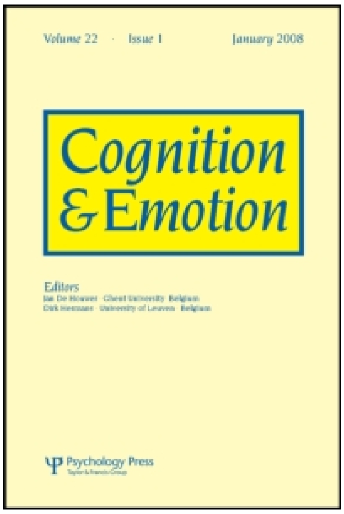


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# Reduced memory for the spatial and temporal context of unpleasant words

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# Reduced memory for the spatial and temporal context of unpleasant words

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Emotional stimuli are consistently better remembered than neutral stimuli. However, the reported effects of emotional stimuli on source memory are less consistent. In four experiments, we examined spatial and temporal source memory and free recall for emotional words previously studied in an fMRI experiment. In the fMRI experiment, the unpleasant but not the pleasant words were shown to activate the amygdala. In the experiments reported here, spatial and temporal source memory were reduced for the unpleasant words compared to pleasant and neutral words. Reduced spatial memory for unpleasant words was observed across studies that varied the specific stimuli, task conditions, and incidental versus intentional encoding instructions. Free recall was enhanced for the pleasant and unpleasant words compared to neutral words. The results demonstrate reduced source memory for unpleasant words even when item recall is enhanced. Our findings are consistent with prior reports of amygdala-mediated amnestic effects evoked by unpleasant stimuli.

An extensive literature supports the idea that, in general, emotionally arousing stimuli are better remembered than emotionally neutral stimuli. In behavioural studies, this effect has been observed with a variety of visual (Bradley, Greenwald, Petry, & Lang, 1992; Cahill & McGaugh, 1995), auditory (Bradley & Lang, 2000) and semantic (Rubin & Friendly, 1986) stimuli. Converging evidence from lesion and functional imaging studies suggests that the amygdala, via its modulating effect on hippocampal

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function, has a key role in the enhancement of memory for emotionally arousing stimuli, especially stimuli pertaining to fear or threat (Cahill & McGaugh, 1998; Richardson, Strange, & Dolan, 2004).

More recently, investigators have examined the effect of emotionally arousing stimuli on source memory. Source memory refers to "a variety of characteristics that, collectively, specify the conditions under which a memory is acquired (e.g., the spatial, temporal and social context of the event; the media and modalities through which it was perceived)" (Johnson, Hashtroudi, & Lindsay, 1993, p. 3). Interestingly, studies of the effect of emotion on various aspects of source memory have yielded mixed results instead of showing a consistent memory-enhancing benefit for emotional stimuli. A number of studies suggest that emotional stimuli enhance source memory. For example, long-term spatial memory for the screen locations of taboo words was enhanced compared to neutral words in a study that allowed participants to learn the stimulus–location pairings over multiple trials (MacKay & Ahmetzanov, 2005). In addition, researchers found enhanced spatial memory for emotional stimuli in studies where participants viewed each stimulus only once (D'Argembeau & Van der Linden, 2004). Furthermore, two studies have shown enhanced source memory for colour associated with emotional words studied with intentional encoding instructions. Doerksen and Shimamura (2001) found that memory for both the colour in which words were printed and the colour of a border surrounding words was enhanced for emotional words compared to neutral words and that there was no difference in source memory performance between the pleasant and unpleasant words. Kensinger and Corkin (2003) reported that memory for the colour of words was better for unpleasant words than for neutral words. In contrast, D'Argembeau and Van der Linden (2004) found enhanced source memory for the colour of emotional words, but only with incidental encoding instructions. They found no effect in participants given intentional encoding instructions. Collectively, these studies support the idea that emotional stimuli generally enhance various aspects of source memory.

There have been a number of other studies, however, that have suggested that unpleasant emotional stimuli may impair source memory. Neutral words presented during an unpleasant film were less well remembered than neutral words presented during a pleasant or emotionally neutral film (Anderson & Shimamura, 2005). Two studies found reduced short-term memory for the locations of emotional pictures compared to neutral pictures presented on a computer screen. One of these studies found reduced spatial source memory for both pleasant and unpleasant pictures (Mather et al., 2006) while the other study used only unpleasant pictures (Mitchell, Mather, Johnson, Raye, & Greene, 2006). Using a Von Restorff paradigm, several studies have reported reduced memory for the neutral word immediately preceding an unpleasant oddball word (Hurlemann et al., 2005, 2007;

Strange, Hurlemann, & Dolan, 2003). The combination of unpleasant words and novelty may lead to greater levels of arousal compared to unpleasant words studied in the absence of a Von Restorff effect. This amnestic effect on words preceding unpleasant oddball words was abolished by selective bilateral amygdala damage (Hurlemann et al., 2007; Strange et al., 2003).

The nature of the emotional stimuli used in studies of source memory and emotion may be critical in determining the observed mnemonic effects. In studies that found enhanced source memory for emotional stimuli (D'Argembeau & Van der Linden, 2004; Doerksen & Shimamura, 2001; Kensinger & Corkin, 2003), the researchers used emotional words as their stimuli. However, most studies reporting impaired source memory for unpleasant stimuli used stimuli of a visual nature. Anderson and Shimamura (2005) used films to create an emotional context, while Mather et al. (2006) and Mitchell et al. (2006) used emotionally arousing photos as test stimuli. It is reasonable to expect that both unpleasant films and unpleasant photos elicit stronger emotional reactions than unpleasant words because films and photos tend to be more engaging and arousing than words. As unpleasant experimental stimuli increase in emotional intensity, so does activity within the amygdala (Lewis, Critchley, Rotshtein, & Dolan, 2007; Phan et al., 2004). Studies combining unpleasant words with the Von Restorff effect also demonstrate impaired memory for contextual information, and this effect appears to be mediated by the amygdala (Hurlemann et al., 2005, 2007; Strange et al., 2003). Whether or not the unpleasant stimuli used in source memory experiments engage specific amygdala-mediated processes may determine whether or not memory for contextual information is impaired.

