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The Emotional Distinctiveness of Odor-evoked Memories

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Abstract

A modified paired-associate learning paradigm was used to test whether odors or verbal odor labels evoked more emotional memories. Subjects were presented with emotionally positive and negative paintings (to-be-remembered items) in association with positive and negative odors and odor labels. Painting recall and associated emotional experience were tested after 48 h. Odor-evoked memories were found to be more emotional than verbally cued memories on a variety of measures. Moreover, if the cue for recall (odor or label) was hedonically congruent with the painting to be remembered, memory for original emotional experiences was enhanced. The findings are discussed within a general cognitive framework and implications for using odors to dissociate the emotional and representational aspects of memory are addressed. Chem. Senses 20: 517–528, 1995.

Introduction

In *Swann's Way* (Proust, 1919), the smell of a madeleine biscuit dipped in linden tea triggers intense joy and memories of the author's childhood. This experience, now referred to as the Proust phenomenon, is the basis for the hypothesis that odor-evoked memories are more emotional than memories evoked by other sensory stimuli. There is descriptive behavioral evidence consistent with this proposition (Herz and Cupchik, 1992; Laird, 1935), as well as indirect neurological support. The primary projections from the olfactory system are onto the amygdala-hippocampal complex of the limbic system, which is known to be directly involved with basic level emotion and memory processing. In contrast, vision and audition project primarily onto neural substrates that are relatively distant from the limbic system both in anatomical and functional terms.

In addition to compelling biological support regarding the special relationship between odor and emotion in memory, the available cognitive data suggest that odor-evoked memories may be processed and stored differently than memories associated with other senses (see Richardson and Zucco, 1989, for a review). However, the claim that odors evoke more emotional memories than memories elicited by other sensory stimuli has not been empirically established. The purpose of the present research was thus to investigate whether odor-evoked memories are distinguished from memories evoked by other cues by their emotional potency. Previous work has proved that paired associate (PA) learning and cued recall paradigms are successful for assessing olfactory memory (Davis, 1977; Cann and Ross, 1989; Schab, 1990; Smith *et al.*, 1992). For the present research, an incidental learning PA protocol was developed, and then implemented in two experiments examining cue-evoked memories for both their emotional quality and the effect of retrieval cue types on memory accuracy. The first experiment

demonstrated that odors evoked more emotional memories than did verbal odor labels, the second experiment replicated this finding and further explored the strength and emotional quality of odor-evoked memories.

Experiment 1A

The aim of Experiment 1A was to investigate the emotional distinctiveness of memories evoked by olfactory versus verbal cues. On the basis of neurological implications and the suggestions of earlier findings (Laird, 1935; Herz and Cupchik, 1992), it was hypothesized that memories evoked by odors would be more emotional than memories evoked by verbal cues.

In order to assess the emotional quality of memories triggered by cues within a PA paradigm the to-be-remembered (TBR) items had to be unfamiliar and emotionally involving. Research has shown that representational paintings are viewed in personal emotional terms by individuals who are formally unfamiliar with them (Cupchik and Gebotys, 1988, 1990). Accordingly, we chose representational paintings as TBR stimuli for the present experiments. Verbal cues for odors, given in the form of 'imagine the smell of __' (experimentally denoted as 'labels'), were chosen as the most appropriate non-odor contrast cues in the present experiments. There is an apparent asymmetry between sensation and cognition that occurs for olfactory stimuli. Unlike visual or auditory stimuli where a cognitive representation (memory, name, image) can elicit the corresponding physical sensation in a more or less symmetrical way, true olfactory imagery may not be possible (Engen, 1987; Schab, 1990; Crowder and Schab, 1995). Thus, verbal-imagery cues reflect an odorant's semantic equivalent, yet are processed very differently from the sensory odor percept (Engen, 1987; Schab, 1990).

To obtain a quantitative measure of the emotional quality of painting experiences and memories, we recorded whether or not subjects made inferences about the emotional state of characters in the paintings beyond those depicted, or reported that the painting elicited feelings in them. Such descriptions were formally defined as 'inferred emotion'. For example, in a painting depicting a boy and a dog, inferred emotion would be indicated if the subject wrote 'the boy is looking lovingly at his dog', or 'this painting makes me feel happy', but not if the subject simply reported content, i.e. 'the painting is about a boy and his dog'. Prior to the first experimental trial, subjects were shown an example painting description in which only a content report of the painting was given. Thus, there was no implication that emotional inferences or responses were to be provided. To obtain a quantitative measure of the efficacy of retrieval cue-type (odor versus label) on memory accuracy, subjects were tested by cued recall for their memory of the paintings associated to each cue.

