Motivation and Emotion, Vol. 28, No. 4, December 2004 (© 2004)
DOI: 10.1007/s11031-004-2389-x

Olfaction, Emotion and Associative Learning: Effects on Motivated Behavior

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Two experiments were conducted to investigate emotional associative learning to odors and subsequent behavioral effects. In Experiment 1, participants experienced a frustration mood induction in the presence of an unfamiliar ambient odor and later worked on puzzle tests in a room scented with either the same-odor, a different-odor, or no-odor. Participants in the same-odor condition spent significantly less time working on the tests than participants in the other conditions; however, test accuracy did not vary. To clarify the findings, Experiment 2 included a test-only control and an emotionally neutral same-odor conditions. Results were compatible with the conclusion that decreased time spent by participants in the negative-same-odor condition was due to emotions elicited by associative learning to the ambient odor, although alternative interpretations remain possible. These data extend our previous results with children and suggest that odors readily become associated to emotions and can thereby influence behavior.

KEY WORDS: odors; emotion; associative learning; behavior; motivation.

Associative learning, the process by which one event or item comes to be linked to another through experience, is critically involved in human cognition and behavior (Wasserman & Miller, 1997). It has also been proposed that associative learning principles explain human perceptual responses to odors (Engen, 1988, 1991; Herz, 2001). Specifically, it is proposed that odor hedonic perception (e.g., liking/pleasantness) is derived from a learned association with the emotional context in which that odorant was first encountered. That is, one would dislike the smell of rose if it were first encountered in an unpleasant setting (e.g., a funeral).

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Developmental and cross-cultural literature provide strong evidence that associative learning with emotion as the mediating variable governs odor hedonic perception. Mennella and colleagues found that infants of mothers who consumed distinctive smelling volatiles (e.g., garlic, alcohol, cigarette smoke) during pregnancy or lactation showed preferences for these smells compared to infants who had not been exposed to these scents (Mennella, 1995; Mennella & Beauchamp, 1991, 1993). Notably feeding, in addition to providing nutrition, is an opportunity for close physical contact and emotional bonding. Association through affectionate cuddling also induces preferences for specific (yet arbitrary) scents, such as cherry oil or mother's perfume (Balogh & Porter, 1986; Davis & Porter, 1991; Lott, Sullivan, & McPherson, 1989; Schleidt, Hold, & Attili, 1981). Moreover, among adults no empirical data have shown cross-cultural consensus in odor evaluation for either common "everyday" odors (Ayabe-Kanamura et al., 1998; Schleidt et al., 1981) or even 'offensive' scents. Indeed, in a recent study undertaken by the US military to create a "stink bomb" it was impossible to find an odor (including US army issue latrine scent) that was unanimously considered repulsive across various ethnic groups (Dilks, Dalton, & Beauchamp, 1999). Direct evidence supporting the emotional associative learning hypothesis for odor perception was recently offered by Robin, Alaoui-Ismaili, Dittmar, and Vernet-Mauri (1998) and Herz, Beland, and Hellerstein (2004). Robin and colleagues found that the smell of eugenol ("clove" odor used in dental cement) was evaluated negatively and elicited autonomic fear responses among patients who were afraid of dental procedures, but not unafraid patients (Robin et al., 1998). In our study we showed that hedonic evaluation of a novel odor directionally changed (positively and negatively) as a function of the emotional experience that had been paired with it (Herz et al., 2004).

Prior research has shown that odors that are liked or disliked have a congruent impact on mood and cognition. Pleasant fragrances used in a "real life setting" were shown to improve mood and even alleviated some of the symptoms associated with menopause (Schiffman, Sattely-Miller, Suggs, & Graham, 1995; Schiffman, Suggs, & Sattely-Miller, 1995). In other studies, participants exposed to the ambient smells of chocolate or baby powder reported being in a better mood than people in a no-odor condition (Knasko, 1995), and participants exposed to dimethyl disulphide (rotten eggs) reported being in a less pleasant mood than participants exposed to lavender (Knasko, 1992). Several studies have also shown that pleasant and unpleasant odors elicit physiological changes (heart-rate, GSR, eye-blink) that are consistent with positive and negative emotional states (Alaoui-Ismaili, Robin, Rada, Dittmar, & Vernet-Maury, 1997; Ehrlichman, Kuhl, Zhu, & Warrenburg, 1997; Miltner, Matjak, Braun, Diekmann, & Brody, 1994). Note that in these laboratory studies the physiological and subjective mood changes observed to odors only occurred in individuals who experienced the odors as "pleasant" or "unpleasant," respectively.

Positive mood has generally been shown to lead to increases in productivity, creativity and the tendency to help others (e.g., Isen, 1984, 2000). Negative mood has also been shown to influence cognition and behavior though less consistently and predictably than positive affect (see Forgas, 2002; Gendolla, 2000; Russ, 1993, for reviews). The discrepancies between positive and negative affect on behavior are beyond the scope of this paper. Notably, in the few studies reported, ambient odors have been found to elicit mood effects on cognition and behavior. Ehrlichman and Bastone (1992) found that the presence of a pleasant ambient odor improved creative problem solving relative to an unpleasant odor condition, and Rotton (1983) found that the presence of a malodor reduced participants' subjective judgments and lowered their tolerance for frustration. Participants in these olfactory studies also reported concordant mood changes and liking or disliking of the odors in question was directly related to the mood change that occurred.

