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Journal
International Journal of Comparative Psychology, 17(4)

ISSN
2168-3344

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Publication Date
2004-12-31

Peer reviewed

International Journal of Comparative Psychology, 2004, **17**, 315-338.

Changing Odor Hedonic Perception Through Emotional Associations in Humans

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A long-standing debate in olfactory perception is whether hedonic responses to odors are learned or innate. To test the hypothesis that olfactory hedonic responses are acquired through associative learning with emotion, two experiments were conducted that varied with regard to whether a novel ("target" odor) was pre-experimentally pleasant or unpleasant and the emotional association was positive or negative. Participants were randomly assigned to an Experimental Group (odor + emotional association) and various Control Groups. Evaluations of the target odor and several common odors that were not explicitly part of the association procedures (anchor odors) were made: prior to the manipulations, postmanipulation, 24 h after the manipulation, and 1 week from the start date. In both experiments, evaluation of the target odor by all participants was comparable at premanipulation and responses to the anchor odors were unaffected by time or experimental condition. However in each experiment, post-emotional manipulation ratings to the target odor were significantly altered in the Experimental Groups and showed that odor perception had changed in accord with the emotional valence of the associated experience. These findings support the hypothesis that olfactory hedonic responses are learned through emotional associations and raise new methodological and theoretical questions for future research.

A long-standing debate in theories of olfactory perception is whether hedonic responses to odors are innate or learned. Hedonic perception refers to affective evaluations that center on liking. Traditionally in odor research, the perceptual factors of pleasantness, familiarity, and intensity have been used to evaluate hedonic perception (Moskowitz et al., 1976; Sulmont et al., 2002). The *innate view* of hedonic perception claims that we are born with a predisposition to like or dislike various smells. Though widely held, this view has not been empirically validated in humans and is largely due to extrapolations from animal pheromonal communication (Rasmussen & Schulte, 1998). In contrast, the *learned view* states that we are born merely with a predisposition to learn to like or dislike smells, and that whether a smell is liked or not is due to the emotional valence of the experiences that have been associated to it (Bartoshuk, 1991; Engen, 1991; Herz, 2001).

Associative learning, the process by which one event or item comes to be linked to another because of an individual's past experiences, is responsible for a large part of human cognition and behavior (Wasserman & Miller, 1997). It is proposed that odor hedonic responses are formed from a learned association combining the sensory percept and the emotional experience when the percept was first encountered (Bartoshuk, 1991; Engen, 1991; Herz, 2001). For example, a novel odor is experienced in conjunction with an emotional event that induces anxiety, such as a surgical procedure in a hospital. The odor through its association with the

This research was supported by a grant from Oakland Innovation, Cambridge, UK to RSH. We thank Ben Bredesen for programming the computer games that were developed for this research and AromaSys Inc. for odor supplies and consultation. Comments concerning this article may be addressed to Rachel S. Herz, Department of Psychology, Brown University, 89 Waterman Street, Providence, RI 02912, U.S.A. (Rachel_Herz@Brown.edu).

emotion of anxiety then acquires the emotional significance of anxiety, which imbues the odor with hedonic meaning, thus influencing perception (e.g., unpleasant). Thus the reason why we like or dislike various smells is due to the associative history of the odors in question. It is not always necessary to have direct contact with an odor in an emotional context in order to learn its significance because cultural learning provides meaning to many unencountered stimuli. That is, one does not need to have been trapped in a burning house to know that the smell of smoke signals danger; learning that where there is smoke there is fire can be sufficient.