Methods

Subjects

Subjects were 16 male and 16 female students enrolled in an Introductory Psychology course at the University of Toronto. The mean age of subjects was 19 years. Subjects were all artistically inexperienced as determined by a brief screening questionnaire. None of the subjects smoked and all were in good respiratory health. Each individual was tested alone and received bonus course credit for their participation in the study.

Material selection

Paintings and odors were selected by 37 artistically inexperienced subjects (19 female, 18 male), who did not serve in the main experiments. These individuals rated 36 paintings that three art-trained individuals had selected for emotional evocativeness, and 30 chemical odors provided by International Flavors and Fragrances, each on a pleasantness scale (1 = very unpleasant, 7 = very pleasant).

Paintings

Sixteen paintings were chosen as test items in Experiment 1A. Eight paintings selected were positive (M = 4.92), and eight were negative (M = 2.20). The means differed significantly [t (14) = 9.47, P<0.01]. An additional selection criterion was that the thematic content of each painting be different. Painting titles were also presented with each painting after it was observed during pilot testing that subjects sometimes missed central features of the paintings, e.g. that there was a dog in the 'A Boy and His Dog' painting. The titles were developed by the experimenter, as many of the artist-generated titles were not thematically informative (see Table 1 for a list of the paintings and titles presented).

Odors

Eight odors were selected as hedonically positive (M = 5.82) and eight as hedonically negative (M = 2.93). The means differed significantly [t (14) = 11.90 [P<0.01]. Odor selections were determined on the basis of the pre-test

Table 1 Painting stimuli and associated 'titles'

Artist	Painting (date)	'Title'
Experiment 1		
Positive paintings		
1.	Boucher—The Breakfast (1742)	'Breakfast Game'
2.	Tissot—L'Ambiteuse (1883)	'The Grand Entrance'
3.	Manet—House at Rueil (1882)	'Lazy Days of Summer'
4.	Renoir—Luncheon at the Boating Party (1881)	'The Garden Party'
5.	Vermeer—Girl with Guitar (1667)	'The First Encore'
6.	Hals—Jonker Ramp (1645)	'The Wedding Toast'
7.	Robson—Heading Home (1990)	'Winter Wonderland'
8.	Murillo—Boy and His Dog (1650)	'A Boy and His Dog'
Negative paintings		
9.	Munch—Evening on Karl Johan St. (1892)	'Procession of Despair'
10.	Bellows—Both Brothers in the Game (1909)	'The Fatal Blow'
11.	Copley—Watson and the Shark (1778)	'Terror at Sea'
12.	Goya—Third of May 1808 (1814)	'The Massacre of Civilians'
13.	Caravaggio—Salome with Head of J B (1600)	'After the Beheading'
14.	DeRibera—Martyrdom of St Bartholomew (1630)	'Martyrdom of a Saint'
15.	Freud—Hotel Bedroom (1954)	'The Threatening Intruder'
16.	Degas—Melancholy (1874)	'The Mourning Mother'
Experiment 2		
Positive paintings		
1.	Miller—Springtime (1990)	'Jenny and Her Puppies'
2.	Tissot—L'Ambiteuse (1883)	'The Grand Entrance'
3.	Manet—House at Rueil (1882)	'Lazy Days of Summer'
4.	Renoir—Luncheon at the Boating Party (1881)	'The Garden Party'
5.	Loates—Courtship (1990)	'Best Friends'
6.	Murillo—A girl and her Duena (1655)	'While we Watched'
7.	Ruysdaele—Landscape with Windmill (1665)	'Country Scene in Holland'
8.	Cassatt—Mother and Child (1891)	'Motherly Love'
Negative paintings		
9.	Circle of K.A. Ruthart—A Leopard Attacking Mandrill Baboon in a Tropical Forest (1655)	'The Kill'
10.	Bellows—Both Brothers in the Game (1909)	'The Fatal Blow'
11.	Copley—Watson and the Shark (1778)	'Terror at Sea'
12.	Goya—Third of May 1808 (1814)	'The Massacre of Civilians'
13.	Caravaggio—Salome with Head of J B (1600)	'After the Beheading'
14.	DeRibera—Martyrdom of St Bartholomew (1630)	'Martyrdom of a Saint'
15.	Freud—Hotel Bedroom (1954)	'The Threatening Intruder'
16.	Nerdrum—The Arrest (1975)	'The Arrest'

ratings in conjunction with the criterion that the odors all smell discriminantly different from one another, as judged by five independent raters. Chemical odorants were either pure oils or synthetic compounds. The odorants were absorbed into diethyl phthalate pellets. Two pellets of each odor were placed into an opaque jar (diameter = 5 cm, height = 5 cm) and covered with pure cotton. When the cue was presented as an odor, the subject unscrewed the lid of a jar and sniffed