Another behavioral effect influenced by mood is cognitive effort. Persistence, the total time a participant will work at a task before giving up or turning to an alternate activity, is one way in which cognitive effort is measured (Feather, 1961). In other words, cognitive effort is the motivation to persist at a cognitively taxing task. The influence of mood on cognitive effort was shown by Kavanaugh who reported that college students persisted longer at solving an anagram task when they were under the influence of a happy mood induction than a sad mood induction, and performance was independent of their skill level (Kavanaugh, 1987). Motivational level influenced by ambient odor has not been previously studied and will be a primary variable in the present research.

The work reviewed above shows that there is a correlation between ambient odor, mood and behavior. However, the mechanisms underlying the observed effects are unclear. We hypothesize that through associative learning with particular emotional experiences, odors operate as cues to these past emotional experiences and consequently exert the same type of cognitive and behavioral influences that the emotions themselves would produce. That is, in addition to altering odor hedonic perception, emotions can become attached to odors such that these emotions are elicited when that odor is encountered again. From a theoretical perspective, the mechanism by which the association between an odor and concurrent emotion is formed may be described by classical conditioning. That is, a specific emotional state (unconditioned stimulus) is paired with a neutral ambient odor (conditioned stimulus), after which the odor conditioned stimulus becomes able to elicit that emotion (conditioned response) and mood congruent behavioral changes. Evaluative conditioning (Martin & Levey, 1978), a form of classical conditioning where the unconditioned responses are affective states, has been used to demonstrate preference shifts for flavor and odor stimuli (Baeyens, Eelen, van den Bergh, & Crombez, 1990; Baeyens, Wrzesniewksi, De Houwer, & Eelen 1996). However, non-perceptual behavioral changes as a consequence of odor–emotional conditioning in humans has received scant attention. In the animal literature, behavioral effects such as fear conditioning based on learned associations to odor cues is a very reliable effect. In general, pairing an originally neutral odor (conditioned stimulus) with a fearful event such as shock (unconditioned stimulus) results in the odor subsequently being able to elicit typical conditioned fear responses (see Otto, Cousens, & Herzog, 2000). Although fear conditioning has been examined in humans (e.g., Lovibond, Davis, & O'Flaherty, 2000), no studies to date have involved odor cues. Indeed the only study to investigate emotional conditioning as a function of odor-associative learning was a previous study conducted in the Herz laboratory (Epple & Herz, 1999).

In the Epple and Herz study, 5-year-olds were subjected to a failure–frustration manipulation in the presence of an unfamiliar ambient odor. After a 20 min break in an unscented area, they were given a test of motivated behavior in the presence of the same-odor, a different-odor or no-odor. The test task comprised a sheet of 120 animal drawings, 40 of which were puppies and 20 of those puppies were missing their tails. The object of the test was to find and circle as many puppies missing their tails as they could by the time a voice counted to 10 (90 s). Performance was assessed by the number of puppies correctly circled as a function of ambient odor condition (same, different, no-odor). The children were also videotaped so that facial expressions of affect could later be determined. Results revealed that children who performed the test in the presence of the same-odor circled significantly fewer puppies (had lower performance scores) than participants in any other group. Performance of participants in the different-odor and no-odor groups did not differ. Facial expressions at the end of the maze task were judged as predominantly negative, thus it was inferred that the failure–frustration task had induced negative affect. This study provides support for the hypothesis that emotional experiences can become associated to odors and when re-presented influence behavior in a mood consistent manner. However, it can not be conclusively argued that the effects observed were due to emotional associative learning, as there was no condition in which the same odor was present during both parts of the experiment but not associated to a mood manipulation. That is, it could be that the detrimental effects observed in the same-odor condition were merely due to over-exposure to the ambient odor (lack of change) producing boredom and thus less interest or motivation for the task.

The purpose of the present research was to validate the findings of Epple and Herz (1999) in an adult population and further explore the mechanisms involved. Two experiments were conducted to meet these goals.

EXPERIMENT 1

In a previous study (Epple & Herz, 1999), we examined 5-year-olds to test the hypothesis that odors can become associated to specific emotional states and that subsequent odor exposure can produce mood congruent effects on motivated behavior. Specifically, we found that exposure to a novel odor during the experience of failure–frustration produced a detrimental effect on performance on a motivated test task when it was later present. The purpose of Experiment 1 was to reproduce this finding with adults. Before explaining the present procedures some paradigmatic issues relevant to the original Epple and Herz (1999) study need to be elucidated. First, the performance measure in Epple and Herz (1999), though a numerical score indicating the number of correct responses (number of puppies correctly circled), represented a motivational not a cognitive ability based task. Subjects' mental ability was assessed in a pre-screening procedure prior to the start of the study and children who did not meet the criteria were excluded. Thus, the children in the study were intellectually comparable. Vision was also normal in all children or corrected by wearing glasses. Thus, the task of "circling puppies missing their tails" was neither an intellectual nor a visual task but rather a test of willingness to exert the effort to find the tailless-puppies from amidst a large array (i.e., motivation). Furthermore, the time spent doing this task was delimited therefore time spent "persisting" could not be assessed. In the present study, we sought to investigate performance on a test which would assess ability and motivation. However, due to the extensive experience the participants in this study have with testing scenarios we suspected that demonstrated accuracy (ability) on the tests might be less sensitive to mood effects than persistence at working on the test tasks would be. In particular, we hypothesized that participants who worked on the test tasks in the presence of the same odor that had been associated to a frustrating mood would re-experience that frustration and be less motivated, hence spend less time working on the tests, than participants who did not have this associative history.