The type of contextual information tested in studies of emotion and source memory may also have a significant influence on the observed mnemonic effects. Memories of highly arousing emotional events often differ from memories of neutral events (Christianson, 1992). This effect of emotion on source or context memory is characterised by enhanced memory for the gist or central features of the event and impaired memory for peripheral information associated with the event. This phenomenon is often referred to as the weapon focus effect (Easterbrook, 1959) and is attributed to emotional arousal causing a narrowing of attention towards the central part of the stimuli at the cost of reduced attention to peripheral details related to the stimuli. Similarly, Kensinger, Piguet, Krendl, and Corkin (2005) found that memory for the central features of a photo was better while memory for peripheral details was worse for unpleasant images compared to neutral images in incidental memory tests. Studies of patients with selective amygdala lesions show that both of these effects are mediated by the amgydala (Adolphs, Denburg, & Tranel, 2001; Adolphs, Tranel, & Buchanan, 2005). Thus, amygdala-mediated arousal might play a complex role in the effects of emotion on source memory, such that it enhances memory for central features of source information and reduces memory for peripheral features of source information.

The current study was designed to study emotional effects on spatial source memory using emotionally arousing words known to evoke a specific pattern of brain activation. In a prior fMRI study from our lab, participants made valence judgements of well-matched pleasant, unpleasant and neutral words. We observed that the unpleasant words, but not the pleasant words, evoked significant activation of the amygdala when contrasted with the neutral words (Maddock, Garrett, & Buonocore, 2003). Based on this finding, we reasoned that if the amygdala mediates emotional source memory effects for these stimuli, they will be evident for the unpleasant words, but not the pleasant words, when compared to the neutral words. Amygdala-mediated effects might lead to either increased or reduced memory for source information, depending on whether or not the information tested is central to the "gist" of the emotional stimulus. Spatial information is not expected to be central to the gist of unpleasant words. Furthermore, prior studies using highly arousing emotional stimuli have observed reduced spatial source memory (Mather et al., 2006; Mitchell et al., 2006). Thus, we reasoned that an amygdala-mediated process evoked by these stimuli would result in reduced spatial source memory specifically for the unpleasant words.

## EXPERIMENT 1A

### Method

*Participants.* Forty-eight University of California Davis students (34 females), aged 17 to 24 years ($M = 19.77$ years), gave informed consent, received course credit for their participation, and were included in the primary data analysis. Ten additional participants were excluded. One was dropped from data analysis due to experimenter error during the data collection portion of the study. Because these words had previously been normed by a large group of students, agreement with normative valence ratings was used as a control measure for determining whether participants understood and attended to the rating task. As a conservative approach to participant inclusion, we decided a priori to exclude participants giving non-normative valence ratings (ratings that differed by more than 3 points on our 9-point scale from the mean rating in our original sample; Maddock et al., 2003) for more than 10% of the items. Nine participants were excluded from the data analysis for this reason.

*Materials.* Valence and arousal are the two primary semantic dimensions along which emotionally salient stimuli vary (Bradley & Lang, 1994; Lang, Greenwald, Bradley, & Hamm, 1993; Osgood, Suci, &Tannenbaum, 1957; Russell, 1980). In studies of verbal memory, Rubin and Friendly (1986) demonstrated that arousal was one of the three key characteristics, along with familiarity and imagery, that influence recall of words. Stimuli for this study were carefully matched on these and other dimensions. A total of 12 unpleasant, 12 pleasant and 12 emotionally neutral words was selected from a larger set of 64 unpleasant, 64 pleasant and 128 neutral words (all nouns or adjectives) previously normed for valence, arousal, imagery, frequency, length, and part of speech (Maddock et al., 2003). Because the unpleasant and pleasant words were constrained by a semantic theme (unpleasantness or pleasantness), members of those lists were semantically related. Therefore, we imposed a parallel constraint in selecting emotionally neutral words and used words whose meanings pertained to shapes or configural features and relationships.

The unpleasant, pleasant, and neutral words were matched on normative values for imagery (rated on a 1–9 scale; unpleasant: $M = 5.41$, $SD = 0.98$; pleasant: $M = 5.54$, $SD = 1.13$; neutral: $M = 5.37$, $SD = 1.31$), log frequency of usage (Kucera & Francis, 1967); unpleasant: $M = 1.46$, $SD = 0.44$; pleasant: $M = 1.56$, $SD = 0.49$; neutral: $M = 1.51$, $SD = 0.34$), number of syllables (unpleasant: $M = 2.42$, $SD = 0.67$; pleasant: $M = 2.25$, $SD = 0.75$; neutral: $M = 2.42$, $SD = 0.79$) and percent nouns (unpleasant 75%; pleasant 92%; neutral 75%). The unpleasant and pleasant words were matched on normative values for arousal (rated on a 1–9 scale; unpleasant: $M = 7.13$, $SD = 0.40$; pleasant: $M = 6.98$, $SD = 0.39$; both exceeded arousal ratings for neutral words: $M = 2.57$, $SD = 0.79$) and on the absolute value of normative valence ratings measured from the midpoint of the 1–9 scale (unpleasant: $M = 2.74$, $SD = 0.45$; pleasant: $M = 3.04$, $SD = 0.31$; both exceeded the corresponding value for neutral words: $M = 0.26$, $SD = 0.22$). We estimated the degree of semantic relatedness within the three groups of 12 words by Latent Semantic Analysis (LSA; Landauer, 1998; Landauer, Foltz, & Laham, 1998) using the Encyclopaedia corpus of 60,768 words. This yielded an average relatedness estimate of 0.128 ($SD = 0.070$) for the unpleasant words, 0.125 ($SD = 0.099$) for the pleasant words, and 0.102 ($SD = 0.096$) for the neutral words (averaged over the 66 pairwise comparisons of each word with every other word in the group). One-way analysis of variance (ANOVA) showed no significant difference in relatedness across word types, $F(2, 195) = 1.66$, *ns.* (Word lists are shown in the appendix).

