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Emotional potentiation may be a key variable in the formation of odor-associated memory. Two experiments were conducted in which a distinctive ambient odor was present or absent during encoding and retrieval sessions and subjects were in an anxious or neutral mood during encoding. Subjects' mood at retrieval was not manipulated. The laboratory mood induction used in Experiment 1 suggested that anxiety might increase the effectiveness of an odor retrieval cue. This trend was confirmed in Experiment 2 by capturing a naturally stressful situation. Subjects who had an ambient odor cue available and were in a preexam state during encoding recalled more words than subjects in any other group. These data are evidence that heightened emotion experienced during encoding with an ambient odor can enhance the effectiveness of an odor as a cue to memory.

Odor-evoked memories are typically distinguished from other stimulus-evoked memories by their emotional potency (Laird, 1935; Herz & Cupchik, 1992). The possibility of such differences is consistent with the unique neural interconnections between olfactory areas of the central nervous system and the amygdala–hippocampal complex of the limbic system. Only two synapses separate the olfactory nerve from the amygdala, critical for the expression and experience of emotion (Aggleton & Mishkin, 1986) and human emotional memory (Cahill, Babinsky, Markowitsch, & McGaugh, 1995); and only three synapses separate the olfactory nerve from the hippocampus, involved in the selection and transmission of information in working memory, short-term and long-term memory transfer, and various declarative memory functions (Eichenbaum, 1996; Schwerdtfeger, Buhl, & Gemroth, 1990; Staubli, Ivy, & Lynch, 1984, 1986). The fact that no other sensory system makes this kind of direct and intense contact with the neural substrates of emotion and memory has long been advanced as indirect support for the emotional distinctiveness of odor-evoked memory.

Recently, behavioral data have become available (Herz & Cupchik, 1995; Herz, 1996). We paired 16 emotionally evocative paintings, as to-be-remembered (TBR) items, with eight odors and eight odor names,

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as associated memory cues, in an incidental learning procedure. Painting recall and the emotionality of memory were tested 48 hr later by cued recall. The results showed that odor-evoked memories were more emotional than memories evoked by words, but that the accuracy of memory was the same with both cue types. More recently, memories associated with cues represented in either olfactory, tactile, or visual form were compared (such as the smell of an apple, the feel of an apple, and the sight of an apple), showing again that odor cues produced the most emotional memories but that there were no differences in recall accuracy as a function of sensory cue type (Herz, 1996). Together, these findings illustrate that although odors do not differ from other cues in their capacity to retrieve events from memory, odor-evoked memories are significantly more emotionally loaded.

Associative learning mechanisms play a major role in the development of odor responses. Engen (1988) observed that children aged 4 did not show any differentiation in their response to either butyric acid (rancid butter odor) or amyl acetate (banana odor), but by age 8 had come to model cultural norms. Similarly, preweanling rat pups who were exposed to a peppermint odor while being stroked or receiving food showed selective preference and increased 2–deoxy-glucose uptake response to peppermint odor later in life (Sullivan & Leon, 1986, 1987).

Based on the importance of associative mechanisms in olfactory learning and the unique connection between olfaction and emotion, it was proposed that if an odor is first experienced in an emotionally salient context, it will be an especially effective memory cue (Herz, 1992). The reasoning is as follows: Emotional experiences result in higher levels of activation in the amygdaloid complex, the amygdala has been shown to be critical for emotional memory (Cahill, Prins, Weber, & McGaugh, 1994; Cahill et al., 1995), and olfactory neurons synapse directly into the amygdala. Thus, if odor encoding takes place in an emotionally heightened state, increased limbic activation may cause the connection between an odor and event to become more tightly fused (for example, by long-term-potentiation mechanisms) than if encoding occurs in a nonemotional state. As a result of the specific odor–event integration that takes place during encoding, the odor becomes an especially effective retrieval cue for the associated event.

The present research tested the hypothesis that an ambient odor will be a more effective retrieval cue if it is encoded in an emotionally charged state than if encoded in an emotionally neutral state. Two experiments were conducted in which a distinctive ambient odor was either present during both the incidental learning session for a list of neutral nouns and the free recall session or was never present, and subjects were either in

an anxious mood during the encoding session or in a neutral mood. At retrieval, subjects were always in a nonmanipulated mood.