METHOD

Participants

Thirty-three female volunteers from Brown University were individually tested (meanage = 20.06). Participants were pre-screened to be non-smokers, in good respiratory health and to be inexperienced at playing computer games (so that they would be less likely to suspect that the mood manipulation was fixed, see below). Participants received either course credit or performed the study voluntarily without compensation. Participants were randomly allocated to three test conditions ($N = 11$): (1) same-odor, (2) different-odor, and (3) no-odor.

Experiment Rooms and Ambient Odors

Two rooms of similar dimensions ($8' \times 14'$ and $9' \times 14'$) but decorated differently were used in the experiment. One room was used for the odor association mood manipulation (Room 1) and the other for the behavioral test tasks (Room 2). Two novel complex odor mixtures were used as the ambient odor stimuli. The two odors were selected from a group of 10 candidate odors after pre-testing with 10 participants who were not involved in the main experiment. The criteria for odorant selection were: mean familiarity rating ≤ 3, mean pleasantness $4 < X < 6$ (1–7 Likert scales) and clear distinctiveness between the two odorants. Thus the two odors used were unfamiliar and pleasant. Low familiarity was important because if the odors were familiar, prior learned associations might confound or interfere with the present manipulations. Ambient odor A ("Inspiration") was obtained from Time Labs, and ambient odor B ("Aquarium") was obtained from Intercontinental Fragrances. The air in the room the test took place in (Room 2) was scented with either the odor that had been present during the mood manipulation (same-odor condition), the alternate ambient odor (different-odor condition) or was unscented (no-odor condition). Each ambient odor was paired with the mood manipulation for half of the participants and served as the different odor for the other participants. The ambient odors were dispersed using an EAS1000 delivery device (AromaSys Inc.) and adjusted to yield approximately equal intensities in both rooms. When there was a change in ambient odor condition the room was completely aerated. The psychology building, where this study was conducted, has an efficient positive air pressure and ventilation system that enabled fast and effective elimination of odor from ambient air. The experimenter also assessed the test rooms prior to the arrival of each participant to ensure that air quality was as expected. From previous research it is known that participants need to be at least indirectly aware of ambient room odor in order to make an event-odor attribution (Herz, 1997a). To elicit awareness, participants completed a Room Environment Questionnaire (Herz, 1997a) when they first entered each room, which asked, among other things, for ratings of ambient odor quality. This method has been used effectively in previous research on ambient odor and mood (Herz, 1997a, 1997b; Herz et al., 2004).

Mood Manipulation

To induce a frustrated mood state the rigged computer game and methodology that was successfully employed in a previous experiment to create frustrated mood during tests of odor perception was used (Herz et al., 2004). The game involves multiple trials where the participant has to pick which hat a coin is under after a varying number of hats have been shuffled at different speeds on the screen. Although it does not appear so, all speeds are faster than human visual tracking detection. To begin the game, the participant is given \$2.50 and told they have the opportunity to win as much as \$5.00 or go down to \$0.00. The game is programmed to oscillate between wins and losses and ends in a final decline to \$0.00, taking approximately 15 min to complete. Every loss trial is also accompanied by an annoying sound effect. Fifteen minutes was chosen as an appropriate amount of time to ensure encoding of the ambient odor with the emotional experience, while minimizing the possibility of odor adaptation (Dalton & Wysocki, 1996).

Mood Measurement

Ratings of self-reported mood were taken at the start of each session (baseline), after the mood manipulation (post manipulation), and at the end of the test tasks (end). To measure mood, the Affect Grid, which is based on the circumplex model of mood was used (Russell & Carroll, 1999; Russell, Weiss, & Mendelsohn, 1989). The Affect Grid is a 9×9 matrix with the horizontal axis corresponding to varying degrees of pleasure and the vertical axis corresponding to varying degrees of arousal. Participants rate their current mood by placing an “X” at the appropriate location on the matrix. Each square in the matrix yields two scores (pleasure, arousal) with a numerical range from 1 to 9. The Affect Grid has been effectively used to assess mood change in many studies involving mood induction, including previous research from my laboratory (Herz, 1997b, 1999; Herz et al., 2004). During debriefing, participants were also asked to describe the emotions they experienced from the manipulation, so that a more detailed account of the mood manipulation could be obtained.

Test Task

To assess the influence of ambient odor on motivated behavior we developed a cognitive test task to measure ability and persistence time. The test task consists of three word puzzles that progress in difficulty. Puzzle test 1 comprised 15 items of the following type: *99 B of B on the W* (answer: 99 bottles of beer on the wall). Test 2 comprised 12 sentences with missing words each being an anagram of the other, for example: *It is amazing how Joe . . . (4) his . . . (4) through his opponents guard to land a punch* (answer: It is amazing how Joe “fits” his “fist” through his opponents guard to land a punch). Test 3 comprised 12 anagrams in various categories (e.g., animals) with items as follows: *moral dial* (answer: armadillo). In pre-testing, these tasks were found to be appropriate in complexity and content for the study population.