*Procedure.* Participants rated the valence of unpleasant, pleasant and neutral words and typed them into a unique spatial location within a $6 \times 7$ cell spatial grid. Each word appeared individually on a computer screen centred above a rectangular grid composed of six columns and seven rows. Three different templates were used for the grids in the experiment. Each template had 18 open cells and the remaining 24 cells were filled with a distinctive graphic pattern. One type of word (pleasant, unpleasant or neutral) was uniquely associated with each template for an individual participant. Pairings of templates and word types were counterbalanced across participants. Each template contained an equal number of words of each valence on the left and right sides of the grid. Two versions of each pairing of template and word type were used so that every word appeared on the left and right sides of the grid an equal number of times across participants. Each grid contained a single asterisk located in a unique, open cell within the grid. Participants typed each word directly into the cell indicated by the asterisk and then rated the pleasantness of the word using a 1 to 9 scale. Scale anchors were "*very pleasant*" and "*very unpleasant*" and were counterbalanced across participants. A sample study grid is shown in Figure 1.

Participants first completed a 3-item practice session. Once participants indicated that they fully understood the task, they began the study portion of the experiment. Participants progressed through the study task at their own pace. In addition to the 36 experimental words, two neutral words were presented as the initial and final words studied. These words were not

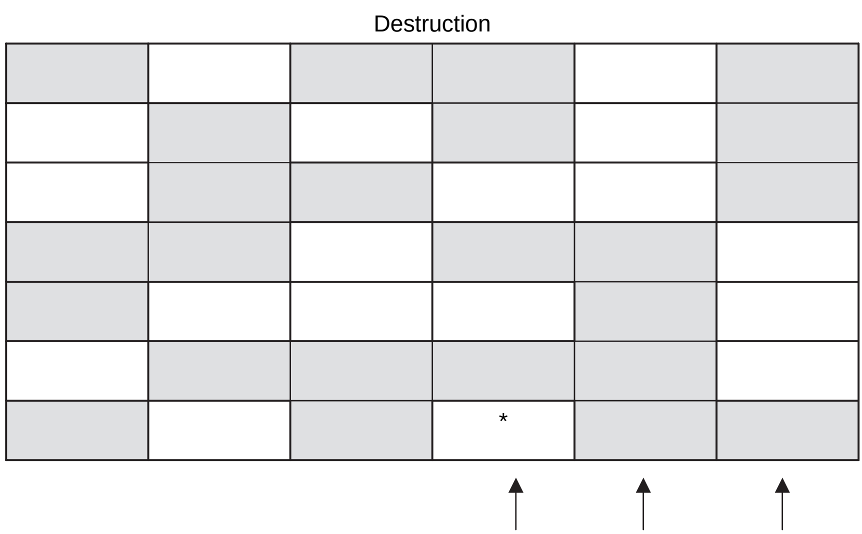


**Figure 1.** Sample grid used in Experiments 1a, 1b, 2, and 3. In the study phase, the asterisk appeared in the cell, but the arrows did not appear below the grid. In the test phase for Experiments 1a and 1b, the asterisk did not appear in the cell, but the three arrows below the grid were added to indicate the half of the grid where the word originally appeared.

included in the memory testing phase. Each of the 38 words presented was associated with a unique cell location in the grid for each participant and was presented only once. Participants were not told that they would be tested on the spatial location of the words or on the contents of the word list.

Upon completion of a distracter task, participants took part in a surprise incidental spatial memory test. Participants again saw each of the 36 words, now in a different order, centred individually above the 6 × 7 grid. Test order was balanced by valence across participants. As shown in Figure 1, all of the 18 open cells were empty and participants were instructed to type each word in the same cell in which they had typed it during the study phase. An arrow was displayed immediately below each of the three columns on either the left or right side of the screen to indicate the half of the grid in which participants had originally typed the word. This information was provided to minimise valence-related laterality effects on participant's responses because pilot studies suggested that participants placed more of the pleasant words on the right side of the grid and more of the unpleasant words on the left side of the grid. Memory for the spatial location into which each word was previously entered by the participant is a form of source memory as defined by Johnson and colleagues (Johnson et al., 1993).



Pilot studies showed that participants often made "near misses" suggesting partial retention of information about spatial context. Thus, spatial accuracy was scored using a graded scale. Participants received four points for each word that they typed in the correct cell. Because each of the individual cells were rectangular in shape, the distance from the centre of the target cell to the centres of the cells directly above and below it was shorter than the distance from the centre of the target cell to the centre of the cells to the left, right and diagonally connected to the target cell. This shorter distance was interpreted to mean that words placed in cells directly above and below the target cell were physically closer to their original location than were words placed in any other cell adjacent to the target cell. Consequently, two points were awarded for each word typed in a cell directly above or below the target location and one point for each word typed in a cell to the left, the right, or diagonally connected to the target cell. Grids were counterbalanced so that an equal number of incorrect, but open cells appeared above, below, to the left, to the right, and diagonally connected to the target cell for each word type. After the spatial memory task, participants were given a surprise free recall task that lasted five minutes. The effect of valence on spatial memory scores was analysed by repeated measures ANOVA with alpha = .05. Significant differences across word types were further analysed by planned comparisons using paired $t$-tests with alpha = .05 (two-tailed). The effect of valence on free recall was also analysed by ANOVA followed by paired $t$-tests with alpha = .05 (two-tailed). Valence categories for each word were based on normative valence ratings.

## Results and discussion

A repeated measures ANOVA indicated a main effect of word type for the spatial memory scores, $F(2, 94) = 5.78$, $MSE = 126.47$, $p < .005$. Post hoc analyses revealed that there was no difference in spatial memory scores between the pleasant and the neutral words, $t(47) = 0.50$; *ns*. However, spatial memory scores for the unpleasant words were significantly lower compared to both the pleasant, $t(47) = 2.69$; $p < .01$, and the neutral words, $t(47) = 3.25$; $p < .0025$ (see Figure 2). This deficit in source memory for the unpleasant words cannot be attributed entirely to arousal because the unpleasant and the pleasant words were selected to have equivalent levels of arousal. A repeated measures ANOVA of free recall performance demonstrated a main effect of word type, $F(2, 94) = 28.2$, $MSE = 49.38$, $p < .0001$. As shown in Figure 3, the pleasant words were remembered better than the unpleasant, $t(47) = 6.77$; $p < .0001$, and the neutral words, $t(47) = 6.55$; $p < .0001$, and the unpleasant words showed a non-significant trend for being recalled better than the neutral words, $t(47) = 1.79$, $p = .08$. Side of grid in which the word was presented was also included as a factor in data analysis and results were non-significant either as a main effect or for interactions for this and all subsequent experiments.