Developmental and cross-cultural literature provide strong evidence that associative learning with emotion as the mediating variable determines 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 & Beauchamp, 1991, 1993; Mennella et al., 1995). Moreover, it has been shown that early learned odor preferences influence food and flavor preferences in later childhood (Mennella & Garcia, 2000) and adulthood (Haller, et al., 1999). Note that flavor is produced primarily by odor; taste contributes only the sensations of salt, sour, sweet, bitter, and savory (Bartoshuk & Beauchamp, 1994). 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 (Balough & Porter, 1986; Davis & Porter, 1991; Lott et al., 1989; Schleidt & Genzel, 1990; Sullivan et al., 1991). In contrast, when there has been no prior learning, the hedonic responses of infants are generally undifferentiated to odors that are regarded as highly pleasant or unpleasant by adults (Stein et al., 1958; Engen, 1988). Only one published study has reported that young children (3-year olds) show adult-like responses to certain odors (Schmidt & Beauchamp, 1988). However, this experiment has been criticized on methodological grounds (Engen & Engen, 1997). In sum, the developmental literature demonstrates both the lack of a priori hedonic responses to odors, as well as the readiness of the olfactory system to learn the significance of odors/flavors based on associative learning and the emotional valence of the associated experience.

Crosscultural data provides further support that associative learning, rather than hardwired responses, is responsible for olfactory preferences. No empirical data have shown cross-cultural consensus in hedonic evaluations for either common "everyday" odors (Ayabe-Kanamura et al., 1998; Schleidt et al., 1981) or "offensive" scents. Indeed, in a recent study undertaken by the United States military to create a "stink bomb" it was impossible to find an odor (including US army issue latrine scent) that was unanimously considered unpleasant across various ethnic groups (Dilks et al., 1999). The following example illustrates how associated emotion is at the root of these effects. In the mid-1960s, in Britain, Moncrieff (1966) asked adult respondents to provide hedonic ratings to a battery of common odors. A similar study was conducted in the United States in the late 1970s (Cain & Johnson, 1978). Included in both studies was the odorant methyl salicylate (wintergreen). Notably, in the British study, wintergreen was given one of the lowest pleasantness ratings, whereas, in the American study it was given the highest pleasantness rating. The reason for this difference can be explained by history. In Britain, the smell of wintergreen is associated with medicine and, particularly for the participants in the 1966 study, with analgesics that were popular during World War II, a time that these individuals would not remember fondly. Conversely, in the United States, the smell of wintergreen is exclusively a candy mint smell and one that has sweet, positive connotations. Thus, the key to olfactory associative learning is the experience that occurs when the odor is first encountered and in particular the emotional connotation of that experience (Bartoshuk, 1991; Engen, 1991; Herz, 2001).

Neuroanatomy also supports the proposition that our olfactory system is especially prepared to learn the significance of odors (Herz, 2001). The orbitofrontal cortex, the area of the brain responsible for processing olfaction, is also the area of the brain critical for assigning affective value to stimuli; in other words, assigning hedonic meaning (Davidson et al., 2000). Furthermore, the amygdala which synapses directly with the olfactory nerve is critical for emotional associative learning (Davis & Whalen, 2001).

To our knowledge there have been three previous empirical demonstrations of olfactory hedonic responses altered via emotional associations. Hvastja and Zanuttini (1989) presented children between the ages of 6.5 to 10.5 with odors paired with either positive or negative slides and showed that, for the younger children in the sample, odors paired with positive pictures were evaluated as better than odors paired with negative pictures. Baeyens and Wrzesniewski (1996) examined naturalistic manipulations of a familiar odor paired with idiosyncratically perceived pleasant and unpleasant toilet experiences and found that, compared to a control odor, the paired odor changed more in accord with the individual's emotional attribution of toilet experiences. Most recently, in an experiment assessing autonomic responses to odors, Robin et al. (1998) 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.

Notably in each of these studies, changes in olfactory perception were somewhat equivocal. One problem with the experiments just described is that they involved associations to familiar odors. We propose that associative learning to odors is strongest with novel odors. This is because familiar odors necessarily have associations to them and it is known that proactive interference in olfactory memory is especially strong, which would impair the formation of new associations (Lawless & Engen, 1977). Another methodological problem with the previous experiments is lack of full control over the olfactory stimuli presented and the general ambient environment. Finally, in these past experiments tests of olfactory perception occurred at various times after associative learning and thus it is not known whether effects would be different immediately after association compared to after some time, or how longlasting the effects of associative learning are.

The purpose of the present study was to test the emotional associative learning hypothesis for odor hedonic perception in a controlled laboratory setting with novel odor stimuli. We also examined the duration of associative learning on odor perception and its time function over a one week period. Two experiments were conducted to achieve these goals.