Procedures

All participants played the frustrating computer game in a room scented with one of the ambient odors. Following the protocol of Epple and Herz (1999), after the computer game experience, participants were taken to an unscented area for 20 min and told to relax and peruse (if they wished) a number of general interest magazines that were available. Following this break the participant was brought to Room 2 to perform the test tasks under one of three possible ambient odor conditions: (1) same-odor, (2) different-odor, (3) no-odor. Participants were given the three puzzle tests in order from easiest to hardest. They were instructed to go at the own pace and to complete as many items on each sheet as they could and that when they felt they had done as much as possible to go to the next test. No time limit was imposed and participants were not required to finish one puzzle test in order to start the next one. However, participants were not allowed to go back to a test sheet once they had deemed it completed. Unbeknownst to the participants, the amount of time they spent on each test was recorded. Performance was thus assessed by two measures: (1) accuracy (ability): items completed correctly per test and total; (2) persistence: time spent on each test and total time spent. After completion of all three puzzle tests, or upon giving up, participants were debriefed and asked several questions about the experiment, including if and how the computer game affected their mood, and whether they noticed the fragrance in Room 1. Participants in conditions 1 and 2 were also asked whether they noticed the fragrance in Room 2 and, if so, whether they thought it was the same as or different from the fragrance in Room 1.

RESULTS

Affect grid data were analyzed to determine the success of the computer game as a negative mood manipulation and the changes of mood that occurred over time in the experiment. Mixed model analysis of variance (ANOVA) conducted on the mean *pleasure* scores, with time (time 1, baseline; time 2, post-manipulation, time 3, end) as the repeated measure and condition (same, different, no-odor) as the between subjects factor, revealed a main effect for time, $F(2, 60) = 18.55$, $p < 0.01$. Newman–Keuls post-hoc comparisons ($0 < 0.01$) revealed a significant decrease in pleasure for all participants from time 1 ($M = 6.03 \pm 0.26$) to time 2 ($M = 4.33 \pm 0.25$). No effect for condition and no significant time $\times$ condition interaction was obtained. Therefore all participants were equally affected by the mood manipulation. Post-hoc comparisons also showed that at the end of the experiment all participants were in a significantly worse mood than they had been at the start but better than immediately after the game manipulation (M-end $=$ 5.09 ± 0.26). No statistically reliable effects were obtained for *arousal* at any time or by condition. Table I shows the mean ratings for pleasantness and arousal by participants in each condition at the three rating times.

Data from the puzzle tests were first examined to assess whether differences in participant's ability would be observed as a function of the ambient odor test condition. A one-way ANOVA on the number of items completed, with condition as the independent variable, revealed no mean differences on any test or on overall performance (see Table II). ANOVA conducted on the mean accuracy scores

Table I. Mean Mood Ratings Over Time in Experiments 1 and 2

Condition	Affect Grid pleasure			Affect Grid arousal		
	Time 1	Time 2	Time 3	Time 1	Time 2	Time 3
Experiment 1						
Same-odor	5.55 ± 0.45	3.82 ± 0.44	4.55 ± 0.46	5.36 ± 0.49	4.54 ± 0.55	4.91 ± 0.48
Different-odor	6.09 ± 0.45	4.54 ± 0.44	5.00 ± 0.45	4.73 ± 0.50	5.54 ± 0.55	5.64 ± 0.48
No-odor	6.45 ± 0.45	4.63 ± 0.45	5.73 ± 0.46	4.72 ± 0.50	4.00 ± 0.55	4.82 ± 0.47
Experiment 2						
Same-negative	6.00 ± 0.31	4.90 ± 0.43	5.00 ± 0.44	4.80 ± 0.42	5.10 ± 0.65	4.80 ± 0.56
Same-different	6.10 ± 0.31	5.00 ± 0.44	5.30 ± 0.44	4.90 ± 0.42	4.60 ± 0.65	5.10 ± 0.57
Same-neutral	6.20 ± 0.31	6.90 ± 0.44	4.40 ± 0.44	4.30 ± 0.42	4.40 ± 0.64	5.30 ± 0.56

Note. For all tables, means are expressed ± the standard error of the mean (SEM). Time 1, baseline. Time 2, post mood manipulation. Time 3, end of test tasks.

(number correct out of total completed) also revealed no effect for condition on any test or overall (see Table II).

As a measure of task motivation, persistence, the mean time spent (in seconds) on each puzzle and the total time spent on puzzles was analyzed (see Table III). A one-way ANOVA conducted on mean time spent on test 1, revealed no main effect for condition. However, ANOVAs conducted on the mean time spent on tests 2 and 3 were significant for condition, $F(2, 20) = 3.46$, $p < 0.05$, and $F(2, 30) = 5.17$, $p < 0.05$, respectively. Newman–Keuls post-hoc comparisons showed that participants in the same-odor condition spent significantly less time on both tests than participants in the different-odor and no-odor conditions, and there was no difference between the time spent by participants in the different-odor and no-odor conditions. A one-way ANOVA, with condition as the independent variable, conducted on the mean total time spent on the tests, also revealed a main effect of condition, $F(2, 30) = 6.30$, $p < 0.01$. Newman–Keuls comparisons confirmed that participants in the same-odor condition spent significantly less time overall on the tests than participants in the different-odor and the no-odor conditions. There

Table II. Experiment 1: Performance Ability Results

Condition	Test 1	Test 2	Test 3	Total
Mean number of items completed				
Same-odor	10.09 ± 0.64	6.36 ± 0.89	3.18 ± 0.54	19.63 ± 0.69
Different-odor	11.45 ± 1.10	6.18 ± 0.55	3.82 ± 0.69	21.45 ± 0.78
No-odor	10.91 ± 1.10	5.27 ± 0.65	3.45 ± 0.76	19.63 ± 0.83
Test accuracy				
Same-odor	0.96 ± 0.02	0.93 ± 0.07	0.81 ± 0.10	0.90 ± .06
Different-odor	0.96 ± 0.02	0.95 ± 0.03	0.86 ± 0.09	0.92 ± 05
No-odor	0.95 ± 0.03	0.92 ± 0.07	0.85 ± 0.09	0.91 ± .06

Note. Total problems on Test 1 = 15, Test 2 = 12, and Test 3 = 12. Accuracy is expressed as a proportion of items completed.