EXPERIMENT 1

Experiment 1 evaluated whether a laboratory induction of anxiety experienced during the encoding of words in the presence of a distinctive ambient odor would increase the efficacy of that odor as a retrieval cue. Anxiety was chosen as the mood to be manipulated for the following reasons: Unpleasant affective states are more threatening and hence generally more meaningful than pleasant affective states (Averill, 1976; Rozin & Fallon, 1987), items learned in arousing contexts (the ascending arm of the Yerkes–Dodson curve; see Hebb, 1955) are better remembered than items learned in nonarousing contexts (Craik & Blankstein, 1975; Eysenck, 1976), and experimental inductions of anxiety are well documented and have proved to be effective in other settings (see Heatherton, Herman, & Polivy, 1991).

Subjects participated in two experimental sessions (encoding and retrieval) separated by 48 hr. Word list learning was incidental during the encoding session, and memory for the words was tested by free recall 48 hr later at the retrieval session.

METHOD

Design and procedures

A 2×2 between-subject factorial design, with odor condition (violet leaf present at both encoding and retrieval, no odor present) and mood at encoding (anxiety induction, neutral induction) as the independent variables, was adhered to. Twelve subjects were randomly assigned to the four experimental groups, with an equal number of males and females in each. A full factorial design, manipulating odor presence/absence at encoding and retrieval, was not deemed necessary because previous work has clearly shown that an odor is an effective retrieval cue only if it is present at both encoding and retrieval (Herz, 1997; Schab, 1990).

Subjects

Forty-eight University of Toronto undergraduates (24 males and 24 females) participated in Experiment 1 in exchange for course credit. All subjects were individually tested by the same experimenter and were in good respiratory health. Five of the 48 subjects replaced subjects who did not return for the retrieval session. When this occurred, a new subject was contacted and run in the appropriate encoding and retrieval sessions. Of the 5 supplanted subjects, 2 replaced subjects in the no-odor/anxiety group (1 male, 1 female), 1 in the

odor-present/anxiety group (male), 1 in the odor-present/neutral group (female), and 1 in the no-odor/neutral group (male).

Encoding session

The encoding session room was 7 × 9 ft, carpeted, and illuminated by bright overhead fluorescent lights. It was furnished with a filing cabinet, a desk, two chairs, and an old polygraph machine. There were no wall decorations. After subjects were seated and informed consent obtained, the experimenter explained that the purpose of the study was to examine the effects of context, both external environment and internal feeling states, on thought processes. Participants in the odor-present conditions were then alerted to the presence of the ambient odor with the following comment so that a correct attribution between the odor and the environment would be made (Fernandez & Glenberg, 1985; Herz, 1996):

> You may have noticed that this room has a certain smell to it. This is just how some of the rooms in this building happen to smell. The reason I draw your attention to it is because this experiment has to do with context, and smell is one aspect of the context you are in.

To further ensure that subjects attended to the ambient odor, all subjects were given a room environment questionnaire (REQ) (Herz, 1997), which asked for scalar ratings of the room's lighting, temperature, *odor*, appearance, and general comfort. Ratings obtained on the REQ were not statistically analyzed. After subjects completed the REQ, mood manipulation took place, following which Eich's autobiographical event generation procedure (Eich, Macaulay, & Ryan, 1994) was conducted as the incidental word learning task. For this task, subjects were presented with 16 common, concrete, semantically unrelated, and affectively neutral English nouns (such as pencil, airplane, key), selected from the Brown and Ure (1969) word norms as to-be-remembered (TBR) items. Subjects were read each target word and asked to describe, in a few sentences, an event that had happened to them that the word reminded them of. Subjects were told that the event had to be a specific incident (as opposed to an everyday occurrence) and from at least 1 month before. These restrictions were imposed to ensure that the words were not superficially processed. The experimenter wrote down each event recounted. No time limit was given for event recollections, so the interval between TBR words was subject paced and variably determined. Most subjects completed the incidental work learning task within 20 min. Subjects were then thanked and asked to return in 2 days for further testing. No mention of future memory tests was ever made.

Ambient odor manipulations. The ambient odor used in the odor-present conditions was violet leaf. Violet leaf is an unfamiliar and mildly unpleasant odor (Herz & Cupchik, 1992). It was chosen to be hedonically congruent with an unpleasant mood. A moderate level of odor intensity was achieved by placing 12 diethyl phthalate polypropylene pellets saturated with 10% violet leaf solution in three bowls (4 pellets in each bowl) around the room (Herz, 1997). One bowl was placed near the subject's chair, and two other bowls were placed at equidistant room locations. A floor fan set on low helped circulate the air.