When participants who were dropped from the study due to excessive non-normative valence ratings were included in the data analysis, the spatial

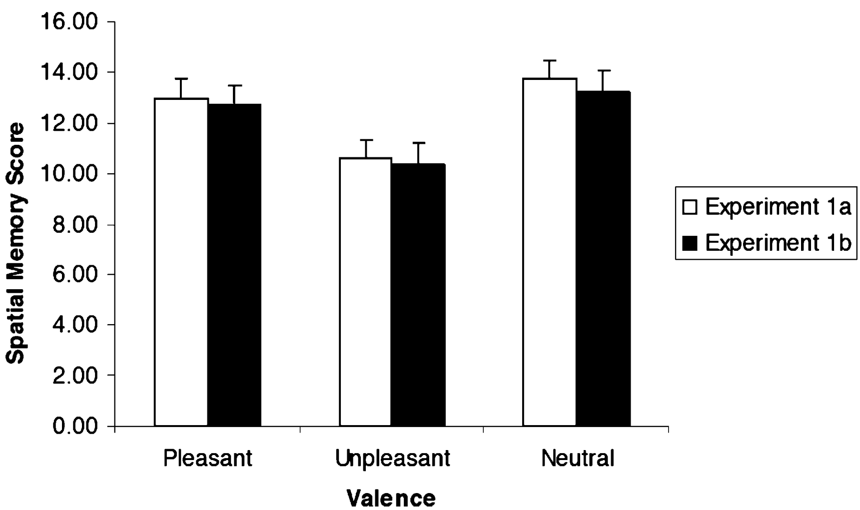


**Figure 2.** Mean spatial memory scores (+*SEM*) for pleasant, unpleasant and neutral words in Experiments 1a and 1b. For both experiments, a significant effect of valence on ANOVA followed by *t*-tests showed spatial memory to be worse for unpleasant then either pleasant or neutral words (all *p*s <.05). Chance score on spatial memory test = 8.85 (performance for all word types was significantly better than chance by single group *t*-test, all *p*s <.05).

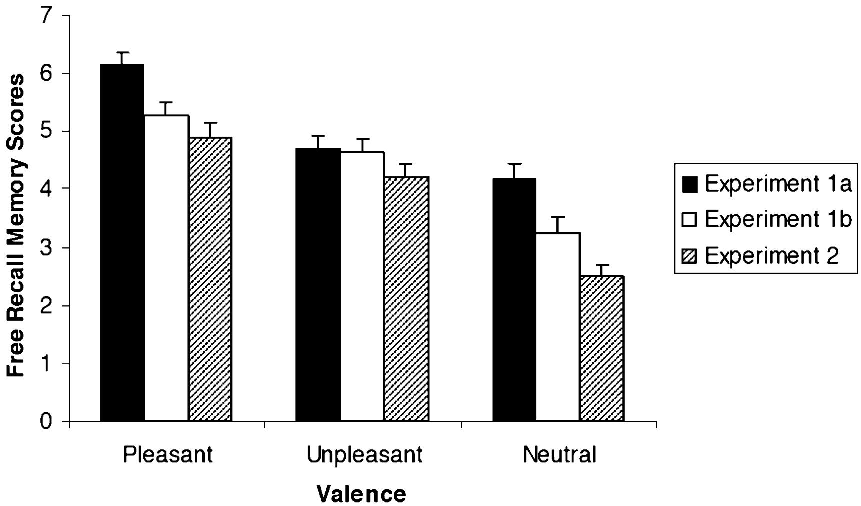


**Figure 3.** Mean free recall memory scores (+*SEM*) for pleasant, unpleasant and neutral words in Experiments 1a, 1b, and 2. Only Experiment 2 provided a quantitative measure of valence effects on free recall free of the potentially confounding effects of prior spatial memory testing. For all experiments, the effect of valence on free recall was significant (all *p*s $<.0001$). For Experiment 2, free recall was better for both pleasant and unpleasant words than for neutral words (both *p*s $<.0001$), and free recall was better for pleasant words than for unpleasant words ($p<.005$). Similar effects and trends were observed in Experiments 1a and 1b. Maximum possible recall is 12 words.



memory results were unchanged. The only change in the free recall memory results was that the difference between unpleasant and neutral words now reached significance, $t(56) = 2.52$, $p < .05$. It should also be noted that for this experiment and Experiment 1b, the ratings that participants provided for each word were analysed to determine if there was any specific subset of items that participants were consistently rating incorrectly on the valence task so that those words could be replaced. No such subset of words was identified.

## EXPERIMENT 1B

The results of Experiment 1a suggested a valence-specific reduction in incidental spatial memory for unpleasant words presented with task instructions requiring explicit processing of the spatial information. To test the possibility that this finding resulted from idiosyncratic features of the stimulus set rather than representing a general phenomenon, Experiment 1b was conducted using a set of 36 different words.

## Method

*Participants.* Forty-eight University of California Davis students (40 females), aged 17 to 27 years ($M = 19.08$ years), gave informed consent, received course credit for their participation and were included in the primary data analysis. One participant was dropped from data analysis for failing to complete the entire study and six additional participants were dropped from data analysis for making non-normative valence ratings on more than 10% of the items.