Table III. Experiment 1: Test Persistence Results

Condition	Test 1 mean	Test 2 mean	Test 3 mean	Mean total
Time spent on tests				
Same-odor	209.90 ± 21.17	320.45 ± 24.38	206.18 ± 28.03	736.55 ± 53.96
Different-odor	295.00 ± 34.01	418.55 ± 24.23	353.82 ± 23.68	1067.36 ± 57.10
No-odor	296.36 ± 39.50	415.27 ± 38.78	383.36 ± 49.76	1050.00 ± 101.65

Note. Time is in seconds.

was no difference in total time spent between the different-odor and no-odor conditions.

From the responses obtained during debriefing it was verified that the computer game had subjectively put participants into a bad mood. In answer to the question: "Did the computer game affect your mood? Yes or No and if Yes how?" 29/33 (88%) of participants responding affirmatively and used one of the following adjectives to describe how their mood had changed: frustrated, negatively/badly, annoyed, impatient, aggravated, bored. Of the four participants who responded "no," to this question, all of them had in fact made a one-unit negative shift in mood after the game on either the arousal or pleasantness dimension of the Affect Grid. All participants were asked during debriefing if they had noticed the odor in the room with the computer game. If the participant was in condition 1 or 2 they were also asked if they had noticed the odor in the second room (test room) and if they thought it smelled the same or different as the air in room 1. If the participant was in condition 3 they were not asked about the smell of the test room. All participants responded that they noticed the scent in the room with the computer game right away. All participants in condition 1 stated it was the same in as the scent in room 2, and all participants in condition 2 said it was different.

DISCUSSION

Experiment 1 showed that participants who were exposed to an unfamiliar, pleasant odor during a frustrating task later spent less time working on difficult word puzzle tests when that same odor was present compared to participants who were exposed to a comparable different odor or no odor while working on these puzzle tests. This was interpreted as indicating that the frustrating mood of the computer game became associated to the ambient odor, such that the ambient odor was then able to elicit frustration and have a detrimental effect on motivation for working on the test tasks. This finding is taken to replicate the results from Epple and Herz (1999) in an adult population. Notably, all participants, regardless of condition, performed equally well in terms of their accuracy on the puzzle tests. The lack of difference in test accuracy across conditions was suspected to appear because of the similar intellectual ability of the participants and their practice with test taking. However, this finding also poses a problem for interpreting the time data as reflecting decreased motivation. That is, it could be viewed that the fact that participants in the same-odor condition spent less time on the tests indicates their efficiency (a positive effect) rather than their lack of motivation and hence could have nothing to do with associative learning. A second caveat regarding the performance effects is that there was no condition where mood and odor were not manipulated and therefore it is not possible to definitively conclude that performance ability was stable and independent of mood states. Finally, the problem that was inherent to the original Epple and Herz (1999) experiment was still present in Experiment 1, as the alternate hypothesis that over-exposure to the same odor throughout the experiment led to a decrease in performance on the test tasks, rather than the detriment being due to an associated emotional response, has not yet been over-ruled.

EXPERIMENT 2

Experiment 2 was conducted to verify that the behavior of participants who experienced the same ambient odor during a negative emotional experience and subsequent test tasks was due to: (1) decreased motivation (persistence) rather than increased efficiency; (2) emotional associative learning and not over-exposure to the same ambient odor; and (3) that equivalent performance scores on the test was due to a consistent ability among the college sample studied that was insensitive to mood. In order to assess changes in persistence and the efficiency explanation, the time participants spent on the test tasks was analyzed as a function of how they answered each test item (correct, incorrect, left blank). It was hypothesized that, in particular, the time taken by participants on items that they ended up leaving blank would be influenced by motivational level. This is because it was surmised that participants who were exposed to the same ambient odor that had been associated to a frustrating emotional state should be less motivated to work on especially challenging problems and thus give up more easily (spend less time) on items that they ultimately left blank than participants who were not experiencing this emotional association. Motivated behavior was thus assessed by two measures: (1) motivation/persistence as measured by the total time spent on the tests; (2) motivation/persistence as measured by the time spent on each test item as a function of the participant's response (correct, incorrect, blank). In order to rule out the over-exposure hypothesis for decreased time among participants exposed to the same odor at both phases of the experiment, a condition where participants were exposed to an odor first during a neutral mood manipulation and then again to the same odor during the test tasks was included. The performance issue was studied by including a control group of participants who did not receive any mood manipulation or any odor exposure and simply performed the test tasks. If the ability of participants in this group was equivalent to participants in the other groups then we could conclude that our sample of Brown University students was at a certain capability level for the test tasks and that this ability was independent of mood state.

METHOD

Participants

Thirty-two female volunteers from Brown University were individually tested following the same criteria as Experiment 1 (mean age = 18.33). Participants were paid for their participation.

