, per se, it is negative valence that enhances binding of intrinsic but not extrinsic memory features (Kensinger, 2007, 2009; Mather & Sutherland, 2009). These claims are consistent with the finding that emotion enhances memory for features intrinsic to the emotional stimulus, for example, the font color, specific visual details, temporal order, and spatial location (D'Argembeau & Van der Linden, 2004, 2005; Doerksen & Shimamura, 2001; Dougal, Phelps, & Davachi, 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 contrast, emotion has been found to have no effect or to impair memory for features that are not intrinsic to the emotional stimulus, such as the type of encoding task or a peripheral object (Burke, Heuer, & Reisberg, 1992; Cook, Hicks, & Marsh, 2007; Kensinger & Schacter, 2006; Sharot & Yonelinas, 2008; Touryan, Marian, & Shimamura, 2007).

None of the above-mentioned studies have directly examined the relationship between the enhanced subjective sense of recollection consistently observed for emotional stimuli and recollection of different types of contextual details. Given that (a) the emotional memory enhancement is typically observed for central details, and (b) we previously found a dissociation between the enhanced subjective sense of remembering negative scenes and recollection of peripheral details, we set out to examine the relationship between the subjective sense of remembering negative stimuli and recollection of different types of *central* contextual details.

In the first experiment, like in our previous study (Rimmele et al., 2011), we used color as a contextual detail. In contrast to our previous study, however, in which color was presented as a peripheral contextual detail (colored frame surrounding the scene), in the present experiment, we made color a spatially central contextual detail by presenting colored dots in the conceptual center of the negative/neutral scenes. We hypothesized that if the previously found dissociation between the enhanced subjective sense of remembering negative scenes and accurate recollection of the color of the surrounding frame were due to an attentional narrowing mechanism, making color spatially central should result in better memory for the color of the dots presented on negative scenes. Furthermore, this should be related to the enhanced sense of remembering negative scenes.

In addition, spatial location and temporal context, which are important kinds of source memory, have been hypothesized to be intrinsic stimulus features and should benefit from emotion-based binding (Mather, 2007). Therefore, in a second and third experiment, we examined the relation between the subjective sense of remembering and memory for spatial location and temporal context. We hypothesized that negative scenes will be recalled with an enhanced subjective sense of remembering and that recovery of spatial location, as well as temporal context, will contribute to the increased subjective sense of recollection for negative scenes.

In a fourth experiment, we examine the relationship between the subjective sense of remembering and memory for spatial location of a real life flashbulb memory.

In Experiments 1 to 3, we will be focusing on two measures of subjective experience: the judgment of remember/know and confidence ratings. In the case of the latter, we will be contrasting the performance of participants when they provided high confidence ratings with performance when they provided lower confidence ratings. Experiment 4 focuses solely on confidence ratings.

Experiment 1

Method

Participants. The sample of the experiment consisted of 25 subjects ($M = 22.52$, $SD = 4.74$ years, 13 female). All participants provided written informed consent and were paid for their participation. The experiment was approved by the University Committee on Activities Involving Human Subjects (UCAIHS) at New York University.

Stimuli. We used the same scenes as in our previous studies (Rimmele et al., 2011). 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 were selected from the International Affective Picture Set, based on the 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 set (arousal: $M = 5.62$, $SD = 0.63$; valence: $M = 2.88$, $SD = 0.74$) and a neutral set (arousal: $M = 3.87$, $SD = 0.94$; valence: $M = 5.58$, $SD = 0.60$). Negative and neutral scenes were matched on visual complexity. Visual complexity was rated by a separate group of participants ($n = 5$) on a 9-point scale (1 = *not at all complex* to 9 = *highly complex*). Neutral ($M = 4.77$, $SD = 1.53$) and negative ($M = 5.24$, $SD = 1.40$) scenes did not differ in their visual complexity, $p > .26$. For both the negative and neutral scene sets, approximately two-thirds depicted humans and the remaining one-third depicted animals and inanimate objects to an equal degree. The scene set used as foil also contained about two-thirds humans and one-third animals and inanimate objects.

For each scene, we placed 20 colored dots (either yellow, red, blue, or green) into the conceptual center of the scene (see Figure 1). The conceptual center was defined as being the essence of the scene and two independent raters assessed its location. Each dot was scaled to 5 mm in size. The colors of the dots were counterbalanced across neutral and negative scenes and across the sets for encoding and test. In addition, the colors were equated to be present in half of the negative pictures and half of the neutral pictures. The stimuli were created using Adobe Photoshop conditional stimulus (CS)®, and were presented on a 19-in computer monitor, scaled to the screen size using E-Prime® software.

Design and procedure. The experiment consisted of an incidental encoding task followed 1 hr later by a surprise memory test that assessed recognition and subjective recollection for the presented scenes, and recognition of the color of the dots for correctly recognized scenes. At encoding, each trial consisted of a 4,000-ms presentation of a scene that included 20 dots of the same color spatially central to the gist of the scene. For each trial, participants were instructed to indicate whether or not the color of the dots appeared elsewhere in the scene by pressing one of two response keys. After each scene presentation, a white fixation cross was shown for 1,000 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 participants beforehand to ensure that they understood the task.

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

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/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 and 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 colored dots, intermixed with an equal number of novel scenes. Scenes were presented pseudorandomly in six blocks of 20 scenes, with no more than three consecutive negative or neutral scenes. After presentation of each scene (2,000 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 “1”

Figure 1. Negative and neutral scene with colored dots placed in the conceptual center of the scene (Experiment 1). The displayed images present similar content as the IAPS images that were used in Experiment 1 to 3.

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, and a "3" indicated that they were guessing that they had not seen it. A "4" indicated that they were guessing that they had seen the scene before, a "5" indicated that they were unsure they had seen the scene before, and a "6" response indicated that they were sure that they had seen the scene. 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.