The experimenter assessed the room before each subject's entry to ensure that the smell was consistent, and refreshed the odor pellets as necessary. Rooms were completely aerated when there was any change in ambient environment caused by either subject artifact (such as perfume) or a change in odor experimental conditions. In the odor-absent conditions, there was no manipulated room scent.

Mood assessment. A mood matrix (affect grid; Russell, Weiss, & Mendelsohn, 1989) was used to measure mood. The mood matrix is composed of nine intersecting columns (horizontal axis) and rows (vertical axis). The horizontal axis of the matrix corresponds to varying degrees of pleasure, ranging from extremely unpleasant feelings in the far left column to extremely pleasant feelings in the far right column. The vertical axis corresponds to varying degrees of arousal, ranging from extremely high arousal in the top row to extremely low arousal in the bottom row. To indicate mood, the subject places an "X" at the appropriate location on the matrix. One mark yields two scores that can range from –4 to +4, one for pleasantness and the other for arousal. Negative scores indicate unpleasant mood or below-average arousal; positive scores indicate pleasant mood or above-average arousal. A mark in the center of the matrix (0) corresponds to average (neutral) pleasantness and arousal. Mood matrix ratings were obtained at both the encoding and retrieval sessions.

Anxious mood induction. Anxiety was induced in the laboratory by using a "speech threat" manipulation (Heatherton et al., 1991). Subjects were told that they would have to give 2–min speeches in front of classmates who would criticize them for dysfluencies or ungrammatical style, and that their performance was a serious measure of verbal fluency. After making this announcement, the experimenter left the subject alone, saying that she was going to look for the classmates. The experimenter then returned 5 min later and informed the subject that the classmates were confused as to the time of arrival and would be there in about 20 min (that is, after the incidental word learning task). The subject then rated his or her mood on a mood matrix and the incidental word learning task began.

Neutral mood induction. Subjects in the neutral mood condition were informed that they would be left alone in the laboratory for 15 min, and that they should just sit and relax during this time. Several general-interest magazines were placed on the table adjacent to the subject, and subjects were told they could read if they chose to. This 15–min waiting procedure was used on the basis of pilot testing which showed that neutral mood could be reliably manipulated in this way. Subjects were told that the waiting period was for familiarization with the room environment and experimental control. When the experimenter returned after 15 min, the subject indicated his or her mood using a mood matrix and the incidental word learning task began.

It should be noted that all subjects spent at least 25 min in the encoding session room. The somewhat longer exposure to odorant of subjects in the odor-present/neutral-mood group compared with subjects in the odor-present/anxious-mood group was not expected to affect olfactory perception in any detectable way (Dalton, 1996).

Retrieval session

Forty-eight hr later the subject returned for the retrieval session. The retrieval session room was adjacent to the encoding room, and though similar in size and general furnishings was clearly distinguishable in specific features. No mention of ambient odor was made at the retrieval session, regardless of the ambient odor condition, and no mood was induced. At the start of the retrieval session, subjects filled out a new mood matrix and REQ. Since mood was not manipulated, all subjects were expected to be in an "average" (nonanxious) mood. Subjects were then given a surprise free recall test for the words presented during the encoding session, for which they were asked to try to recall as many words as they could from the first session, in any order, within 10 min. Word-associated event reminiscences were encouraged to facilitate target word recall. Subjects spoke the words and any associated memories aloud and the experimenter wrote down what was recounted. Only recalled target words were scored. Subjects were then fully debriefed.

RESULTS AND DISCUSSION

Pleasure and arousal ratings

Pleasure and arousal mood matrix ratings were examined in 3–factor anovas separately for the encoding and retrieval session data. The factors were odor presence, mood at encoding, and subject sex. At encoding, there was a significant main effect of mood for both pleasure, $F = 45.19$, $p < 0.01$, and arousal, $F = 15.83$, $p < 0.01$. Mean pleasantness and arousal ratings for subjects in the anxious and neutral mood groups were –2.00 and 1.96, and 1.00 and 0, respectively. These results confirm that subjects who had undergone the anxiety manipulation felt significantly more unpleasant and aroused than subjects in the neutral mood condition. No effects caused by odor presence or subject sex were obtained on the pleasure and arousal ratings and there were no significant interactions. At retrieval, no significant differences in ratings of pleasure or arousal were observed as a function of any of the independent variables. Mean scores on pleasure and arousal were 0.87 and 0.83, and 1.0 and 0.96, for subjects who were formally in anxious or neutral moods, respectively.