Table 2 Olfactory-verbal cues

Chemical odorant	Verbal label	[Conc] in DEP[1]
Positive		
iso-amyl acetate	banana	1%
peppermint oil natural	peppermint	10%
bubble gum	bubblegum	10%
watermelon	watermelon	20%
cinnamon bark	cinnamon	10%
lemon oil	lemon	pure
rose	rose	10%
coconut	coconut	10%
Negative		
violet leaf ABS	mildew	10%
n-butyric acid[2]	rancid butter	1%
beech-wood creosote	tar	10%
myrrh coeur	vinegar	10%
cumin oil	curry	10%
seafood	fishy	25%
rosemary oil	turpentine	10%
vetiver oil bourbon	rotting leaves	pure

Chemical odorants were obtained from International Flavors and Fragrances, Union Beach, NJ, except where indicated.
[1]DEP = diethyl phthalate solution
[2]Obtained from Sigma, St Louis, MO.

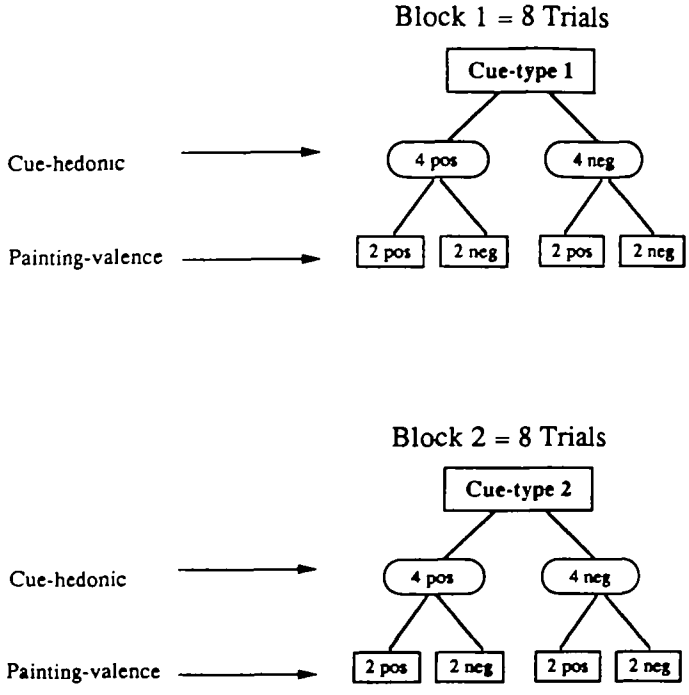

Figure 1. Schematic representation of cue-painting pairing during study session

at the cotton inside. For later reference, jar bottoms were labeled with an identification number. When the cue was presented as a label, the subject was told to 'imagine the smell of __' (see Table 2 for a list of the cues used).

Design and procedure

The experiment was divided into two sessions (study and test) separated by 48 h. Learning was incidental during the study procedure and involved 16 different cue-painting pairs. Subjects experienced two blocks of eight cue-painting trials. One block comprised eight odor-painting pairs, while the other comprised eight label-painting pairs. Block presentation was counterbalanced across subjects. Within each block there were four positive and four negative cues, and each of these was paired with two positive and two negative paintings. Accordingly, each subject experienced four hedonically congruent (positive-positive and negative-negative) cue-painting trials and four hedonically incongruent (positive-negative and negative-positive) cue-painting trials per block (see Figure 1). Additionally, paintings and cues were systematically rotated to that each painting appeared in every position of the 16 trial sequence, paired with every cue as both an odor and a label, counterbalanced across male and female subjects.

Study session

Before the experimental session began subjects were informed that the purpose of the study was to examine the effects of odors (both smelled and imagined) on the perception and experience of paintings. Subjects were told that experiencing art involved both visual and emotional aspects, and that they should attend to both of these components while viewing the paintings. At no time was any mention of memory or memory tests ever made.

Subjects sat at a table in a semi-darkened, 3.05 × 3.35 m windowless room. The door to the room was kept slightly ajar, and a floor fan set on low helped to circulate the air. A slide projector was positioned 1.22 m above the floor on a trolley beside the subject. The viewing screen was positioned approximately 2 m in front of the subject. The projector lens size (70 mm) was set to provide entire screen coverage (110 × 100 cm) for maximum viewing impact and visibility.