Design and Procedures

Participants were randomly assigned to four experimental conditions ($N = 8$) as follows: (1) control-no manipulations; (2) same-negative; (3) different-negative; (4) same-neutral. Participants in condition 1 were given the test tasks to perform in an unscented room with the same instructions as described in Experiment 1, but with no prior mood manipulation or odor exposure. Participants in conditions 2 and 3 underwent the frustration mood manipulation in the presence of ambient odor and then performed the test tasks in the presence of the same or different ambient odor. Participants in condition 4 underwent a neutral mood procedure in the presence of an ambient odor and were exposed to the same ambient odor for the test tasks. Note that there was no no-odor condition in this experiment.

General methods and ambient odor stimuli and delivery were the same as described in Experiment 1. The frustration mood manipulation (computer game) was the same as in Experiment 1, and a neutral mood maintenance procedure was also included (see below). The test tasks were the same as in Experiment 1. In addition to the time participants spent on each of the three puzzle tests, the time participants spent on each question (of each test) was recorded and then analyzed as a function of the response made to it (answered correctly, answered incorrectly, left blank). In order for this to be done, participants were given strict instructions that they had to answer the test items in order and that once they had worked on a problem and then gone to the next one they could not go back to work on it again. This was not the case in Experiment 1 (restriction was by puzzle test only).

Neutral Mood Manipulation

To maintain or induce neutral mood, we have developed a waiting room manipulation (Herz et al., 2004). Participants are left seated alone with general interest magazines available (e.g., National Geographic, Entertainment Weekly, Consumer Reports) for 15 min. Affect Grid ratings from Herz et al. (2004) showed

Table IV. Experiment 2: Test Ability and Time Scores by Condition

Condition	Mean total items completed	Mean total accuracy	Mean total time
Behavior categories			
Same-negative	22.25 ± 1.84	0.84 ± 0.05	1365.88 ± 167.71
Different-negative	24.37 ± 1.84	0.80 ± 0.05	2175.25 ± 167.71
Same-neutral	22.63 ± 1.84	0.82 ± 0.05	1938.25 ± 167.71
Control	24.55 ± 1.84	0.82 ± 0.05	1807.00 ± 167.71

that participants' baseline mood was unchanged by this manipulation. This method of neutral mood maintenance was used for condition 4.

RESULTS

Affect grid data were analyzed to determine the effects of the computer game and the neutral mood procedure and how mood changed over the course of the experiment. Mixed measures ANOVA conducted on mean *pleasure* scores, with time (time 1, baseline; time 2, post-manipulation; time 3, end) as the repeated measure and condition (same-negative, different-negative, same-neutral) as the between subjects factors, revealed a significant condition × time interaction, $F(2, 21) = 5.22$, $p < 0.01$. Newman–Keuls post-hoc comparisons showed that for participants who played the computer game their self-rated pleasure significantly decreased after the game compared to before, whereas for participants who experienced the neutral mood procedure there was no change. Post-hoc comparisons also showed that only participants who did not play the game (same-neutral) was mood significantly decreased after the test tasks compared to after the mood procedure. ANOVA on *arousal* ratings revealed no significant effects or interactions (see Table I for details).

To assess task persistence, the mean time spent (in seconds) working on the puzzles, and how much time was spent as a function of whether a given test item was answered correctly, incorrectly or left blank were analyzed. A one-way ANOVA conducted on total test time revealed a main effect of condition, $F(3, 28) = 6.82$, $p < 0.01$. Newman–Keuls comparisons showed that participants in the same-negative condition spent significantly less time working on the tests than participants in the same-neutral or different-negative conditions (see Table IV). Notably, time spent by participants who did not undergo any manipulation (control group) was less than the time spent by participants in the different-negative condition and not statistically different than participants in either the same-neutral or same-negative conditions. However, as this group of participants underwent shortened procedures their general motivational level may have been somewhat different. For this reason, only the main experimental conditions were included for the persistence by answer-type analysis.

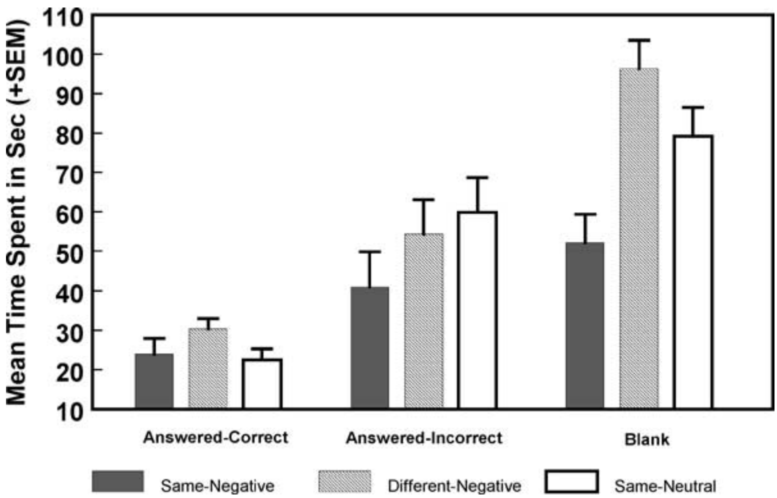

Fig. 1. Mean time in seconds (+SEM) spent on each test item as a function of how it was answered (correct, incorrect, blank) for participants in the same-negative, different-negative and same-neutral conditions in Experiment 2.