Word recall

The number of words correctly recalled out of 16 for each subject was evaluated in a 2–factor anova, with odor presence and mood at encoding as the independent variables. A significant main effect for odor presence was obtained, $F(1,44) = 5.78$, $p < 0.05$ ($MS_E = 5.2$) (see Figure 1). Subjects who experienced an ambient odor at both encoding and

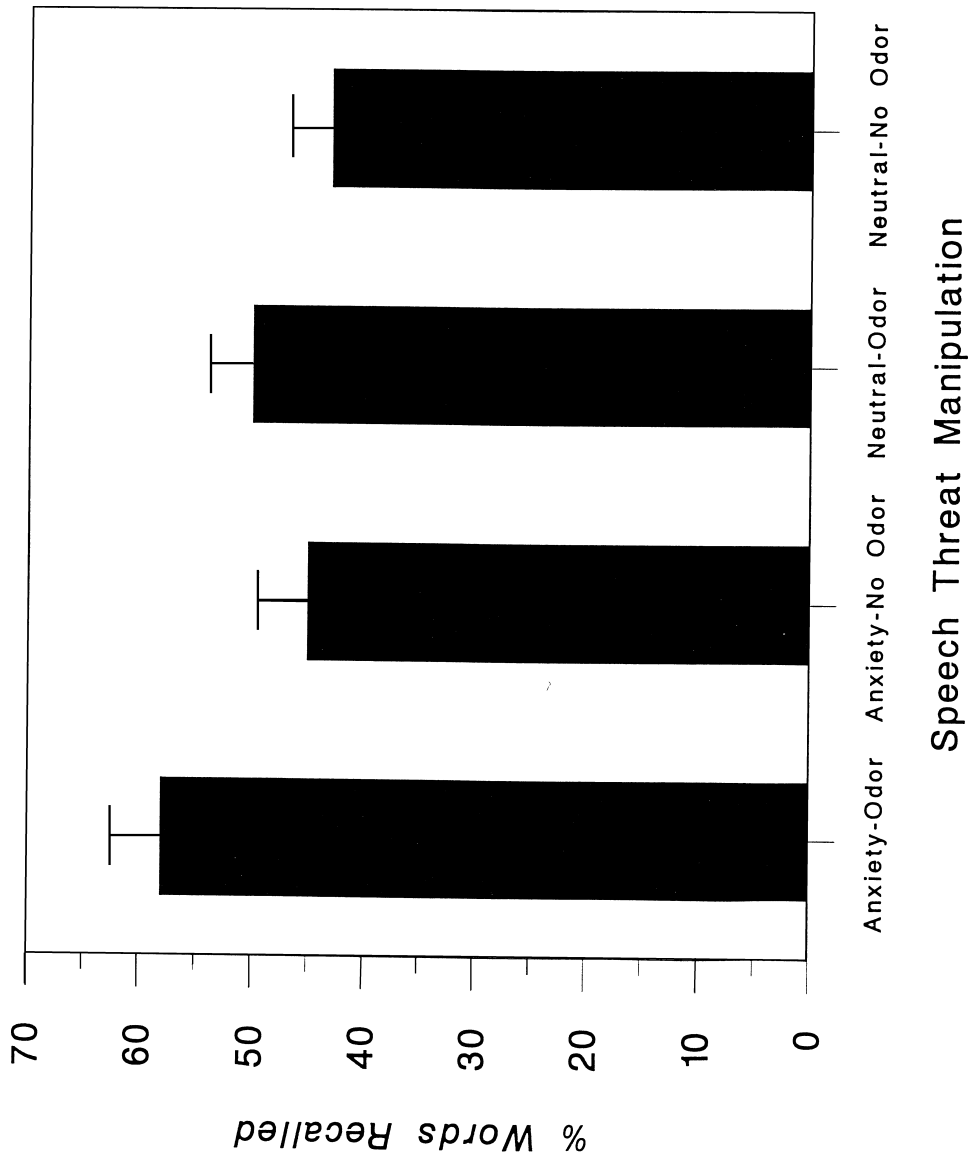

Figure 1. The effects of laboratory-induced anxious mood or neutral mood at encoding, and ambient odor presence or absence at both encoding and retrieval on recall for words. Word recall is expressed in percentages (± *SEM*).

retrieval recalled more words (M = 54%) than subjects who did not have an odor context cue available (M = 44%).