Dot color recognition. For each scene that was given a remember response or a know response, participants had to chose the color (out of the four possible colors) of the dots that had been presented spatially central to the main conceptual meaning of the scene during study. In order to minimize guessing, participants were also given the option to indicate that they did not know the color. All five options appeared underneath the scene, labeled numerically from 1 to 5 to indicate the corresponding keystroke.

Data analysis. Statistical analyses relied on analyses of variance and dependent sample *t* tests. An alpha level of .05 was used for all statistical tests.

Results

Encoding. Participants took significantly longer to judge whether the color of the dots appeared in negative scenes (M = 2,132 ms, SEM = 53 ms) than in neutral scenes (M = 1,868 ms, SEM = 48 ms), $t(24) = 14.3$, $p < .001$, $d = 1.04$.

Memory for scenes.

Recognition memory for scenes. A 2 (Rhits + Khits vs. Rfalse alarms + Kfalse alarms) × 2 (negative vs. neutral) repeated measures analysis of variance (ANOVA) for scene memory showed a main effect of response type, $F(1, 24) = 873.46$, $p < .001$, indicating a higher hit rate ($M = 0.82$, $SEM = 0.02$) than false alarm rate ($M = 0.09$, $SEM = 0.02$). In addition, a Response Type × Emotion interaction was observed, $F(1, 24) = 3.64$, $p = .06$. However, subsequent planned comparisons failed to reach significance for both hit rates (negative scenes: $M = 0.84$, $SEM = 0.02$; neutral scenes: $M = 0.81$, $SEM = 0.02$) and false alarm rates (negative scenes: $M = 0.08$, $SEM = 0.02$; neutral scenes: $M = 0.10$, $SEM = 0.02$), all $ps > .19$.

Subjective sense of remembering for scenes. A 2 (Rhits vs. Rfalse alarms) × 2 (negative vs. neutral) ANOVA for scene memory revealed significant main effects of response type (Rhits: $M = 0.61$, $SEM = 0.04$; Rfalse alarms: $M = 0.02$, $SEM = 0.01$), $F(1, 24) = 265.69$, $p < .001$, and emotion, $F(1, 24) = 16.13$, $p = .001$, as well as a Response Type × Emotion interaction, $F(1, 24) = 15.00$, $p = .001$. Planned comparisons indicated that participants responded with more Rhits for negative scenes ($M = 0.67$, $SEM = 0.04$) relative to neutral scenes ($M = 0.54$, $SEM = 0.04$), $t(24) = 4.02$, $p < .001$, $d = 0.64$ (see Panel A of Figure 2), whereas Rfalse alarms did not differ between negative and neutral scenes, $p > .14$. Emotion had no influence on the subjective sense of knowing, $p > .59$, as assessed by familiarity responses (the probability for responding know to a stimulus, given that the stimulus was not remembered, corrected for false alarms, $[(K_{\text{hit rate}}/(1 - R_{\text{hit rate}}) - K_{\text{false alarm rate}}/(1 - R_{\text{false alarm rate}})])$. An analysis of high confidence judgments, which were scenes recognized with a "6" response, revealed a similar pattern. On average, participants provided more correct high confidence recognition judgments for negative ($M = 0.66$, $SEM = 0.04$) compared with neutral scenes ($M = 0.58$, $SEM = 0.04$) judged as old, $t(24) = 2.90$, $p < .01$, $d = 0.50$ (see Panel A of Figure 2).

Memory for the color of the dots. Memory for the color of the dots in the presented scenes was assessed using two measures. First, we assessed memory between the color of the dots and the scenes, independent of recollection and familiarity measures for the scenes. Second, we assessed the memory for the color of the dots with respect to remember responses and with respect to high confidence judgments for scenes.

Memory for the color of the dots with respect to correctly recognized scenes. Correct identification of the previously presented color of the dots (indexed by recognized scenes with correct color attribution/scenes correctly identified as old) was significantly better for neutral scenes ($M = 0.52$, $SEM = 0.05$) compared with negative scenes ($M = 0.34$, $SEM = 0.04$), $t(24) = 6.21$, $p < .001$, $d = 0.84$.

Memory for the color of the dots with respect to the subjective measures of recollection for scenes. A 2 (proportion R_{hits} for scenes with correctly identified color vs. proportion of K_{hits} for scenes with correctly identified color) × 2 (negative vs. neutral) repeated measures ANOVA showed a main effect of response type, $F(1, 23) = 28.10$; $p < .001$, indicating that the color of the dots on the scenes during encoding was more often correctly identified for scenes given an R response ($M = 0.46$, $SEM = 0.04$) than for scenes given a K response ($M = 0.35$, $SEM = 0.06$). Most importantly, the ANOVA revealed a main effect of emotion, $F(1, 23) = 10.62$, $p = .003$, and a Response Type × Emotion interaction, $F(1, 23) = 4.34$, $p < .05$, reflecting that a lower proportion of negative versus neutral scenes, that were given an R response was accompanied by a correct color attribution ($M = 0.37$, $SEM = 0.04$ vs. $M = 0.58$, $SEM = 0.05$), $t(24) = 6.03$, $p < .001$, $d = 0.96$ (see Panel B of Figure 2), whereas color attribution did not differ for K responses.