In every trial, the subject first rated the pleasantness, familiarity and intensity of a cue (odor or label) on 7-point scales (1 = very low, 7 = very high). When the cue was a label, it was understood that ratings referred to what the

subject's impression of an odor which smelled like '__' would be. As soon as the ratings were completed, the title of a painting appeared across the screen for 4 s (white lettering on blue background). Then, the image of the corresponding painting appeared on the screen for 60 s. Subjects were instructed to study the slide and to try to combine the experience of looking at the painting with the experience of the cue. To aid with this subjects were instructed to smell the odor, or were told to imagine the smell of '__' (label cue) three times, at 0, 30 and 60 s. A beep from the computer reminded the subject and the experimenter of these time intervals. At the end of 60 s the slide and the cue were withdrawn, and the subject completed a corresponding Painting Description form. On each form, the title of the painting was printed at the top, followed by four blank lines which the subject was instructed to fill in with a description of the painting. Subjects were to describe what the painting was about, such as the theme, who or what was there, and what it looked like. The following Painting Description was provided as an example before the experimental trials began:

> The painting is about an old man and a boy. The old man is leaning over and holding the boy, while the boy kneels in front of him. Some other people are looking on. Everyone looks kind of drab and ragged.
> ['Return of the Prodigal Son', Rembrandt, 1665 (not presented in study)].

Painting Description forms were designed to obtain both an assessment of the painting experience and to promote incidental learning. Subjects were given a maximum of 2 min to complete a form before proceeding to the next cue-painting trial. When the first block of eight trials was completed, the subject was informed that the next cue set would be different (i.e. either odors or labels, depending on the previous condition) but that everything else would remain the same. At the end of the second block, subjects were dismissed and asked to return in 2 days for further testing.

To verify that the paintings were indeed unfamiliar, subjects were asked whether they had seen each painting before. One positive and one negative painting were reported as previously seen by one subject each. Responses to these paintings were deleted from the data for these two subjects.

Test session

Subjects were tested for cued recall of the paintings they had seen 2 days before. Each individual was presented with the same cues that they had experienced at the study session (i.e. the same eight cues as odors plus the same eight cues as labels). However, the order of cues within each block was re-randomized to ensure that positional effects (i.e. primacy or recency) would not confound the results.

Each trial proceeded as follows: the subject was presented with a cue and asked to recall the specific painting that had been paired with that cue. If a painting was recalled, the subject wrote out a brief description as before. Subjects who could not provide a written response (i.e. no recall) after a minute or so were told to leave the section blank. The subject was then presented with the next cue and the trial repeated as above. Subjects saw no paintings during the test session.

Results

Separate three-way analyses of variance (ANOVAs) treating sex, as the between-subjects factor, and cue type (odor versus label), and cue hedonics (positive versus negative) as the within-subjects factors, were performed on the pleasantness, familiarity and intensity cue-rating scale data. All other dependent measures were analysed by separate four-way mixed design ANOVAs, treating sex as the between-subjects factor, and cue type, cue hedonics and painting valence (positive versus negative) as the within-subjects factors.

Study session

Cue ratings

A main effect of cue hedonics was significant for both ratings of pleasantness [F (1,30) = 446.08, $P<0.01$] and familiarity [F (1,30) = 120.93, $P<0.01$]. Positive cues were rated as more pleasant (M = 5.64) and more familiar (M = 5.84) than negative cues (M = 2.52 and M = 4.01 for pleasantness and familiarity ratings of negative cues, respectively). A significant main effect of cue type was obtained for familiarity, demonstrating that labels were rated as more familiar (M = 5.34) than odors [M = 4.50, F (1,30) = 21.44, $P<0.01$]. No main effects or interactions concerning cue intensity were found.

Emotional experience

All painting descriptions were assessed for inferred emotion by one judge as either emotional (1) or not (0). Two other judges rated a random subset (30%) of the descriptions to assess inter-rater reliability. All judges were blind to the experimental and subject conditions. Whenever inter-rater

Table 3 Mean percentages of paintings correctly recalled by sex, cue type, cue hedonics and painting valence: Experiments 1A and 1B

Cue-paint trial		Female odor	Female label	Male odor	Male label	Row $\bar{X}$s
Positive cue	1A	38	28	25	31	31
Positive paint	1B	38	34	16	22	28
Positive cue	1A	28	16	9	22	19
Negative paint	1B	28	22	9	9	17
Negative cue	1A	22	22	16	38	25
Positive paint	1B	28	22	16	25	23
Negative cue	1A	9	19	19	25	18
Negative paint	1B	25	19	16	31	23
Column $\bar{X}$s	1A	24	21	17	29	
	1B	30	24	14	22	

Cue refers to cue hedonics (positive versus negative).
Paint refers to painting valence (positive versus negative).

Table 4 Mean percentages of correctly recalled paintings containing inferred emotion by sex, cue type, cue hedonics and painting valence Experiment 1A

Cue-paint trial	Female odor	Female label	Male odor	Male label	Row $\bar{X}$s
Positive cue Positive paint	33	11	12	10	17
Positive cue Negative paint	33	0	67	14	29
Negative cue Positive paint	57	0	20	33	28
Negative cue Negative paint	33	50	50	38	43
Column $\bar{X}$s	39	15	37	24	

Cue refers to cue hedonics (positive versus negative).
Paint refers to painting valence (positive versus negative)

reliability fell below 100%, judgements were discussed until 100% agreement was obtained. On the study day, no significant main effects or interactions emerged for the inferred emotion ratings ($P > 0.50$). This implies that any differences in inferred emotion found for the painting descriptions at test were not produced by the associated cues during study.