Although the mood by odor interaction was not statistically reliable (p = 0.45), a trend in the expected direction was observed (see Figure 1). Subjects who underwent the anxiety induction at encoding and had an ambient odor cue available appeared to recall more words than subjects in the other groups. Effect size (ES) and power were determined for the interaction term (Cohen, 1988), and an ES of 0.11 with power of 0.10 was obtained. Thus, the probability that statistically significant results could be achieved in this experiment was only 10%. Moreover, it was considered that, despite the differences in mood ratings between the anxiety and neutral mood groups, the laboratory mood inductions used may not have been sufficient to produce differential effects on odor encoding.

EXPERIMENT 2

Experiment 1 suggested that anxiety might potentiate ambient odors as memory cues. It was suspected that this effect would have been stronger if the mood manipulation had produced more intense mood group differences. Experiment 2 was therefore designed to explore whether a more realistic and personally meaningful mood could enhance odor context cue effects. One common situation for students that induces substantial natural anxiety is exams (Smith & Ellsworth, 1987). To capture natural mood fluctuations using this scenario, the encoding sessions for Experiment 2 were run in either the hour just before a midterm exam (anxious mood group) or in the hour before a routine class day (neutral mood group). Retrieval sessions were all conducted in the hour before a routine class in the same course.

METHOD

Design and procedures

A 2 × 2 between-subject factorial design was used, with odor condition (violet leaf present at both encoding and retrieval, no odor context cue) and mood at encoding determined by class condition (preexam, routine class day) as the independent variables. Subject sex was not included as a variable because of the unequal numbers of males and females who were available for testing, and because Experiment 1 indicated that subject sex did not contribute to the data.

Subjects

Forty University of British Columbia undergraduates (17 males, 23 females) participated in Experiment 2 in exchange for course credit. All subjects were

tested by the same experimenter. Subjects were students in a 1–semester evening course that was offered in the fall and spring terms. Subjects in the odor-present / preexam and odor-present / routine-class groups were from the fall course, and subjects in the no-odor / preexam and no-odor / routine-class groups were from the spring course. The order of subject groups tested was odor-present / preexam, odor-present / routine-class, no-odor / preexam, no-odor / routine-class. Thus, in addition to explicit appeals for confidentiality made during subject debriefing, the order of groups tested ensured that subjects in the key experimental groups would not be affected by discussion with classmates. To minimize variations in other extraneous academic demands that may have influenced performance between groups, subjects in each course were tested in the middle of the term and within 2 weeks of each other. Subjects were tested in groups (initially comprising 15–20 students) and were in good respiratory health. Several subjects in each condition did not return to complete the retrieval phase of the experiment, but a minimum of 10 subjects remained in each group. To minimize violations to anova assumptions, group sizes were equated to 10 (based on the minimum group size) using a randomization procedure.

Encoding and retrieval session conditions

A classroom (26.5×13.5 ft), in a separate building from where the psychology class was held, was used for the encoding and retrieval sessions. There were approximately 40 individual folding desk chairs in the room, as well as one large wooden desk. Two of the walls had blackboards, one had windows, and one was bare. Because subjects were recruited from an evening course that met only once a week, the interval between encoding and retrieval sessions was 7 days.

At the encoding session, subjects were met by the experimenter in front of their psychology classroom and escorted to the room used for testing. Subjects were given the same explanation for the purpose of the study as given to subjects in Experiment 1. Once subjects were seated (subjects were free to sit in any of the individual chairs), the mood matrix and REQ were administered. Subjects were then given instructions for a written version of the incidental word learning task. A written version was used to accommodate group testing. Subjects received sheets with the same 16 words printed on them as were auditorily presented to subjects in Experiment 1. Each printed word was followed by several blank lines for subjects to fill in with their autobiographical event generations. When subjects had finished filling in the sheets, they were free to leave the encoding session.