Likewise, a 2 (proportion confidence "6" judgments for scenes with correctly identified color vs. proportion of confidence "5" judgments for scenes with correctly identified color) × 2 (negative vs. neutral) repeated measures ANOVA for scene memory showed a main effect of response type, $F(1, 24) = 20.08$, $p < .001$, indicating that correct identification of the previously presented color of the dots was higher for scenes that were given a correct high confidence recognition judgment than for scenes given a correct low confidence recognition judgment. Most importantly, the ANOVA revealed a main effect of emotion, $F(1, 24) = 21.25$, $p < .001$, and a Response Type × Emotion interaction, $F(1, 24) = 4.61$, $p < .05$, reflecting that a lower proportion of negative versus neutral scenes given a confidence "6" response was accompanied with correct color attribution ($M = 0.35$, $SEM = 0.04$ vs. $M = 0.57$, $SEM = 0.05$), $t(24) = 6.68$, $p < .001$, $d = 0.97$ (see Panel B of Figure 2), whereas color attribution did not differ for confidence "5" responses.

Discussion

In Experiment 1, we show that emotion enhances overall scene recognition accuracy and the subjective sense of remembering, replicating previous findings (Dolcos, LaBar, & Cabeza, 2005; Kensinger & Corkin, 2003; Ochsner, 2000; Rimmele et al., 2011;

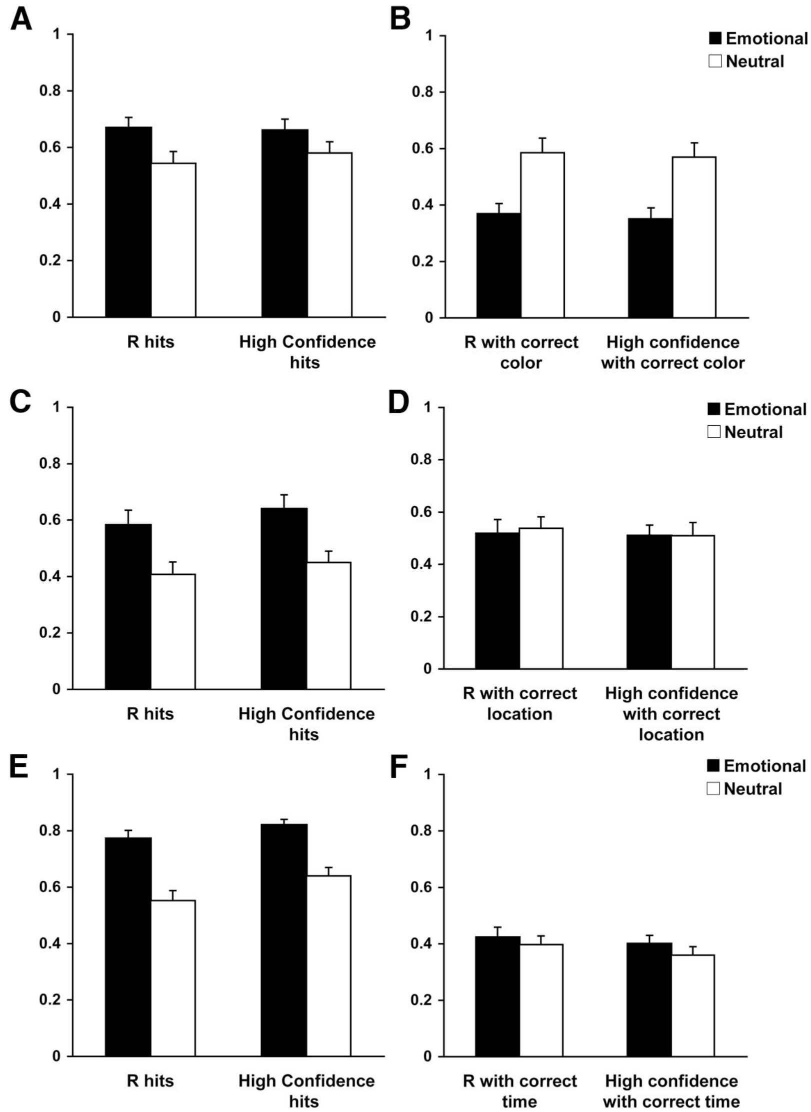

Figure 2. Negative vs. neutral sense were remembered with a higher subjective sense of remembering in Experiment 1, 2 and 3 (Panels A, C, E). The higher subjective recollective experience was accompanied by lower memory accuracy for color (B), but not location (D) or time (F). Error bars indicate SEM.

Rimmele, Domes, Mathiak, & Hautzinger, 2003; Rimmele, Meier, Lange, & Born, 2010; Sharot, Delgado, & Phelps, 2004; Sharot, Verfaellie, & Yonelinas, 2007; Sharot & Yonelinas, 2008). The fact that participants took longer to make their color judgment for negative compared with neutral scenes during encoding might have contributed to the enhanced recognition memory accuracy. In contrast to the emotion-enhancing effect for scene memory, we found that memory for color was better for the dots that had been presented on neutral scenes than for those presented on negative scenes. Most strikingly, we observed a double dissociation. Although the subjective sense of remembering was higher for negative than neutral scenes, recollection of the color of the dots was lower for negative than neutral scenes given a remember/high "6" confidence response. These findings replicate and extend the results of previous studies that showed a double dissociation between the subjective sense of remembering and recollection of contextual information for negative compared with neutral scenes (Rimmele et al., 2011; Touryan et al., 2007). However, in these previous studies, the contextual information was peripheral (colored frame around the scene or object in the corner of the scene), whereas in the present experiment, the contextual information was presented spatially central to the gist of the scene. The current finding therefore indicates that, independent of the spatial location of the contextual color, emotion decrements its recollection. Therefore, the attentional narrowing hypothesis cannot account for the observed double dissociation, as previously proposed (Rimmele et al., 2011). 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). In the present study, the colored dots were presented spatially central to the gist of the scenes and not in the periphery of the scenes. Hence, it is unlikely that a narrowing of attention mechanism has affected the encoding of the colored dots, resulting in subsequent lower recollection and the observed double dissociation.