A mixed measures ANOVA with condition (same-negative, different-negative, same-neutral) as the between subjects factor and item-answer (correct, incorrect, blank) as the within subjects factor revealed a significant condition $\times$ answer interaction, $F(4, 42) = 3.06$, $p < 0.05$. Figure 1 shows the results. As can be seen, the time taken by participants in the same-negative condition for test items that they left blank was significantly shorter than the time taken on these items by participants in the other two groups. Newman–Keuls post-hoc comparisons confirmed these findings and showed that the same-neutral and different-negative groups did not differ in response times for any of the answer types. Time taken for items that were answered correctly and incorrectly was comparable across all three groups.

A one-way ANOVA by condition (control, same-negative, different-negative, same-neutral) conducted on puzzle performance scores revealed no effects or interactions. Mean total items completed and accuracy scores are shown in Table IV. A mixed model ANOVA on the number of response types (correct, incorrect, blank) produced by participants as a function of condition was also non-significant. That is, an equal number of items were answered correctly, incorrectly and left blank across conditions (see Table V).

From the responses obtained during debriefing it was verified that the computer game had subjectively put participants into a bad mood. In answer to the question: “Did the computer game affect your mood? Yes or No and if Yes how?” 30/32 (94%) of participants stated that they computer game had affected their mood using one of the adjectives listed in Experiment 1. Of the two participants

Table V. Experiment 2: Test Response-Type Rates by Condition

Condition	Mean correct	Mean incorrect	Mean blank
Response-type			
Same-negative	18.75 ± 2.00	3.50 ± 1.38	16.75 ± 1.80
Different-negative	19.50 ± 2.00	4.87 ± 1.38	14.50 ± 1.80
Same-neutral	17.63 ± 2.00	5.00 ± 1.38	17.00 ± 1.80
Control	20.33 ± 2.00	4.22 ± 1.38	14.44 ± 1.80

who stated that the game had not affected their mood, one showed a one-unit negative shift on the Affect Grid for arousal and the other a one-unit negative shift for pleasantness. For participants in condition 4 (same-neutral), 2/8 participants said their mood *had* changed and used the words "tired" and "calm" respectively to describe how. Both of these participants displayed a one-unit decrease in arousal on the Affect Grid. There were no other changes. With regard to awareness of ambient odor, debriefing responses confirmed that all participants in conditions 2 and 4 perceived the ambient odor as the same in both rooms and all participants in condition 3 reported that rooms 1 and 2 smelled different.

DISCUSSION

Experiment 2 showed that lowered persistence (motivation), rather than efficiency explained the shorter work time spent by participants in the same-negative condition, as these participants spent less time on the test items that they left blank compared to participants in the other experimental conditions. The time spent on items that were answered (either correctly or incorrectly) was the same across participants in all conditions. Experiment 2 also confirmed that the effects obtained for time spent working on the tasks was due to the presence of the same odor that was associated to frustration (same-negative), and not boredom from over-exposure, because the presence of the same odor that had been associated to a neutral mood procedure (same-neutral) had no effect on work time. Thus, the effects observed in the present study and in Epple and Herz (1999) can be attributed to odor-associative learning and not odor over-exposure.

Experiment 2 further showed that there was no difference in test accuracy between the participants who experienced no manipulations (control group) and participants in the other conditions, and that the number of items completed correctly, incorrectly and left blank was comparable across all groups. Although the specific questions that vexed individual subjects varied, participants in each group got approximately 82% of the questions they answered correct. This finding indicates that, at least for the college students in this study, ability on the test tasks was at a stable maximum level and that ability to perform such tests was unaffected by mood state.

GENERAL DISCUSSION

The results from two experiments showed that a novel ambient odor associated to a negative emotional state had a detrimental impact on behavior when later present. In particular, willingness to persist at challenging test problems was deterred by exposure to the same odor that had been present during a prior experience of frustration. The effects were found to be due to the specific presence of an odor that had previously been associated to frustration, and not odor overexposure. The present findings extend previous data obtained in children (Epple & Herz, 1999) and demonstrate that odors readily become associated to emotions and through this mechanism can exert a directional influence on behavior. These studies are the first to provide a direct examination of odor–emotional conditioning effects in humans and validate previous observational accounts. For example, crying infants have been shown to be soothed by odors from a garment worn by their mother (Sullivan & Toubas, 1998). Our data do not indicate that there is an unique connection between olfaction and emotional conditioning. A test of this hypothesis would require a direct comparison with another sensory modality.

The observed decrease in time spent working (persistence) is consistent with findings from research on mood and cognitive effort (Hirt, Levine, McDonald, Melton, & Martin, 1997; Martin, Achee, Ward, & Harlow, 1993; Sullivan & Conway, 1989). As previously discussed, Kavanaugh reported that college students persisted longer at solving an anagram task when they were under the influence of a happy mood induction than a sad mood induction and performance was independent of their skill level (Kavanaugh, 1987). The present study showed essentially parallel findings using an odor-associative learning paradigm. Participants persisted less at solving challenging word puzzle questions when they were in the presence of an odor associated to frustration than when in the presence of a different odor or the same odor associated to a neutral mood, and this was independent of skill level. Our interpretation of this outcome is that the ambient odor became a trigger for the feelings of frustration which subsequently decreased participant's motivation to work on the test problems. However, several alternate explanations are also possible including efficiency or some form of aversive conditioning.