Test session

Accuracy of painting recall

Memory for the paintings was assessed by the accuracy of the cued written painting descriptions. Painting descriptions were scored as either correct or incorrect. Correct descriptions were defined as clearly identifiable, accurate cue-painting matches. The mean percentages of paintings correctly recalled as a function of each independent variable are presented in Table 3.

The mean percentage of paintings correctly recalled to odor cues was 21%, compared to 25% recalled to label cues. These means did not differ significantly [F (1,30) = 1.23], nor were any significant interactions with cue type found. A significant main effect for painting valence revealed that more positive (M = 27%) than negative paintings (M = 18%) were correctly remembered [F (1,30) = 7.46, $P < 0.01$]. This finding complies with the general tendency for memory to be biased towards positive events (e.g. Matlin and Stang, 1978).

Emotional quality of memories

The mean percentages of correctly recalled paintings in which inferred emotion was indicated are shown in Table 4 by each independent variable. ANOVA revealed a significant main effect of cue type, demonstrating that odor-evoked memories were significantly more emotionally loaded than label-evoked memories [F (1,15) = 7.45, $P < 0.01$]. When the cue was an odor, 36% of the correct painting descriptions contained inferred emotion, as compared to 20% when the cue was a label. Importantly, this effect was not mediated by either the verbosity or painting fluency of the subjects. That is, there were no differences in the length of painting descriptions [measured in terms of the number of words; F (1,15) = 0.19] or in the number of discrete painting features mentioned in the painting descriptions [F (1,15) = 0.12] obtained as a function of cue type. No other main effects or interactions were obtained.

Inferred emotion rates were based on the conditional probability of having correctly recalled the associated painting. For this reason, a non-parametric test for the significance of difference between two proportions was performed on these data to confirm the reliability of the ANOVA result. A z score of 1.94 was obtained when the inferred emotion evoked by odors and labels was compared, indicating a significant difference (one-tailed, $P < 0.05$). This result substantiates the finding that odor-evoked memories are more emotionally loaded than memories evoked by verbal cues.

Experiment 1B

The goal of Experiment 1B was to replicate and expand upon the results obtained in Experiment 1A regarding the emotional properties of odor-evoked memories. An examination of both the emotional quality of memory, as well as the effectiveness of odors for retrieving specific, discrete, emotional responses was undertaken. It was reasoned that if odors mediate a particularly emotional form of memory then they may also be more effective than verbal cues for recalling emotion. Thus, it was hypothesized that compared to verbal cues odors would evoke more emotional memories and lead to more accurate recall for the specific emotions originally experienced.

The method and procedure were the same as in Experiment 1A with the following exceptions.

(i) A new group of 32 volunteer subjects (16 male and 16 female) participated.

(ii) A different set of emotionally evocative paintings was used as TBR items to increase the generality of the stimulus base (see Table 1). Some degree of overlap with the first painting set was unavoidable. Eight paintings were selected as positive (M = 5.42, where 7 = very pleasant), and eight as negative (M = 2.04, where 1 = very unpleasant). The means differed significantly [t (14) = 15.87, $P < 0.01$].

(iii) Five new measures for assessing emotion were added to the study day form and six new measures assessing emotion were added to the test day form.

On the study day, in addition to providing a written description of each painting, subjects listed up to four specific emotions that were evoked by the painting and rated each one for emotional intensity on a 5-point scale (1 = very weak, 5 = very strong). Subjects then indicated their general emotional responses to the paintings on three 9-point scales: pleasantness ('How unpleasant or pleasant does the painting make you feel?' 1 = extremely unpleasant, 9 = extremely pleasant); tense-related ('How tense or relaxed does the painting make you feel?' 1 = extremely tense, 9 = extremely relaxed); and intensity ('Overall, how intense are your feelings about this painting?' 1 = extremely weak, 9 = extremely strong). Subjects were given a maximum of 2 min to complete a form before proceeding to the next cue-painting trial. One negative painting was reported as previously seen by one subject. The responses to this painting were deleted from the data for this subject.