Interestingly, our finding of lower recollection of the color of the dots on negative scenes does not concur with studies that showed enhanced memory for central details of emotional stimuli, for example, the font color of emotional words (D'Argembeau & Van der Linden, 2004; Doerksen & Shimamura, 2001; Kensinger & Corkin, 2003) or visual details of emotional objects (Kensinger et al., 2007b; Kensinger & Schacter, 2007). This discrepancy might reflect differences in the materials. Compared with 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. Another possibility is that even though the colored dots were presented spatially central to the gist of the negative scenes, they may not have been perceived as an inherently meaningful feature of the negative stimulus. Thus, the colored dots may not have profited from an emotional memory enhancement, as it has been shown for item features that are conceptually central to a negative scene. One feature that has been considered to be a central item feature and found to benefit from emotion-based binding is spatial location (Mather, 2007). In Experiment 2, we therefore set out to determine whether spatial location is associated with the enhanced subjective sense of remembering emotional events.

Experiment 2

Method

Participants. The sample of this experiment consisted of 26 subjects ($M = 24.35$, $SD = 5.14$ years, 16 female). All participants provided written informed consent and were paid for their participation. This experiment was approved by UCAIHS at New York University. One male participant was excluded from analysis due to below chance scene recognition.

Stimuli. The same scenes as in Experiment 1 were used. Each scene was scaled to one quarter of the screen size and presented in one corner of the screen. Distribution of location was counterbalanced across neutral and negative scenes and across encoding and test sets. The scenes were shown on a 19-in computer monitor.

Design and procedure. The experiment consisted of an incidental encoding task followed 1 hr later by a surprise memory test that assessed recognition and subjective recollection for the presented scenes, and memory for the location of correctly recognized scenes. At encoding, each trial consisted of a 4,000-ms presentation of a scene. For each trial, participants were instructed to indicate the corner in which the scene was located by pressing one of four response keys. After each scene presentation, a white fixation cross was shown for 1,000 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 participants beforehand to ensure that they understood the task.

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

Scene recognition. The recognition test was identical to that of Experiment 1, except that the location, and not the color of the dots, had to be indicated.

Memory for location of scene. For each scene that was given a remember or a know response, participants had to indicate in which of the four screen corners the screen the scene had been presented during the study. In order to minimize guessing, participants could also indicate that they did not know the location. The scene appeared in the middle of the screen, with the guess response underneath the scene. The four location options were labeled numerically from 1 to 4 in the respective corners to indicate the corresponding keystroke.

Data analysis. Statistical analyses relied on ANOVA and dependent sample *t* tests. An alpha level of .05 was used for all statistical tests.

Results

Encoding. Participants took significantly longer to indicate the location of negative scenes ($M = 1{,}257$, $SEM = 697$ ms) compared with neutral scenes ($M = 1{,}125$ ms, $SEM = 451$ ms), $t(24) = 2.20$, $p < .05$, $d = 0.22$.

Memory for scenes.

Recognition memory for scenes. A 2 (Rhits + Khits vs. Rfalse alarms + Kfalse alarms) × 2 (negative vs. neutral) repeated measures ANOVA for scene memory showed a main effect of response type, $F(1, 24) = 207.54$, $p < .001$, indicating a higher hit rate ($M = 0.72$, $SEM = 0.03$) than false alarm rate ($M = 0.11$, $SEM = 0.02$). Most importantly, the ANOVA revealed a main effect of emotion, $F(1, 24) = 7.20$, $p = .01$, and a Response Type × Emotion interaction, $F(1, 24) = 37.77$, $p < .001$, reflecting that total hit rate was higher for negative ($M = 0.78$, $SEM = 0.04$) versus neutral scenes ($M = 0.67$, $SEM = 0.04$), $t(24) = 5.32$, $p < .001$, $d = 0.64$, whereas false alarm rates did not differ between negative and neutral scenes, $p > .20$.

Subjective sense of remembering for scenes. A 2 (Rhits vs. Rfalse alarms) × 2 (negative vs. neutral) ANOVA for scene memory revealed significant main effects of response type (Rhits: $M = 0.50$, $SEM = 0.05$; Rfalse alarms: $M = 0.02$, $SEM = 0.005$), $F(1, 24) = 107.95$, $p < .001$, and emotion, $F(1, 24) = 28.51$, $p < .001$, as well as a Response Type × Emotion interaction, $F(1, 24) = 37.91$, $p < .001$. Planned comparisons indicated that participants responded with more Rhits for negative scenes ($M = 0.58$, $SEM = 0.05$) compared with neutral scenes ($M = 0.41$, $SEM = 0.04$), $t(24) = 6.06$, $p < .001$, $d = 0.51$ (see Panel C of Figure 2), whereas Rfalse alarms did not differ between negative and neutral scenes ($p > .80$). Emotion had no influence on the subjective sense of knowing, $p > .20$, as assessed by familiarity responses. On average, participants provided more correct high confidence recognition judgment ("6" response) for negative ($M = 0.64$, $SEM = 0.05$) compared with neutral scenes ($M = 0.45$, *SEM* = 0.04), $t(24) = 6.63$, $p < .001$, $d = 0.83$ (see Panel C of Figure 2).

Memory for the location of the scenes with respect to correctly recognized scenes. Memory for the location of the scene was assessed using two measures. First, we assessed memory for scene location independent of recollection and familiarity measures for the scenes themselves. Second, we assessed memory for the location of the scenes with respect to the subjective remember and high confidence judgments for scenes.

Memory for the location of the scenes with respect to correctly recognized scenes. Emotion enhanced memory for the spatial location of the scenes (proportion of correctly recognized scenes for which participants made correct location attribution). Participants more often identified the correct location of recognized negative scenes ($M = 0.44$, $SEM = 0.04$) than the correct location of recognized neutral scenes ($M = 0.31$, $SEM = 0.04$), $t(24) = 4.24$, $p < .001$, $d = 0.62$.