*Materials.* Thirty-six new words were selected from the larger set of 256 nouns and adjectives described in Experiment 1. The 12 pleasant, 12 unpleasant and 12 neutral words were again matched on imagery (unpleasant: $M = 5.62$, $SD = 0.77$; pleasant: $M = 5.51$, $SD = 1.03$; neutral: $M = 5.40$, $SD = 1.12$), log frequency of usage (unpleasant: $M = 1.22$, $SD = 0.41$; pleasant: $M = 1.32$, $SD = 0.42$; neutral: $M = 1.37$, $SD = 0.45$), syllables (unpleasant: $M = 2.58$, $SD = 0.79$; pleasant: $M = 3.08$, $SD = 1.24$, neutral: $M = 2.42$, $SD = 0.67$) and percent nouns (unpleasant = 67%; pleasant = 58%; neutral = 75%). The pleasant and unpleasant words were matched on arousal (unpleasant: $M = 6.78$, $SD = 0.91$; pleasant: $M = 6.67$, $SD = 0.27$; both exceeded arousal ratings for neutral words: $M = 2.62$, $SD = 0.84$) and on the absolute value of valence ratings from the neutral midpoint of the scale (unpleasant: $M = 2.62$, $SD = 0.49$; pleasant: $M = 2.36$, $SD = 0.43$; both exceeded the corresponding value for neutral words: $M = 0.22$, $SD = 0.20$). A one-way ANOVA showed no significant difference in relatedness across word types based on estimates yielded by LSA. The rest of the materials were identical to those used in Experiment 1a.

*Procedure.* The procedure was identical to that used in Experiment 1a.

## Results and discussion

Results of a repeated measures ANOVA demonstrated a main effect of word type for spatial memory, $F(2, 94) = 3.73$, $MSE = 106.88$, $p < .03$. Post hoc analyses again found no difference in incidental spatial memory scores between the pleasant and the neutral words, $t(47) = 0.51$, *ns*. However, there was a significant decrease in spatial memory scores for the unpleasant words compared to both the pleasant, $t(47) = 2.02$; $p < .05$, and neutral words, $t(47) = 2.55$; $p < .02$ (see Figure 2). A main effect for word type was also observed for free recall, $F(2, 94) = 23.69$, $MSE = 51.38$, $p < .0001$. Both the pleasant words, $t(47) = 6.64$, $p < .0001$, and the unpleasant words, $t(47) = 4.90$, $p < .0001$, were recalled more frequently than the neutral words (see Figure 3). There was a non-significant trend for pleasant words to be recalled more frequently than unpleasant words, $t(47) = 2.01$, $p < .10$. Results were unchanged when the data from the six participants who were dropped from the study for non-normative valence ratings were included in the analysis.

The results of the spatial memory tasks in Experiments 1a and 1b are consistent and demonstrate a clear reduction in incidental memory for the spatial context of unpleasant words compared to pleasant and neutral words. The free recall findings are more complex. In Experiment 1a, free recall was worse for unpleasant words than matched pleasant words and in Experiment 1b, there was a non-significant trend in the same direction. However, free recall was better for unpleasant words than for neutral words in Experiment 1b and there was a non-significant trend in the same direction in Experiment 1a.



## EXPERIMENT 2

Free recall for the pleasant, unpleasant and neutral words in Experiments 1a and 1b was tested after spatial memory testing was completed. It is possible that the repeated exposure to the words may have influenced the observed effects of valence on free recall. The aim of Experiment 2 was to test free recall without any prior testing of spatial context memory.

### Method

*Participants.* Forty-eight University of California Davis students (32 females), aged 17 to 34 years ($M = 20.5$ years), gave informed consent, received course credit for their participation and were included in the primary data analysis. One participant was dropped from data analysis for failing to complete the entire study and nine additional participants were dropped from data analysis for making non-normative valence ratings on more than 10% of the items.

*Materials.* The materials were identical to those used in Experiments 1a.

*Procedure.* The procedures for the study and distracter tasks were identical to those of Experiments 1a and 1b. Upon completion of the distracter task, memory for the words was tested using a surprise free recall task. Participants verbally recalled as many words from the study phase as possible. Scoring procedures were identical to those used in the free recall task in Experiments 1a and 1b.

### Results and discussion

The results of repeated measures ANOVA indicated a significant main effect for word type, $F(2, 94) = 42.42$, $MSE = 73.05$, $p < .0001$. Post hoc analyses revealed that participants recalled more pleasant words than either unpleasant, $t(47) = 2.95$, $p < .005$, or neutral words, $t(47) = 7.86$, $p < .0001$. In addition, participants recalled more unpleasant words than neutral words, $t(47) = 6.54$, $p < .0001$ (see Figure 3). Results were unchanged when the data from the nine participants who made excessive non-normative valence ratings valence ratings were included in the analysis. This pattern of effects of valence on free recall is qualitatively similar to that observed in Experiments 1a and 1b. Quantitatively, valence-related differences that were only trends in Experiments 1a and 1b are statistically significant in Experiment 2. Because spatial memory testing was not interposed between word encoding and free recall testing, we consider Experiment 2 to provide the best measure of valence effects on free recall of words studied under these encoding conditions.

In Experiments 1a and 2, free recall was assessed for the same stimuli presented with the same study procedures. The only difference was that participants had a second exposure to the stimuli during spatial memory testing in Experiment 1a. This allowed us to analyse whether this second exposure affected recall differently for the three word types. An ANOVA with one between-participants factor (Experiment) and one within-participants variable (Word Valence) demonstrated a significant main effect for experiment, $F(1, 94) = 25.32$, $MSE = 94.53$, $p < .0001$, with better free recall across word types in Experiment 1a. The expected significant main effect for Valence was also observed, $F(2, 188) = 65.52$, $MSE = 113.78$, $p < .0001$. However, there was also a significant interaction between experiment and valence, $F(2, 188) = 4.98$, $MSE = 8.66$, $p < .008$. Post hoc unpaired *t*-tests showed that the recall advantage for pleasant compared to neutral words did not differ between Experiments 1a and 2, $t(94) = 1.03$, *ns*. However the recall advantage for unpleasant compared to neutral words was significantly smaller in Experiment 1a than Experiment 2, $t(94) = 3.04$, $p = .003$, and the recall advantage for pleasant compared to unpleasant words was significant greater in Experiment 1a than Experiment 2, $t(94) = 2.38$, $p = .02$. These results suggest that repeated exposure to the stimuli by spatial memory testing prior to free recall testing improves free recall performance, but this improvement is significantly less for the unpleasant words.