On the test day, subjects were first presented with a cue (odor or label) and asked to provide a written description of the painting that had been previously paired with it. The same cue was presented a second time and subjects were asked to list the specific emotions that were brought to mind by the cue and to rate each one for emotional intensity. Subjects who did not experience any emotions after a minute or so left this section blank. Subjects were also asked to indicate how confident they were that the feelings now evoked by the cue were the same as those they had experienced in conjunction with the cue-painting episode at study (1 = not at all confident, 9 = extremely confident). The cue was then presented for a third time, and subjects were asked to try to recall how the painting had made them feel on the three emotion rating scales (pleasantness, tense-relaxed and intensity). For each of these scales, subjects had the opportunity to indicate that they could not recall their feelings by circling an 'I can't remember' option. Thus, only ratings from trials where the subjects believed they truly remembered their feelings were obtained. This procedure was repeated for each of the 16-cue trials.

Results

Study session

Cue ratings

As expected, a main effect of cue hedonics was significant for both ratings of pleasantness [F (1,30) = 313.49, $P < 0.01$] and familiarity [F (1,30) = 126.69, $P < 0.01$]. Positive cues were rated as more pleasant (M = 5.52), and more familiar (M = 5.84) than negative cues (M = 2.84 and 4.10 for pleasantness and familiarity ratings of negative cues, respectively). A significant main effect of cue type was also found for pleasantness [F (1,30) = 7.65, $P < 0.01$] and familiarity [F (1,30) = 17.51, $P < 0.01$], indicating that labels were rated as more pleasant (M = 4.38), and familiar (M = 5.36) than odors (means were 3.99 and 4.58 for pleasantness and familiarity ratings of odor cues, respectively). No main effects or interactions emerged for ratings of cue intensity.

Emotional experience

There were no significant differences between cue types on any of the measures assessing emotion ($P > 0.50$). This implies that any differences in emotionality at test were due to factors associated with the cues at recall and not produced by the associated cues at study. However, there was a significant cue hedonics by painting valence interaction for the emotional intensity score [summed emotional intensity ratings per painting; F (1,30) = 5.11, $P<0.05$] suggesting that all subjects rated their emotions as more intense when the cue and painting were congruent in hedonic valence (M = 8.77 for positive cue-positive painting, M = 8.88 for negative cue-negative painting) than when they were incongruent (M = 8.37 for positive cue-negative painting, M = 8.01 for negative cue-positive painting).

Test session

Accuracy of painting recall

The mean percentages of paintings correctly recalled as a function of the independent variables are presented in Table 3. The mean percentage of paintings correctly recalled to odor cues was 22%, compared to 23% for label cues. These means did not differ significantly [F (1,30) = 0.08] nor were any significant interactions with cue type found.

Emotional quality of memories

The emotional quality of memories evoked by odors versus labels was assessed by several different measures. First, to verify the findings from Experiment 1A, the degree of inferred emotion in the correctly recalled painting descriptions was examined. The mean percentages of correctly recalled paintings in which inferred emotion was indicated are shown in Table 5 by each independent variable. A significant main effect of cue type [F (1,15) = 8.46, $P < 0.01$] revealed that when the eliciting cue was an odor significantly more painting descriptions contained inferred emotion (14%) than when the cue was a label (5%). Again, this finding was not confounded by description length or painting fluency, as no differences in the number of words written or number of painting features described were obtained as a function of cue type [F (1,15) = 1.27 for number of words, F (1,15) = 2.23 for number of painting

Table 5 Mean percentages of correctly recalled paintings containing inferred emotion by sex, cue type, cue hedonics and painting valence· Experiment 1B

Cue-paint trial	Female odor	Female label	Male odor	Male label	Row $\bar{X}$s
Positive cue Positive paint	17	9	20	0	12
Positive cue Negative paint	11	0	0	0	3
Negative cue Positive paint	11	0	20	0	8
Negative cue Negative paint	25	33	0	0	15
Column $\bar{X}$s	16	11	10	0	

Cue refers to cue hedonics (positive versus negative).
Paint refers to painting valence (positive versus negative).

features described]. A non-parametric comparison of the difference between two proportions yielded a z of 1.56 which is significant for a one-tailed test at $P = 0.05$, and again confirmed the reliability of the ANOVA result. These findings replicate the results obtained in Experiment 1A.

Next, the emotional quality and accuracy of all recollections, independent of correct painting recall, were evaluated. The number of emotions subjects listed at recall and the rated emotional intensity of these emotions were analyzed to determine the general level of emotionality elicited by the cues (see Table 6). A significant main effect of cue type was obtained for both variables [F (1,30) = 5.02, $P < 0.05$ for number of emotions and F (1,30) = 4.12, $P < 0.05$ for emotional intensity]. When the retrieval cue was an odor, subject listed significantly more emotions ($M = 1.25$) and rated these emotions as significantly more intense ($M = 4.45$), than when recall was evoked by a label. With label cues, the mean number of emotions listed was 0.97, and the mean emotional intensity score was 3.49.