With regard to aversive conditioning, it is possible that for participants in the same-negative condition, the ambient odor had become hedonically unpleasant due to is prior association with a negative emotional state and as a consequence participants decreased time on the test tasks was due to their wishing to escape the unpleasantness of the odor. Another related explanation is that due to its associative history the ambient odor elicited general negative emotions and that participants wished to escape the odor to alleviate their bad feelings. Future research should explore these and other alternatives in order to fully elucidate the mechanisms through which emotional associations to odors influence behavior.

A second area of speculation arises from the lack of performance ability effects across conditions. Although it was argued that ability (accuracy scores) was not expected to be influenced by motivational state, some may disagree. Furthermore, the finding that the same-negative group worked faster and performed equivalently to the other groups can be construed as a positive effect (i.e., efficiency). We make the case that the changes in behavior observed in this study and Epple and Herz (1999) were due to effects on motivation from the emotional manipulation associated to the ambient odor. Other researchers studying mood effects elicited by odors have reported findings that concur with motivation changes (see Ehrlichman & Bastone, 1992). However, ability can also be affected by mood. Moreover, ability is influenced by motivation and interest. Therefore, the lack of ability differences in our study is still open for analysis. It may be that had a positive emotional manipulation been used positive changes in puzzle test ability performance would have emerged. The effects of positive mood odor-associative learning and subsequent conditioned behavior were not examined in the present study. During pre-testing for the present research and Epple and Herz (1999) we attempted to develop a conditionable positive mood manipulation but were unsuccessful. However, as there is nothing theoretically different between a positive and negative associative learning procedure, it is expected that with sufficiently inventive or naturalistic mood induction procedures, positive odor associated outcomes could be observed that would affect motivation and potentially also test accuracy (ability) (see Isen, Rosenweig, & Young, 1991).

Further aspects of the present findings that require clarification include the Affect Grid data, performance ability scores in the two experiments, and testing of female subjects only. The Affect Grid data confirmed that the computer game manipulation was successful at inducing negative mood in both experiments. Pleasure ratings were significantly decreased after playing the game compared to before and compared to participants who did not play the game. However, it also appeared that participants' mood was negatively affected by the test tasks, as same-neutral participants in Experiment 2 were in a worse mood after the test than at any other time. This poses a problem for interpreting whether ambient odor condition had a specific effect on mood and that it was the conscious mood of frustration at the time of test that resulted in lowered motivation rather than the test tasks themselves producing frustration or general negative affect. For methodological reasons it was decided that mood should not be assessed immediately upon entering the test room, as mood effects from ambient odor were expected to take place over several minutes of exposure and the experimenter's instructions for the test tasks at that time would also have been distracting. Moreover, it would have drawn undue attention to the ambient odor manipulation and potentially induce demand characteristics if participants were first asked to sit in the test room for a few moments before any other instructions were given. Despite the potential mood confound of the procedures, the fact that there was a clear and consistent effect on persistence time only among participants in the same-negative condition across experiments shows that this manipulation had a direct effect on behavior. Moreover, whether the observed post-test decrease in mood was due to frustration that occurred during the test experience or simply indicative of ennui at the end of the experiment is unknown.

It is also noted that arousal ratings were unaffected by the computer game manipulation. From the debriefing responses it can be seen that the type of negative affect experienced by participants from playing the game varied in arousal from "bored" to "impatient." Systematic analyses of the arousal data were not conducted as a function of the debriefing descriptors. However, we suspect that the different emotional states produced by the game may have nullified an observable effect for arousal. In future research a more detailed analysis of the subjective emotions induced by the mood manipulation and a consideration of personality factors would be instructive.

A comparison of Tables II and IV suggests that the mean accuracy rates in Experiment 2 were somewhat lower than in Experiment 1. It is most likely that this was due to methodological discrepancies between the two experiments and not differences in the samples' ability. In Experiment 2, participants were not allowed to work on a test item again once they had moved to the next one in a puzzle sheet. This was not the case in Experiment 1, which allowed participants to go back to previous items in a given test, thus enabling them to change previously incorrect answers or correctly complete items that were initially skipped over.

Females only were tested in the present experiments because an earlier study indicated that women may be more susceptible than men to emotional conditioning with odors (Kirk-Smith, Van Toller, & Dodd, 1983) and as this was the first study of this kind with adults we wished to maximize the likelihood of finding an effect. Now that an effect has been shown, this study should be replicated with males. Encouragingly, in some of our recent work on associative learning and odor perception we used a similar paradigm and found equivalent outcomes for male and female participants (Herz et al., 2004). Moreover, in our earlier study with children we tested both boys and girls and obtained equivalent results. Thus, we do not expect sex differences to mediate the outcomes of emotional odor-associative learning.

It was suggested in this study that the behavioral manifestation of odor-associative learning could be described by classical conditioning. The present data support this interpretation, however, many questions regarding the specific parameters central to classical conditioning paradigms remain unanswered. Further research involving a classical conditioning analysis of the effects of emotional conditioning to odors and their impact on behavior is now required. This would be especially beneficial for clinical situations, such as post-traumatic stress disorder, where odors that were associated to emotional trauma become primary triggers of unwanted behavioral or emotional responses and the need to deal with classical conditioning features such as generalization and extinction are very important (see Vermetten & Bremner, 2003).

ACKNOWLEDGEMENT

This research was supported by a grant from Oakland Innovation, Cambridge, UK, to RSH. We thank Ben Bredesen for programming the computer game and AromaSys Inc., for odor supplies.

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