At the retrieval session, 1 week later, subjects were met by the experimenter and escorted to the classroom used for the experiment. Once all subjects were seated, the mood matrix and REQ were administered. Then subjects were given blank sheets and instructed to write down as many of the target words (and associations) from the encoding session as they could remember. Only recalled target words were scored. Ten min were allocated for this task, and subjects were required to remain seated for the entire time. At the end of the session, subjects were fully debriefed and dismissed.

Ambient odor. The ambient odor used was violet leaf (10%). Ambient room scent was achieved as previously described.

Mood manipulations. Experiment 2 exploited the natural academic stresses and nonstressful routines of a psychology class to influence the mood that subjects experienced. Subjects designated as undergoing the anxiety manipulation were students who participated in the encoding session in the hour just before their only midterm exam in a psychology course. To further increase anxiety in the preexam groups, the experimenter soberly reminded the students of the seriousness and imminence of their upcoming exam. Subjects designated as undergoing a neutral mood manipulation were students who participated in the encoding session in the hour just before a routine class in the same psychology course. The experimenter did not make any additional mood comments to these subjects.

RESULTS AND DISCUSSION

Pleasure and arousal ratings

Pleasure and arousal mood matrix ratings from the encoding and retrieval sessions were examined in separate 2–factor anovas for the encoding and retrieval sessions, respectively. The independent variables were odor presence and mood at encoding. At encoding, there was a significant main effect of mood for both pleasure ($F = 25.41$, $p < 0.01$) and arousal ($F = 10.29$, $p < 0.01$). Mean pleasantness and arousal ratings for subjects in the preexam and routine class groups were –1.35 and 0.80, and 1.70 and –0.80, respectively. This confirms that subjects in the preexam groups felt significantly more unpleasant and aroused than subjects in the routine class groups. At retrieval, no significant differences on pleasure and arousal ratings were observed as a function of previous mood condition or ambient odor presence. Mean scores on pleasure and arousal were –0.25 and 0.70, and 0.70 and 0, for subjects who had been in the preexam and routine class groups, respectively. No effects or interactions due to odor presence were found for the pleasure or arousal ratings.

Word recall

The numbers of words correctly recalled out of 16 for each subject were evaluated in a 2–factor anova, with odor presence, and mood at encoding, as the independent variables. Figure 2 shows that the mood-by-odor interaction was significant, $F(1,36) = 6.09$, $p < 0.01$; $MS_E = 5.03$; see Figure 2. Newman-Keuls post hoc comparisons ($p < 0.05$) confirmed that subjects who were anxious during encoding and had an ambient odor cue available recalled more words ($M = 59\%$) than subjects in any other group. Mean word recall for subjects in the no-odor / anxious-mood, odor-present / neutral-mood, and no-odor / neutral-mood groups were 33%, 46%, and 41%, respectively. These means did not differ significant-