Memory for the location of the scenes with respect to the subjective measures of recollection for scenes. A 2 (proportion R_{hits} for scenes with correctly identified location vs. proportion of K_{hits} for scenes with correctly identified location) × 2 (negative vs. neutral) repeated measures ANOVA for scene memory showed a main effect of response type, $F(1, 24) = 70.71$, $p < .001$, indicating that the location of the scenes during encoding was more often correctly identified for scenes given an R response ($M = 0.54$, $SEM = 0.05$) than for scenes given a K response ($M = 0.23$, $SEM = 0.05$). Crucially, the ANOVA revealed neither a main effect of emotion nor a Response Type × Emotion interaction, all $ps > .57$, reflecting that about the same proportions of negative ($M = 0.54$, $SEM = 0.05$) versus neutral scenes ($M = 0.52$, $SEM = 0.04$) given an R response were accompanied with correct location attribution (see Panel D of Figure 2).

Likewise, a 2 (proportion confidence "6" judgments for scenes with correctly identified location vs. proportion of confidence "5" judgments for scenes with correctly identified location) × 2 (negative vs. neutral) repeated measures ANOVA for scene memory showed a main effect of response type, $F(1, 24) = 63.30$, $p < .001$, indicating that correct identification of the location was higher for scenes that were given a correct high confidence recognition judgment than for scenes given a correct low confidence recognition judgment. Most importantly, about the same proportion of negative and neutral scenes given a confidence "6" response were accompanied with correct location attribution ($M = 0.51$, $SEM = 0.04$ vs. $M = 0.51$, $SEM = 0.05$) for main effect of emotion and Response Type × Emotion interaction, $p > .10$ (see Panel D of Figure 2).

Discussion

In Experiment 2, we examined the relationship between the subjective and objective measures of recollection for negative and neutral stimuli and their spatial location. Location of the scenes was manipulated by presenting the scenes in one of four different screen positions.

Replicating Experiment 1, emotion enhanced overall recognition and the subjective sense of remembering the scenes. The fact that participants took longer to indicate the location of negative compared with neutral scenes during encoding might have contributed to the enhanced recognition memory accuracy. In addition, participants were better at remembering the location of negative scenes compared with neutral scenes judged as old (collapsed across remember and know responses). Although not uniform (Mather et al., 2006), this finding is consistent with previous studies that show that emotion benefits memory for spatial location (D'Argembeau & Van der Linden, 2004; MacKay & Ahmetzanov, 2005; Mather & Nesmith, 2008).

For both negative and neutral scenes, the subjective sense of remembering was accompanied by accurate recollection of spatial location. This finding is in contrast to the double dissociation between the enhanced subjective recollection, but lower memory, for contextual details for negative compared with neutral scenes, which we found in Experiment 1 as well as in two previous studies (Rimmele et al., 2011). Instead, our current results indicate that the enhancement of the subjective sense of remembering negative scenes is associated with accurate recollection of some specific types of contextual information, such as spatial location. Notably, location is a key feature of episodic memory and a frequently recalled aspect of naturally occurring flashbulb memories. Another essential feature of episodic memory is temporal information (Clayton & Dickinson, 1998; Ergorul & Eichenbaum, 2004; Tubridy & Davachi, 2010; Tulving, 2002). As is the case for location, information about when an event occurred in relation to other events is often reported in flashbulb memories. Considering these special characteristics of spatial location and temporal context, in a third experiment, we set out to examine whether the enhanced subjective sense of remembering negative scenes is likewise associated with more accurate recollection of the time at which the scenes were previously encountered.

Experiment 3

Method

Participants. The sample of this experiment consisted of 32 subjects ($M = 23.90$, $SD = 5.99$ years, 18 female). All participants provided written informed consent and were paid for their participation. This experiment was approved by UCAIHS at New York University.

Stimuli. The same scenes as those in Experiments 1 and 2 were used. For encoding, the scenes were shown in three blocks, each containing 20 scenes (10 neutral, 10 negative). The order of the presentation of the blocks was counterbalanced across participants.

Design and procedure. The procedure was the same as in Experiments 1 and 2, except that, during encoding, subjects were instructed to merely watch the scenes, and that presentation of the three blocks was separated by two 3-hr intervals. One hour after the third encoding block, during which subjects watched the same movie as in Experiments 1 and 2, a self-paced memory test was administered to assess recognition and subjective recollection for the presented scenes, and memory for when (in which block) a correctly recognized scene had been presented.

Memory for time of scene presentation. For each scene that was given a remember or a know response, participants had to decide during which of the three blocks the scene had been presented during study or indicate that they did not know when the scene had been presented (this option was given to minimize guessing). The scene appeared in the middle of the screen, with the time option labeled numerically from 1 to 3 and the "I do not know" response located underneath the scene.

Data analysis. Statistical analyses relied on ANOVA and dependent sample *t* tests. An alpha level of .05 was used for all statistical tests.

Results

Memory for scenes.

Recognition memory for scenes. A 2 (Rhits + Khits vs. Rfalse alarms + Kfalse alarms) × 2 (negative vs. neutral) repeated measures ANOVA for scene memory showed a main effect of response type, $F(1, 31) = 1835.02$, $p < .001$, indicating a higher hit rate ($M = 0.88$, $SEM = 0.02$) than false alarm rate ($M = 0.07$, $SEM = 0.01$). Most importantly, the ANOVA revealed a main effect of emotion, $F(1, 31) = 32.09$, $p < .01$, and a Response Type × Emotion interaction, $F(1, 31) = 32.18$, $p < .001$, reflecting that total hit rate was higher for negative ($M = 0.94$, $SEM = 0.01$) versus neutral scenes ($M = 0.81$, $SEM = 0.02$), $t(31) = 6.48$, $p < .001$, $d = 1.37$, whereas false alarm rates did not differ between negative and neutral scenes, $p > .57$.