## EXPERIMENT 3

The purpose of Experiment 3 was to determine whether the memory reduction found for the spatial context of unpleasant words would also be found for the temporal context of unpleasant words.

## Method

*Participants.* Forty-eight University of California Davis students (29 females), aged 18 to 24 years ($M = 19.9$ years), gave informed consent, received course credit for their participation and were included in the primary data analysis. Thirteen additional participants were dropped from data analysis for making non-normative valence ratings on more than 10% of the items.

*Materials.* The materials used were identical to those used in Experiment 1a and 2.

*Procedures.* The procedures were identical to those used in Experiments 1a, 1b, and 2 for the study and distracter tasks. In the test phase, participants received an $8.5 \times 11$ inch sheet of paper with eighteen pairs of words listed on it. Words pairs were listed one pair per line, double spaced, in 12 point Times New Roman font. Participants had to indicate which word in each pair they had viewed first during the study phase of the experiment. Both words in each pair were from the same group (pleasant, unpleasant or neutral) and the word pairs were matched for temporal distance across the three word types. Average temporal distance between the word pairs was ten items. Temporal memory scores were calculated by counting the number of correct responses for each word type. Free recall was not tested.

## Results and discussion

A repeated measures ANOVA demonstrated a main effect for word type, $F(2, 94) = 7.29$, $MSE = 9.17$, $p < .002$. Post hoc analyses found no difference in temporal memory scores between the pleasant and neutral words, $t(47) = 0.81$, *ns*. However, the temporal memory scores for the unpleasant words were significantly lower than for both pleasant words, $t(47) = 4.30$, $p < .0005$, and neutral words, $t(47) = 2.51$, $p < .02$ (see Figure 4). Results were unchanged when the data from the thirteen excluded participants was included in the analysis. This pattern of results is consistent with those obtained for spatial memory in Experiments 1a and 1b and demonstrates that unpleasant words have a detrimental effect on incidental source memory for both temporal and spatial context. In Experiments 1a and 1b, the participants were required to actively process the spatial information associated with each word. In contrast, participants were not required to actively process temporal information associated with the words. The finding of a similar pattern of valence effects on temporal and spatial source memory suggests that active processing of source information is not an essential precondition of the reduced source memory for unpleasant words.

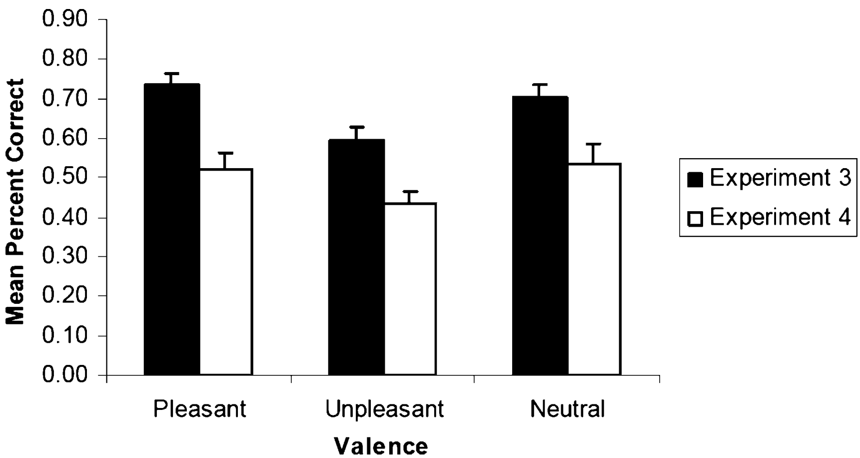


**Figure 4.** Mean percent correct (+*SEM*) on temporal memory task (Experiment 3) and spatial memory task (Experiment 4) for pleasant, unpleasant and neutral words. For Experiment 3, a significant effect of valence on ANOVA followed by *t*-tests showed temporal memory to be worse for unpleasant then either pleasant or neutral words (all $p$s $<.02$). Chance = 50% correct (performance for all word types was significantly better than chance by single group *t*-test, all $p$s $<.05$). For Experiment 4, a significant effect of valence on ANOVA followed by *t*-tests showed spatial memory to be worse for unpleasant then either pleasant or neutral words (all $p$s $<.05$). Chance = 25% correct (performance for all word types was significantly better than chance by single group *t*-test, all $p$s $<.05$).

## EXPERIMENT 4

The results of Experiments 1a and 1b demonstrate a reduction in spatial source memory for unpleasant words presented with incidental task instructions. Experiment 4 was designed to see if this finding generalises to intentional spatial source memory. In this experiment, participants were explicitly instructed to remember the spatial locations of each word for subsequent memory testing.

### Method

*Participants.* Twenty-four University of California Davis students (17 females), aged 18 to 26 ($M = 20.67$ years), gave informed consent, received course credit for their participation and were included in the primary data analysis. Eight additional participants were dropped from data analysis for making non-normative valence ratings on more than 10% of the items.

*Materials.* All seventy-two words from Experiments 1a and 1b were used in this study. Two additional neutral words were included as the first and last word in the study phase of each block to account for primacy and recency effects. The words were presented in two blocks and the order of the blocks was counterbalanced across participants. A new $2 \times 2$ grid was used in this study in place of the $6 \times 7$ rectangular grid that had been used in the previous four studies.