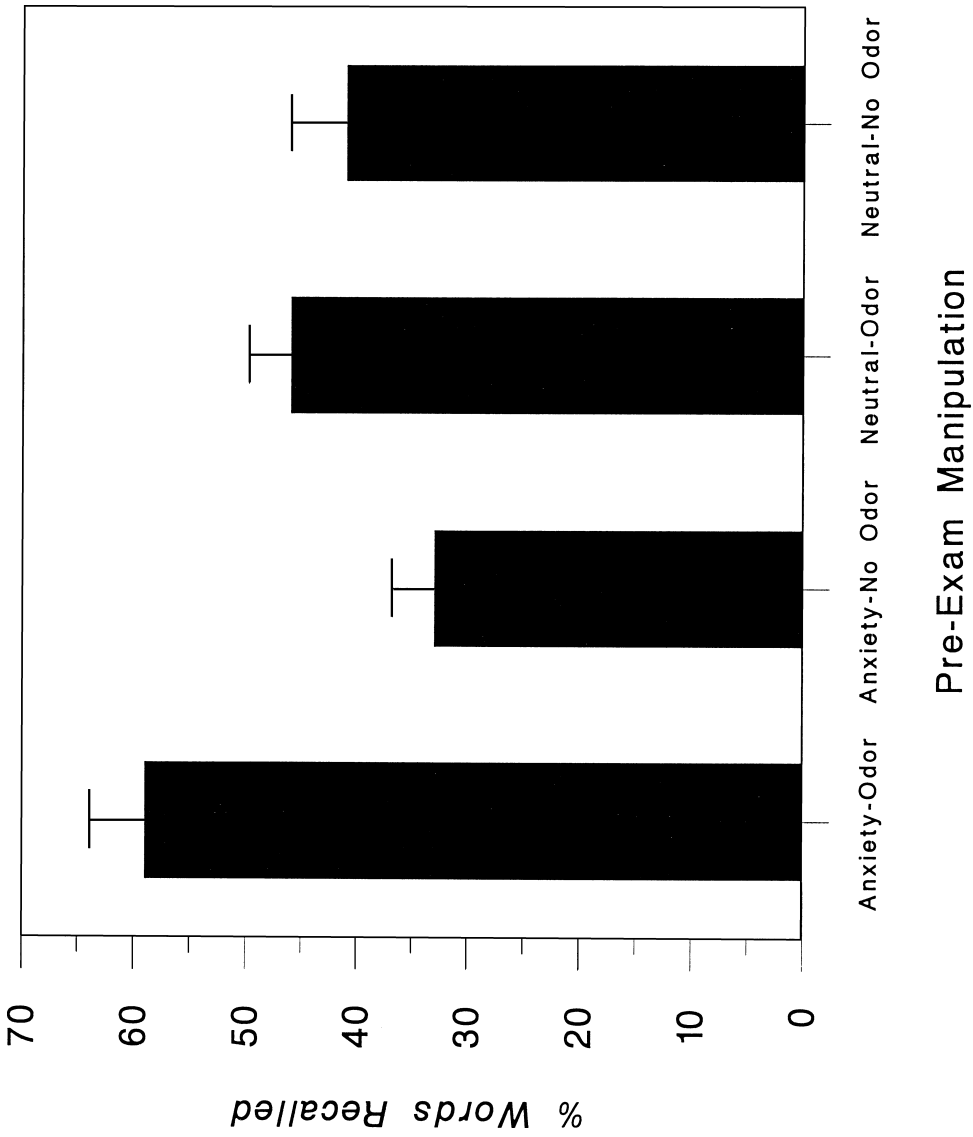

Figure 2. The effects of naturally occurring anxious mood or neutral mood at encoding, and ambient odor presence or absence at both encoding and retrieval on recall for words. Word recall is expressed in percentages (± *SEM*).

ly. Effect size and power values were calculated for the interaction term, yielding an ES of .42 and power of .68. The large ES (Cohen, 1988) and statistically significant *F* ratio obtained for the odor-by-mood interaction demonstrate that a salient emotional state experienced in the presence of an ambient odor can substantially enhance the effectiveness of an ambient odor as a memory cue. A main effect of odor presence was also obtained, $F(1,36) = 12.94$, $p < 0.01$, showing that, in general, the presence of an ambient odor cue enhanced word recall (53% versus 37%).

GENERAL DISCUSSION

Experiments 1 and 2 showed that word recall was higher when an ambient odor cue was available during both encoding and retrieval than when no ambient odor was present. This finding is consistent with evidence that distinctive odors are effective context cues (Cann & Ross, 1989; Herz, 1997; Schab, 1990; Smith, Standing, & de Man, 1992). More importantly, subjects in Experiment 2 who were anxious during encoding and had an odor context cue available recalled more words than subjects in any other group. Notably, subjects' mood at retrieval did not mediate this effect.

The present results demonstrate that heightened emotion experienced during encoding with an ambient odor can enhance the effectiveness of an odor as a retrieval cue. This finding supports the theory that emotional potentiation is a key variable in the formation of odor-associated memory. It was suggested at the outset of this article that such a finding might be explained by olfactory–amygdala interactions. The premise is that emotional activation increases amygdala activity, which because of the direct connections between the olfactory bulb and the amygdala–hippocampal complex intensifies the association between an odor and an event in memory. The amygdala is necessary for the experience of emotion (Aggleton & Mishkin, 1986), and the hippocampus is a critical mediator for learning and memory associated to context (Eichenbaum, 1996; LeDoux, 1994; Maren & Fanselow, 1995). Thus amygdala–hippocampal circuitry in olfactory cognition may be related as follows. Hippocampal connections may be necessary for the association of odor to context (that is, an ambient odor in a particular environmental and experiential context), whereas amygdala connections are necessary for the emotional component of the memory to be formed and experienced (anxiety in the presence of an ambient odor). Direct recording from relevant brain areas during odor + emotion encoding and retrieval episodes or pharmacological blockade experiments such as those described by Cahill and colleagues (1994) would greatly inform this hypothesis.