Subjective sense of remembering for scenes. A 2 (Rhits vs. Rfalse alarms) × 2 (negative vs. neutral) ANOVA for scene memory revealed significant main effects of response type (Rhits: $M = 0.66$, $SEM = 0.03$; Rfalse alarms: $M = 0.01$, $SEM = 0.005$), $F(1, 31) = 492.13$, $p < .001$, and emotion, $F(1, 31) = 76.86$, $p < .001$, as well as a Response Type × Emotion interaction, $F(1, 31) = 70.50$, $p < .001$. Planned comparisons indicated that participants had more Rhits for negative scenes ($M = 0.77$, $SEM = 0.03$) compared with neutral scenes ($M = 0.55$, $SEM = 0.04$), $t(31) = 8.66$, $p < .001$, $d = 1.20$ (see Panel E of Figure 2), whereas Rfalse alarms did not differ between negative and neutral scenes, $p > .80$. Emotion had no influence on the subjective sense of knowing, $p > .11$, as assessed by familiarity responses. On average, participants also provided more correct high confidence recognition judgment ("6" response) for negative ($M = 0.82$, $SEM = 0.02$) compared with neutral scenes ($M = 0.64$, $SEM = 0.03$), $t(31) = 6.59$, $p < .001$, $d = 1.34$ (see Panel E of Figure 2).

Memory for the time of scene presentation. Memory for the time of scene presentation was assessed using two measures. First, we assessed memory for time of scene presentation independently of recollection and familiarity measures. Second, we assessed memory for the time of scene presentation with respect to the subjective remember and high confidence judgments for scenes with respect to correctly recognized scenes.

Memory for the time of scene presentation with respect to correctly recgnized scenes. Given previous evidence for better temporal memory for emotional than neutral items (D'Argembeau & Van der Linden, 2005), we hypothesized that emotion would enhance memory for the temporal context of scene presentation. Indeed, correct identification of the study block in which the scene was presented during encoding (indexed by recognized scenes with correct time attribution/scenes correctly identified as old), was significantly better for negative scenes ($M = 0.36$, $SEM = 0.03$) than neutral scenes ($M = 0.28$, $SEM = 0.03$), $t(31) = 3.87$, $p = .001$. To investigate whether memory for temporal information differed for the three blocks in which scenes had been presented, we conducted a 2 (emotion) × 3 (time of presentation) ANOVA. A main effect of emotion, $F(1, 30) = 32.84$, $p < .001$, and a main effect of study block, $F(2, 60) = 8.15$, $p = .001$, indicated that memory for temporal context was better for scenes that were presented in the first and third blocks compared with scenes that were presented in the second block. Importantly, however, the ANOVA did not reveal an interaction between emotion and study block, $p > .57$. This finding is in accordance with previous studies and may stem from the fact that the beginning and the end of a study phase represent salient landmarks to which the stimuli may be linked, thereby making temporal judgments more accurate for stimuli presented close to these landmarks compared with stimuli presented in the middle of the study phase (D'Argembeau & Van der Linden, 2005; Friedman, 2001).

Memory for the time of presentation of the scenes with respect to the subjective measures of recollection for scenes. A 2 (proportion R_{hits} for scenes with correctly identified time of presentation vs. proportion of K_{hits} for scenes with correctly identified time of presentation) × 2 (negative vs. neutral) repeated measures ANOVA for scene memory showed a main effect of response type, $F(1, 32) = 83.13$, $p < .001$, indicating that the time of scene presentation was more often correctly identified for scenes given an R response ($M = 0.41$, $SEM = 0.03$) than for scenes given a K response ($M = 0.15$, $SEM = 0.04$). Crucially, the ANOVA revealed neither a main effect of emotion nor a Response Type × Emotion interaction, all *p*s > .39, reflecting that about the same proportions of negative versus neutral scenes given an R response were accompanied by correct location attribution ($M = 0.42$, $SEM = 0.03$ vs. $M = 0.39$, $SEM = 0.03$; see Panel F of Figure 2).

Likewise, a 2 (proportion confidence "6" judgments for scenes with correctly identified location vs. proportion of confidence "5" judgments for scenes with correctly identified location) × 2 (negative vs. neutral) repeated measures ANOVA for scene memory showed a main effect of response type, $F(1, 32) = 69.97$, $p < .001$, indicating that time of presentation was more often correctly identified for scenes that were given a correct high confidence recognition judgment than for scenes given a correct low confidence recognition judgment. Independent of confidence, time of presentation was better identified for negative than neutral scenes (main effect of emotion: $F(1, 32) = 7.45$, $p = .01$). Most importantly, about the same proportion of negative and neutral scenes given a confidence "6" response were accompanied with correct time attribution ($M = 0.40$, $SEM = 0.03$ vs. $M = 0.36$, $SEM = 0.03$ for Response Type × Emotion interaction, $p > .75$; see Panel F of Figure 2).

Discussion

In Experiment 3, we examined the relation between recollection of temporal information and subjective and objective measures of recollection for negative and neutral stimuli. For this purpose, we used a list-discrimination paradigm in which participants were presented with three study lists (each containing 10 negative and 10 neutral scenes) separated by a 3-hr interval.

Replicating Experiments 1 and 2, emotion enhanced overall recognition and the subjective sense of remembering for the scenes. For correctly recognized scenes (collapsed across remember and know responses), participants were better at correctly attributing the time of presentation for negative compared with neutral scenes. This finding confirms and extends the findings of a previous study (D'Argembeau & Van der Linden, 2005) by showing that emotion benefits memory for temporal information not only when lists are subsequently presented but also when there is a longer interval (3 hr) between list presentation.