Together, the emotionality dependent measures show that the nature of the eliciting cue modified the degree of emotion experienced at recall. Odor-evoked memories were more emotional than memories evoked by verbal cues in every case.

Accuracy of emotional memory

Emotions reported at study were compared with those reported at test and categorized as either 'same' or 'different'. To be considered as 'same', identical or nearly identical descriptors had to be used at both times (i.e. loving and lovingly). ANOVA on these data revealed a significant interaction between cue hedonics and painting valence [F (1,30) = 10.19, $P < 0.01$]. *Post-hoc* comparisons demonstrated that when the original cue-painting pair had been congruent and positive, the feelings brought back by the cue were more often the same as those that had been listed on the study day, compared to when the original cue-painting pairs had been incongruent. In particular, when presented with a positive cue at test that had been congruently paired with a positive painting at study, subjects experienced more of their original emotions than in any other condition. Table 7 displays the interaction term means. No other main effects or interactions were obtained.

To examine the effectiveness of cues for recall of general emotional experience, the difference between subjects' ratings at study and test on the three emotion scales (pleasantness, tense-relaxed and intensity) were compared. This involved subtracting the rating given at test from the rating given at study to create a set of absolute difference scores. ANOVA on these scores revealed significant cue hedonics by painting valence interactions for all three scales [F (1,26) = 15.10, $P < 0.01$ for pleasantness, F (1,26) = 7.31, $P < 0.01$ for tense-relaxed, and F (1,24) = 8.51, $P < 0.01$ for intensity]. Interaction term means are presented in Table 7.

Post-hoc multiple comparison tests illustrated that for each scale, memory for how the painting had made the

Table 6 Mean number of emotions listed and emotional intensity score for correctly recalled paintings by sex, cue type, cue hedonics and painting valence: Experiment 1B

Cue-paint trial	Female odor	Female label	Male odor	Male label	Row $\bar{X}$s
Positive cue	1.53 N	1.28 N	0.88 N	0.97 N	1.17 N
Positive paint	5.16 E	4.63 E	2.97 E	3.50 E	4.07 E
Positive cue	1.38 N	1.03 N	1.13 N	0.94 N	1.12 N
Negative paint	5 10 E	3.81 E	4.13 E	3.41 E	4.11 E
Negative cue	1.53 N	0.84 N	1.06 N	0.84 N	1.07 N
Positive paint	5.66 E	3.28 E	3.88 E	2.88 E	3 93 E
Negative cue	1.41 N	0.97 N	1.13 N	0.88 N	1.10 N
Negative paint	4.88 E	3.38 E	3.81 E	3.09 E	3.80 E
Column $\bar{X}$s	1.46 N	1.03 N	1.05 N	0.91 N	
	5.20 E	3.78 E	3.70 E	3.22 E	

Cue refers to cue hedonics (positive versus negative).
Paint refers to painting valence (positive versus negative).
N = mean number of emotions listed (range is 0–4).
E = mean overall emotional intensity score (range is 0–20).

Table 7 Cue hedonics by painting valence interaction means for the number of emotional descriptors correctly recalled and absolute value difference scores on the emotion rating scales Experiment 1B

	Cue hedonics	
Painting valence	Positive	Negative
Positive	0.42 D	0.24 D
	1.83 (P)	2.21 (P)
	1.88 (T-R)	2.20 (T-R)
	1.21 (I)	1.57 (I)
Negative	0.21 D	0.31 D
	2.56 (P)	1.52 (P)
	2.30 (T-R)	1.69 (T-R)
	1.83 (I)	1.35 (I)

D = number of emotional descriptors recalled (range is 0–4)
(P) = absolute difference on pleasantness rating scale
(T-R) = absolute difference on tense-relaxed rating scale.
(I) = absolute difference on intensity rating scale.
For rating scales, the smaller the difference the better the memory. Range is 0–9.

subject feel was best (i.e. difference scores were minimized) when the original cue-painting pair had been congruent. Thus, for the pleasantness and intensity scales, memory for feelings was most accurate in both cases when the cue and painting had been of the same hedonic valence (either positive or negative) than in either condition when the cue and painting had been mismatched in hedonic valence. For the tense-relaxed scale, memory for feelings was most accurate when both the cue and painting had been negative. These results indicate that congruent study conditions led to the most accurate recall of emotions.