*Procedure.* The procedure for this experiment was different from the prior experiments in a number of ways. First, participants were told prior to beginning the study that they would be taking part in a memory test and that they should try to remember all of the words and their locations. Second, the grid was reduced in size from 42 cells to 4 cells. This reduction in size meant that words no longer had unique locations in the grid. Each cell contained an equal number of pleasant, unpleasant, and neutral words during the experiment. Third, participants no longer had to type the words in the cell. Instead a blank 4-square grid appeared on screen for 500 ms. Next, an asterisk appeared in one of the cells. In order to engage explicit processing of spatial information, the participants had to press one of four specific keys that corresponded to the cell that contained the asterisk. Then, a word appeared directly below the asterisk and a rating scale of Pleasant = 1, Neutral = 2, Unpleasant = 3 appeared above the grid. Participants were required to rate the valence of the word by pressing the appropriate number key. Finally, a fixation cross appeared on screen for 10 seconds between each trial. After completing the study portion for block one, participants were presented with complex math problems via the computer for one minute. Next, the participants were tested on the spatial location for the 36 study words from that block. Testing procedures consisted of a blank grid appearing onscreen for 500 ms. Then, a word appeared above the grid and participants were instructed to press the key corresponding to the grid cell in which the word originally appeared. Finally, a fixation cross appeared for 10 seconds between each word. There was a 30 second delay before the second block of items. The study, distracter, and test procedures were repeated for the second block of items. Scoring procedures were such that participants received one point for each word for which they correctly identified the box in which it originally appeared. All stimulus presentation and scoring was done using E-prime software (Psychology Software Tools, Pittsburgh, PA).



## Results and discussion

Results of a repeated measures ANOVA demonstrated a main effect of word type for spatial memory, $F(2, 46) = 5.25$, $MSE = 41.167$, $p < .01$. Post hoc analyses found no difference in intentional spatial memory scores between the pleasant and neutral words, $t(23) = 0.46$, *ns.* However, there was a significant deficit in spatial memory scores for the unpleasant words compared to both the pleasant, $t(23) = 3.24$, $p < .005$, and the neutral words,

$t(23) = 2.39$ $p < .05$ (see Figure 4). Results were unchanged when the data from the eight participants who were dropped for non-normative valence ratings was included in the data analysis.

The results from Experiment 4 extend our findings in several important ways. First, the reduction that we found for incidental spatial memory for unpleasant words is also found when testing intentional spatial memory. In addition, this reduction exists regardless of whether each word occupies a unique location in a grid or if the same grid location is used for multiple words of all three valence types. Finally, we simplified the task responses required of the participants. Instead of having to re-type each word in a specific cell and then rate the word on a 1 to 9 scale, participants simply pressed a button to identify the cell in which a word appeared and then rated the word using a categorical scale of pleasant, neutral, and unpleasant. Even with these changes and the addition of a second block of words to the experimental design, we found the same pattern of spatial memory reduction for unpleasant words compared to pleasant and neutral words as we found in Experiments 1a and 1b.

## GENERAL DISCUSSION

These studies demonstrate a consistent, valence-specific pattern of diminished source memory for unpleasant emotional words. This pattern is evident in the reduced memory for the spatial and temporal context in which unpleasant words are studied, when compared to both pleasant and emotionally neutral words. This is the first report, to our knowledge, of a valence-specific reduction of memory for the spatial and temporal context of emotional stimuli. The spatial and temporal source memory performances for the neutral words are conceptualised as representing participants' baseline ability. We observed no difference between the spatial and temporal memory scores for the neutral and positive words in Experiments 1a, 1b, 3, and 4. This indicates that the positively valenced emotionally arousing words did not change the participants' baseline source memory abilities for spatial and temporal information. However, when unpleasant emotionally arousing words were presented, spatial and temporal source memory performance decreased below the baseline level.

Emotional valence had distinctly different effects on free recall and source memory in this study. In Experiment 2, free recall was tested following encoding procedures identical to those used for testing spatial source memory in Experiments 1a and 1b. Experiment 2 showed that free recall was significantly better for both the pleasant words and the unpleasant words compared to the neutral words. Free recall was also better for the pleasant words than the unpleasant words. This pattern of results is quite different from our source memory findings and suggests that the effects of valence on source memory do not result from effects of valence on item memory. Specifically, the reduced source memory for unpleasant compared to neutral words does not appear to result from reduced item recall for the unpleasant words.

The reduced spatial and temporal source memory observed with unpleasant words in our study is consistent with a recent literature suggesting that emotionally arousing stimuli can lead to reduced memory for some features of the context in which the stimuli were encoded. Anderson and Shimamura (2005) presented neutral words during film clips. They showed that the words were less well remembered when presented during unpleasant films clips than when presented during pleasant or neutral film clips. Several studies have combined the Von Restorff effect with emotional words to study the effect on memory for neutral words immediately preceding or following the oddball emotional words (Hurlemann et al., 2005, 2007; Strange et al., 2003). These studies have consistently found reduced memory for the neutral word immediately preceding the oddball word when the oddball word was unpleasant but not when it was pleasant or neutral. Mather et al. (2006) reported reduced working memory for the spatial location of arousing emotional pictures and found that the effect was similar for pleasant and unpleasant pictures. Unlike the study of Mather et al. (2006), our study and other studies examined long-term memory and found that the reduced memory for contextual information is specific to unpleasant stimuli (Anderson & Shimamura, 2005; Hurlemann et al., 2005, 2007; Strange et al., 2003). It is possible that this difference in valence specificity is due to differences between working memory and long-term memory.

Our findings differ from those of several recent studies reporting enhanced source memory for emotional stimuli. D'Argembeau and Van der Linden (2004) reported enhanced spatial source memory for emotional words. Several important methodological differences between that study and the current study may account for the contrasting findings. Unlike the current study, the D'Argembeau and Van der Linden (2004) study did not incorporate behavioural tasks requiring explicit processing of both emotional and spatial information during each encoding trial. This difference may have influenced the interaction between emotion and source memory. However, explicit processing of source information may not account for the discrepant results, since reduced temporal source memory was demonstrated in Experiment 3 of the current study even though participants were not required to explicitly process temporal information during encoding. In addition, D'Argembeau and Van der Linden (2004) used emotional and neutral word sets that were not matched for imagery or semantic relatedness. Pilot work in our lab suggests that both imagery and semantic relatedness influence spatial source memory. A potentially significant difference is that the emotional words used by D'Argembeau and Van der Linden (2004) may not have been sufficiently arousing to elicit amygdala activation, as had been experimentally demonstrated with our unpleasant words.