Furthermore, we found that the subjective sense of remembering both negative and neutral scenes is accompanied by accurate recollection of temporal information. This result extends the findings from Experiment 2 by showing that the subjective sense of remembering negative information is not only associated with spatial location but also with another fundamental feature of episodic memory, that is, temporal context.

Experiment 4

Our finding of an association between the enhanced subjective sense of remembering and memory for location and time of occurrence but not color suggests that the enhanced subjective sense of remembering flashbulb memories may reflect better memory of certain details, such as spatial location and temporal context. Previous studies assessed the canonical features of flashbulb memories (Brown & Kulik, 1977)—that is, place, informant, ongoing activity at the time of the reception, and the activity immediately following the reception—and found that memory consistency for these details was dissociated from the enhanced recollective experience for the flashbulb memories (Winograd & Neisser, 1992; Schmolck et al., 2000; Talarico & Rubin, 2003). However, these studies have not investigated whether there is a difference in memory consistency for different types of details. It is possible that flashbulb memories are more consistent over time for some, but not other, types of details. Experiment 2 suggests that location of occurrence may be a detail that is more consistent over time than other types of details. To test this hypothesis, we assessed the consistency for the canonical features of the 9/11 flashbulb memory over three time points (1 week, 1 year, 3 years; Hirst et al., 2009). In addition, we assessed confidence ratings for the flashbulb memory features over time.

Method

Participants, recruitment, and procedure. Three hundred ninety-one participants who completed surveys at all three time points participated in the reanalysis (Hirst et al., 2009). Participants were recruited throughout the United States between September 17, 2001, and September 21, 2001, for Survey 1; between August 5 and August 26, 2002, for Survey 2; and between August 9 and August 20, 2004, for Survey 3. The website of the survey was closed 1 day after recruitment and postal surveys returned more than 5 days after recruitment were not included.

Surveys. The surveys contained questions to assess memory for canonical features of flashbulb memories. The questions were as follows: (1) Where were you? (2) What were you doing? (3) How did you first learn about it (what was the source of the information)? (4) How did you feel when you first became aware of the attack? (5) Who was the first person with whom you communicated about the attack? (6) What were you doing immediately after you became aware of the attack? In addition, for each canonical feature, participants were asked, “How confident are you that your recollection is accurate?” Participants responded on a 5-point scale (1 = *not at all* and 5 = *extremely*).

Coding and data analysis. The coding scheme for measuring the consistency of flashbulb memories for Survey 1 was matched with the coding scheme of the other two surveys, producing consistency measures that contrasted Survey 2 with Survey 1 (S12), or Survey 3 with Survey 1 (S13). Two responses were consistent if they were given the same coding number in each survey. The coding manuals are available online at http://911memory.nyu.edu. Location when learning about 9/11 was coded either for actual site, for example, “home” or “work office,” or for geographic site, for example, NYC Brooklyn. If the items were consistent, a “1” was assigned, otherwise a “0” was assigned. To investigate whether more subjects were consistent across surveys in their memory for the location when learning about 9/11 versus their memory for other canonical features, χ^2 tests were used. To examine whether participants differed in the confidence of their memory for location where they learnt about 9/11 versus their memory for other canonical features, *t* tests were performed.

Results

More participants were consistent in their memory reports for the location when learning about 9/11 from Survey 1 to Survey 2 (89%) and from Survey 1 to Survey 3 (82.6%) than any other canonical feature; all χ^2 tests, $p < .001$ (see Table 1). Overall participants gave high confidence ratings for all canonical features (Survey 2: $M = 4.41$, $SD = .64$; Survey 3: $M = 4.25$, $SD = .93$). Interestingly, participants gave higher confidence ratings for their

Table 1
Percentage of Participants Being Consistent in Their Memory for the Canonical Features Across Surveys

	Survey 1 to Survey 2		Survey 1 to Survey 3	
	% Participants consistent	χ^2	% Participants consistent	χ^2
Place	89%		82.6%	
Ongoing activity	66%	54.03	61.9%	75.01
Informant	75.7%	18.06	69.6%	38.44
Own immediate reaction	40.7%	238.29	34.3%	305.63
First communication	57%	194.60	53%	132.38
Postactivity	52.9%	133.12	43.2%	214.26

Note. χ^2 values for tests % participants with correct location memory vs. all other canonical features with 1 df, $p < .001$, in all cases.

memory for location (Survey 2: $M = 4.83$, $SD = .55$, Survey 3: $M = 4.75$, $SD = .71$) than for any other canonical details, all $ps > .001$.

General Discussion

In three experiments, we explored the relationship between subjective reports of recollection and memory for contextual information. The main finding is that the subjective sense of remembering negative scenes is linked with accurate memory for spatial location and temporal context, but not with accurate recovery of the color of dots presented in the conceptual center of an image.

In all experiments, we assessed the subjective sense of remembering by asking for remember/know judgments and by measuring recognition confidence. "Remember" judgments are thought to reflect recollection-based judgments, while "know" judgments are thought to be related to familiarity-based recognition judgments (Tulving, 1985; Yonelinas, 2002). Since it has been previously shown that remember judgments are coupled with better memory for a number of contextual details (Perfect et al., 1996), we first examined the relation between the subjective sense of remembering and the objective recollection of the contextual details independent of the emotionality of the scenes. In all studies, remember compared with know judgments for neutral and negative scenes combined were associated with better memory of contextual information. This finding confirms previous findings that remember-versus-know responses are accompanied by better memory for contextual details of neutral stimuli (Gardiner et al., 1998; Perfect et al., 1996) and extends this pattern to emotional stimuli.