Ancillary analyses

Despite the finding that odors were not generally associated with more accurate recall than verbal labels, there was some evidence that subjects' beliefs about the accuracy of recall was dependent upon cue type. First, subjects' confidence that the emotions they recalled (listed) at test were the same as those that they had experienced at study was significantly higher with odor cues ($M = 3.50$) than with verbal cues [$M = 2.88, F(1,30 = 6.09, P < 0.01$]. Secondly, independent of accuracy, subjects believed that they could remember emotions more often in the presence of an odor than a verbal cue. For the pleasantness scale, the mean number of recollections per subject was 13.56 with odors as compared to 12.50 with labels [t (62) = 2.18, $P < 0.05$]. For the tense-relaxed scale, the mean number of recollections per subject was 13.47 with odors as compared to 12.28 with labels [t (62) = 2.46, $P < 0.01$]. For the intensity scale, the mean number of recollections per subject was 13.22 with odor cues as compared to 11.91 with label cues [t (62) = 2.64, $P < 0.01$].

General discussion

The purpose of the present research was to determine whether odor-evoked memories are distinguished from memories evoked by verbal cues in terms of their emotional potency. The results from our experiments indicate that this is the case. While odors and verbal cues are equipotent stimuli for memory recall, the former are more emotionally potent. In other words, the quality of a memory which is evoked by the smell of a lover's perfume will be more emotionally loaded than the memory of the same person elicited by the name of their perfume, even though the content of the memories may be the same.

The present experiments attempted to create a laboratory analog to the Proust phenomenon. In this regard, it should be noted that the actual number of accurate and emotionally loaded painting memories was quite low (19 and 13 with odors and labels, respectively, in Experiment 1A, and 8 and 3 with odors and labels, respectively, in Experiment 1B). In part, this was due to the fact that the emotional memory measures were dependent on painting recall accuracy, which was modest in both experiments. It is also possible that the procedures elicited lower levels of performance than might otherwise have been observed, because the protocol was designed to minimize the possibility that subjects would discover that their memories were being assessed (cf. Davis, 1977). Be this as it may, observed recall was comparable to the results of other experiments in which incidental learning procedures have been used (Eich, 1989; Schab, 1990). Furthermore, it should be noted that in real life, odor-evoked emotional memories are rather rare occurrences. This makes it all the more remarkable that any truly emotional memories were obtained within the limitations of the present laboratory based paradigm.

In Experiment 1B it was predicted that, besides eliciting more emotional memories, odors would also produce superior recall for the original emotions experienced with the paintings. However, accurate recall for specific emotions and the original emotion ratings were not found to be mediated by cue type. Instead, emotional memory was most accurate when the cues and paintings had been hedonically congruent at study. This finding is consistent with the observation that material is best recalled when the valence

of the material matches the mood of the subject (Bower, 1981). This explanation may bear on the present results. Additionally, depth of processing mechanisms are likely to have played an important role. The study session data from Experiment 1B suggest that cue-painting congruence was associated with greater emotional intensity. This, in turn, could lead to deeper encoding and stronger memories (Craik and Lockhart, 1972; Craik and Tulving, 1975). Consistent with this interpretation, previous work has shown that aesthetic evaluations are intensified when a cue (odor or label) and painting pair are hedonically congruent (Herz and Cupchik, 1993).

Although odors did not enhance emotional recall relative to verbal cues, subjects believed that odors were more effective stimuli. Subjects reported greater confidence in their retrieval of specific emotions and responded more often to the emotion rating scales when odors were the eliciting cues at test. Perhaps subjects felt that odor cues were more connected to their emotional experiences because odors evoked memories that were more emotional than those evoked by the verbal cues which then created the impression that odors are more faithful elicitors of original emotions than are labels.

The finding that odor cues are more emotionally potent than verbal labels, but no more accurate, has important theoretical implications. Specifically, the data suggest that the emotion experienced with a memory is more closely linked to the recollective experience of that memory at the time of remembering than to the veridical experience of emotion in memory, *per se*. This finding demonstrates that a dissociation between emotional experience and memory content can occur in episodic memory. In other words, emotional experience at recall appears to be retrospective, and determined by the sensory characteristics of the eliciting cue and the present connotation of the event to the individual. This was illustrated by the present findings in several ways. First, Experiment 1B showed that memory for emotional experiences was determined more by the hedonic connotation of the cue at the time of retrieval than to the actual pleasantness of the TBR painting. Secondly, the finding that odors and labels elicited memories which were different in emotionality, but that the initial experience of the paintings with either cue on the study day did not vary in emotionality, indicates that memory experiences are influenced by the modality of the associated cue at the time of recollection. Several experiments to further investigate this possibility are planned.

In sum, the present results are the first direct psychological evidence that odor-evoked memories are more emotional than memories evoked by other cues. Additional experiments comparing odors with other sensory stimuli are required to substantiate and generalize the implications of this finding. The flexible nature of olfactory hedonics (Cain, 1984; Engen, 1988), coupled with the present results also suggests that odors could be particularly useful cues for further investigations of the dissociation between emotion and content (event representation) in memory. This distinction is conceptually important to emotion-memory research. Future experiments using odors as cues for investigating emotional memory would profit cognitive research in this domain.

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