In a recent study using neutral and taboo words as stimuli in a colour naming task, MacKay and Ahmetzanov (2005) reported enhanced context memory for the screen locations in which the taboo words had been studied. In their study, participants learned the stimulus–location pairings over multiple trials. However, the nature of taboo words may be sufficiently different from that of emotional words that one cannot generalise from this finding to other types of emotional stimuli. Their results could be due to social and cultural connotations associated with taboo words and the relative infrequency with which people encounter them rather than being due to emotional arousal associated with the semantic meanings of the words. It is also possible that the effects of emotion on spatial context memory differ when participants have the opportunity to learn the stimulus–location pairings over multiple trials rather than a single trial.

Doerksen and Shimamura (2001) and Kensinger and Corkin (2003) reported enhanced colour source memory for emotional words studied under intentional encoding conditions. The latter study used emotional and neutral words matched for imagery. D'Argembeau and Van der Linden (2004) failed to replicate this finding, but found enhanced colour source memory for emotional words encoded under incidental conditions in one of two experiments. It is possible that unpleasant stimuli affect different aspects of source memory in different ways. Temporal order and spatial location represent contextual aspects of source memory while colour represents a perceptual aspect of source memory. Previous research that examined source memory without looking at emotion found that spatial information was encoded automatically, but colour information was not (Mandler, Seegmiller, & Day, 1977; Park & James, 1983; Park & Mason, 1982). It is possible that the unpleasant stimuli may have interfered with this automatic encoding in some way, such as by diverting resources to other automatic processes that are activated when an unpleasant stimulus is encountered, and this diversion of resources may have led to the reduction in contextual memory found in our studies. It is also possible that the unpleasant words used in these studies of colour source memory were not sufficiently arousing to evoke amygdala-mediated amnestic effects.

Another possible explanation for the conflicting findings between our study and previous studies reporting enhanced source memory for emotional stimuli is that the latter tested source memory either following (D'Argembeau & Van der Linden, 2004) or in the context of testing item recognition memory (Doerksen & Shimamura, 2001; Kensinger & Corkin, 2003). In both cases, testing of source memory was limited to items correctly recognised. This approach excludes any information about source memory for items incorrectly judged to be "new". In contrast, we tested source memory for all studied words. Since source recognition memory may not be dependent on item recognition memory (Duarte, Ranganath, & Knight, 2005; Glisky, Polster, & Routhieaux, 1995), we chose our approach to get a more complete measure of source memory performance. In addition, testing item memory prior to testing source memory might alter the interaction between emotion and source memory performance. The possibility of such interference was proposed by D'Argembeau and Van der Linden (2004), who observed different effects of valence on source memory performance depending on whether or not free recall was tested prior to source memory. Similarly, the current study showed that testing source memory prior to testing free recall interacted significantly with the effect of valence on free recall. This methodological difference may account for some of the differences in the observed effects of emotion on source memory.



Our results are broadly consistent with studies demonstrating reduced memory for contextual information not central to the meaning of unpleasant arousing stimuli. Studies of patients with amygdala lesions have demonstrated the critical role of the amygdala in mediating these effects, which may involve both attentional and mnemonic processes. Many studies have shown that memory for the gist or central features of an emotional stimulus or event is enhanced while memory for peripheral information is reduced (Reisberg & Heuer, 1995). This effect is most often attributed to emotional arousal causing a narrowing of attention towards the central part of the stimuli at the cost of reduced attention to peripheral details (Easterbrook, 1959). Studies of patients with selective amygdala lesions show that both the central enhancement and the peripheral reduction in memory are mediated by the amgydala (Adolphs et al., 2001, 2005). A series of recent studies have examined a retrograde amnesia evoked by unpleasant words presented in a Von Restorff paradigm. Neutral words presented immediately before oddball words are consistently less well remembered when the oddball word is unpleasant than when it is pleasant or neutral (Hurlemann et al., 2005, 2007; Strange et al., 2003). This effect is most often attributed to retrograde interference in memory consolidation of the preceding word induced by the unpleasant oddball word (Strange et al., 2003). Two studies of patients with amygdala lesions support the idea that this effect is mediated by the amygdala (Hurlemann et al., 2007; Strange et al., 2003). Thus, in addition to its well-established role in memory enhancement for emotional stimuli (Cahill & McGaugh, 1998; Richardson et al., 2004), the amygdala may also mediate an amnestic effect for some aspects of contextual or source information associated with unpleasant arousing stimuli. The reduced spatial and temporal source memory for unpleasant words demonstrated in the current study may be another manifestation of this amygdala-mediated amnestic effect.

In four studies examining spatial source memory, temporal source memory and free recall, we demonstrated a consistent pattern of reduced source memory associated with unpleasant words. Enhanced free recall for the unpleasant words compared to the neutral words suggests that reduced source memory is not due to a reduction in item memory. Although both enhanced and reduced source memory has been reported for emotional stimuli, our results are consistent with prior studies showing an amnestic effect for some contextual information associated with arousing unpleasant stimuli. The mechanism responsible for the valence-specific reduction in source memory seen in our study is not known. However, our results are consistent with a model of amygdala mediation of reduced memory for some features of the context in which unpleasant stimuli are studied. Future studies are needed to determine the conditions under which this amnestic effect can be observed and the mechanisms underlying it.

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# APPENDIX

| *Stimuli for Experiments 1a, 2, 3, and 4* | | | *Stimuli for Experiment 1b and 4* | | |
|---|---|---|---|---|---|
| *Unpleasant* | *Pleasant* | *Neutral* | *Unpleasant* | *Pleasant* | *Neutral* |
| disaster | excitement | contrast | anxiety | wonderful | structure |
| hatred | love | split | tragic | passion | orbit |
| panic | triumph | slope | cancer | exhilarating | narrow |
| frightened | joyous | circular | hostile | magnificent | vehicle |
| anger | freedom | extension | destruction | thrill | boulder |
| threatening | happiness | junction | agony | outstanding | projecting |
| dangerous | victory | measurement | grief | enthusiasm | layer |
| cruelty | miracle | proportion | violence | celebration | profile |
| failure | kiss | parallel | hazardous | pleasure | external |
| betrayal | success | amount | misery | champion | outline |
| death | beauty | avenue | injury | laughter | mileage |
| rejection | affection | cylinder | shameful | romantic | material |