However, even though we found memory for contextual details to be associated with remember responses for negative and neutral scenes combined, this relationship was not equivalent for negative and neutral scenes depending on the type of contextual information (colored dots in the conceptual center of the scenes in Experiment 1, spatial location of the scene in Experiment 2, and time of presentation in Experiment 3). 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), in all three experiments, participants were more likely to experience a stronger subjective sense of remembering for negative than neutral scenes. The boost for remember and high-confidence responses for negative scenes was linked to accurate memory for both spatial location and temporal context, but not color. These findings indicate that the subjective sense of remembering negative scenes is not coupled with the recollection of all kinds contextual details equally, as it has been observed for neutral stimuli (Perfect et al., 1996).

It is unclear what mechanisms underlie the observation that the subjective sense of remembering negative stimuli is associated with recollection of memory for the place and the time at which the information was acquired, but not color. One explanation may be that similar to the emotional memory benefit of intrinsic, but not extrinsic, features (Kensinger, 2009; Mather, 2007), the subjective sense of remembering negative stimuli may only be coupled with memory for intrinsic contextual details (location, time) but dissociated from memory for extrinsic contextual details (color). Different approaches have been undertaken to determine what features constitute an intrinsic part of a negative stimulus. Features have been defined as intrinsic according to perceptual characteristics (Mather, 2007), conceptual characteristics, like gist or features that cannot be changed without changing the basic nature of the emotional event (Adolphs, Denburg, & Tranel, 2001; Heuer & Reisberg, 1990), or goal-relevant features (Levine & Edelstein, 2009). In the present experiment, the colored dots, even though spatially central to the conceptual center, were not conceptually relevant and therefore may not have benefited from an arousal-induced enhancement of binding to the scene. In contrast, spatial location and temporal information have been proposed to be intrinsic stimulus features (Mather, 2007), and negative arousal elicited upon negative scene presentation might have triggered binding mechanisms that linked them into the memory representation of the negative scenes (Mather, 2007; Mather & Nesmith, 2008). Of note, spatial and temporal information have been encoded incidentally in our experiments. For real-world events, such as 9/11, this is also the case. In addition, the spatial information consisted of constrained locations on the computer screen, unlike spatial information in a natural setting. In contrast, the temporal manipulation seems more consistent with natural temporal judgments, as each block can be considered an event, with each stimulus as a particular detail of that event (of differential emotional value) and with sufficiently realistic time between events. Our similar results for the subjective sense of remembering and memory for location and temporal context in both our laboratory experiments and the real-life memory of 9/11 suggests the laboratory findings may have some ecological validity.

Another explanation may be that the subjective sense of remembering emotional stimuli is associated with the quality of a few recalled memories rather than the quantity 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 sense of recollection, even if other "canonical details" (e.g., interrupted activity when hearing about the event) were not recalled (Brown & Kulik, 1977). Given this evidence, it may be that temporal or spatial information provide a stronger mnemonic signal that may drive the enhanced subjective sense of remembering with emotion.

We additionally tested whether the enhanced subjective sense of remembering consistently found in flashbulb memories may reflect consistent memory for selective types of details, such as spatial location. Reanalyzing a previous data set on memory for the terrorist attacks on 9/11, we found that a higher proportion of the participants were consistent in their memory reports for the location where they learnt about the terrorist attacks over years compared with memory for any other canonical feature. Confidence for all canonical features of the flashbulb memory remained high over time, which replicates previous findings on flashbulb memories (Talarico & Rubin, 2003). Crucially, confidence was higher for memory for location than memory of any other canonical features. This finding shows that for real-life emotional memories, the subjective sense of remembering is associated with more consistent memory for the spatial location when learning about the emotional event compared with memory for other kinds of canonical details, such as informant or ongoing activity.

Another potential explanation for the association of the enhanced subjective sense of remembering with spatial location and temporal context, but not colored details central to the emotional scenes, may be that different neural processes underlie memory for the content and memory for the time and place of a scene (Davachi, Mitchell, & Wagner, 2003; Tubridy & Davachi, 2010). Recent studies show that the binding of different kinds of episodic detail depends on different medial temporal lobe encoding operations. For neutral items, binding of item-related details, such as color, has been specifically related to enhanced activity in the hippocampus and perirhinal cortex, while binding of spatial and temporal context has been found to be associated with enhanced activity in the hippocampus and posterior parahippocampal cortex (Awipi & Davachi, 2008; Farovik, Dupont, & Eichenbaum, 2010; Jenkins & Ranganath, 2010; Staresina & Davachi, 2006, 2008, 2009, 2010; Tubridy & Davachi, 2010). Based on these findings, it has been hypothesized that hippocampal-perirhinal projections may be specifically important for encoding of item-related details (Staresina & Davachi, 2006, 2008), while activity in the hippocampus and the posterior parahippocampal cortex may underlie memory for other kinds of contextual information, such as location (Awipi & Davachi, 2008) and temporal order (Tubridy & Davachi, 2010). Emotion may modulate these binding processes selectively, leading to differences in the way emotional items and their details are remembered (Levine & Edelstein, 2009; Reisberg & Heuer, 2004).

In addition, the neural systems underlying the subjective sense of remembering during memory retrieval 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; Köhler, Crane, & Milner, 2002). These fMRI findings suggest that remember judgments compared with 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 sense 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 judgments compared with 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).

In sum, the findings of our study show that emotion specifically enhances the subjective recollective experience for scenes, which is associated with accurate memory of spatial and temporal context but not of spatially central color details. The same was found for flashbulb memories of 9/11: Participants showed high confidence over time for the flashbulb memory, and more participants showed accurate memory over time for the location where they learnt about the 9/11 than memory for other kinds of canonical features. These findings suggest that the strong recollective experience of an emotional event corresponds to an accurate memory of some kinds, but not other kinds, of contextual details. The mechanisms underlying this discrepancy need further investigation and may provide further insight into the mechanisms involved in flashbulb memories (Winograd & Neisser, 1992; Talarico & Rubin, 2003).

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