It is noteworthy that ambient odors appear to be robust contextual reminders (Cann & Ross, 1989; Herz, 1996; Schab, 1990; Smith et al., 1992). Context-dependent memory (CDM) research is known for inconsistent findings in studies where other physical cues, such as colors, sounds, and physical environments, have been manipulated (Smith, 1988). Perhaps odors lend themselves to contextual associability better than do other stimuli because of their unique interaction with the cortical substrates involved in contextual learning.

Anxiety (arousal) experienced at encoding alone cannot account for the data obtained in Experiment 2 because anxious subjects who did not have an ambient odor cue available showed poor word recall. It is reasonable to surmise that because anxiety was induced by an upcoming threatening event, subjects were distracted from the word-learning phase of the experiment and hence later showed poor word recall. What is interesting is that in the presence of a useful contextual cue (such as an ambient odor), the memory deficits produced by this distraction at encoding were overridden. Stated otherwise, subjects may require a contextual cue as a memory aid for peripheral information (that is, the words to which subjects were exposed in the experiment) to a central event, when that central event is emotionally meaningful (such as an impending exam). This possibility is compatible with the hypothesized role of the hippocampus in olfactory–contextual learning and with Smith's (1995) mental context hypothesis, which states that many incidental events become represented in memory in association with a focal set of stimuli.

Several methodological aspects of this research merit further discussion. First is the issue that different retention intervals were used in Experiment 1 (2 days) than in Experiment 2 (7 days). Do longer intervals between encoding and retrieval strengthen cuing effects? Eich et al. (1994) directly tested this question and found that mood-dependent word recall was substantially worse after 7 days than after 2 days for the mood-congruent memory groups (but not the mood-incongruent groups), showing that, if anything, longer retention intervals can diminish cuing effects rather than enhance them. Notably, in the present research, the average level of word recall did not vary greatly between the two experiments (means were 49% and 45% in Experiments 1 and 2, respectively). Thus, it is unlikely that the longer retention interval in Experiment 2 facilitated the odor–memory effect.

A second issue is that the same room was used for the encoding and retrieval sessions in Experiment 2, and different rooms were used for encoding and retrieval in Experiment 1. It might therefore have been that room artifacts other than the ambient odor manipulated were used by subjects as retrieval cues in Experiment 2. However, if room cues

other than the ambient odor were involved in memory, then recall should not have varied between the groups in Experiment 2 in any systematic way. Moreover, comparable odor-based CDM effects have been found in studies when the same room was used at the encoding and retrieval sessions (Schab, 1990) and when different rooms were used (Herz, 1997). Thus, it seems reasonable to conclude that extraexperimental room cues did not bias the results obtained in Experiment 2.

Third, it might be argued that the hedonic congruency between the ambient odor and mood (both unpleasant) contributed to the findings. Odors have been shown to have mood-altering effects (Ehrlichman & Bastone, 1992; Schiffman, Sattely-Miller, Suggs, & Graham, 1995). Thus, violet leaf (a mildly unpleasant odor) may have contributed to being in an unpleasant mood. This possibility is refuted in the present experiments by the finding that at both encoding and retrieval, subjects' mood was not affected by the presence of the ambient odor alone. Schab (1990) also found that the hedonics of an ambient odor were not related to CDM effects, as both pleasant (chocolate, apple–cinnamon) and unpleasant (mothball) odors produced positive outcomes. Nonetheless, it is possible that an odor vastly different in hedonics from one's mood state might be jarring, and thus more attention might be paid to it (Jaccoby & Craik, 1979). Such a situation would be comparable to the memory benefits observed when learning and retrieval take place in the presence of a distinctive ambient odor, as compared to a nondistinctive ambient odor (Herz, 1997). Direct tests of the relationship between mood and odor hedonics would now be informative.

A final consideration is that the significant results reported here were obtained with anxiety as the operative mood state. It is therefore possible that the findings were caused by the specific effects of experiencing negative emotion or high arousal, as opposed to the general phenomenon of heightened emotional activity (good, bad, calming, or energizing). Experiments separating the relative contribution of arousal from pleasantness should be conducted so that the parameters of pleasantness and arousal that mediate odor cue potentiation can be defined. Furthermore, whether emotion can generally enhance the effectiveness of potential context cues irrespective of the sensory modality through which they are perceived, or whether olfaction is singularly affected by such manipulations, must be explored.

Notes

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