Experiment 1

Method

Participants. Thirty-two paid female volunteers from the Brown University student community were individually tested (mean age 19.37 yrs). Participants were prescreened to be nonsmokers with a self-reported normal sense of smell and had low experience/familiarity with computer games. On days when participants reported to the laboratory they were free from respiratory complications, such as colds or allergies. Two participants were dropped after the first session because they reported getting a cold. Participants were told nothing about associative learning or odor-mood effects and simply given the guideline that the study concerned odor perception. At the end of the last session, participants were debriefed and paid.

Design and Procedures. Participants were randomly divided into two main groups: (1) Experimental (positive mood experience/+ odor association) and (2) Control. There were three types of control conditions as follows: (i) positive mood experience/no odor association; (ii) neutral mood experience/+ odor association; (iii) neutral mood experience/no odor association. These three control conditions represent the relevant dissociations of positive mood and odor exposure. All participants experienced two manipulation sessions. The reason for two manipulation sessions was because it was discovered during pretesting that one positive mood-odor association was not sufficient to produce changes in odor perception. The duration of all manipulation sessions was 15 min. 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).

Odor Stimuli and Evaluation Methods. The novel target odor (a complex mixture) was obtained from AromaSys Inc. (Lake Elmo, Minnesota, U.S.A.) and was selected from 10 candidate odors on the basis of judged low familiarity, distinctiveness and moderate unpleasantness from pretesting 10 females who did not participate in the main experiment. The target odor was prepared by AromaSys Inc. specifically for this research and thus would never have been previously smelled by the participants. The reason why a neutral target odor was not used was because it is virtually impossible to find an odor that is evaluated as “neutral” other than statistically (average rating in the midpoint of a scale) and it was also expected that the effects from positive associative learning would be more discernible if initial hedonic responses diverged from neutral. The anchor odors were familiar and pleasant scents. They were natural rose (100%), natural vanilla (100%), natural lemon (100%), and natural peppermint (100%). The anchor odors were obtained from Haarman & Reimer Inc. (Springfield, New Jersey, U.S.A.). The purpose of the anchor odors was to establish a within participant comparison point. As the anchor odors were familiar and pleasant, it was expected that they would be perceived equally by all participants over time regardless of manipulation condition. Hedonic ratings for pleasantness, familiarity, and intensity were obtained for all odorants using a 9-point Likert scale (1 = extremely low, 5 = neutral, 9 = extremely high).

When participants provided odor hedonic ratings, the odors were presented in opaque plastic jars. Odor solutions were dissolved into odorless diethyl phthalate (DEP) pellets and one pellet was then placed in a jar and covered with pure cotton. The appropriate concentrations for each odorant were determined during pretesting such that they were all of equal perceived intensity. To assess the odorants, participants unscrewed the lid of each jar, sniffed the cotton inside, and then made their ratings. There were no visual cues by which the odors could be discriminated, however, the order of odor presentation was always the same: target odor, rose, vanilla, lemon, peppermint. Participants were told to go at their own pace and were permitted to sniff an odorant as many times as needed to make their judgments.

When participants were exposed to the target odor in ambient air, it was dispersed using an ambient odor delivery device (AromaSys, EAS 1000) that was hidden from view. Pilot testing was conducted to ensure that the perceived quality of the target odor (pleasantness, intensity) was the same when smelled ambiently and from the jars. To ensure that participants were aware of the ambient odor and that an environmental attribution was made, participants were asked to fill out a Room Environment Questionnaire when they first entered the manipulation room (see Herz, 1997, for details). The experimental rooms were equipped with good ventilation systems and were checked prior to each participant to ensure that no lingering scents were present.

Mood Manipulations and Associative Learning Procedures. Participants in the Experimental Group were exposed to the target odor in ambient air at two positive mood manipulation sessions. At Session 1, ambient odor was present while they played a very entertaining rigged computer game developed for this research. To play the game, participants were given $2.50 to start and told that they could either lose it all or double their money depending upon their skill and luck at playing the game. The game began with several exciting oscillations of wins and losses and then completed with the participant winning $5.00 (which they kept). Amusing sound effects and graphics accompanied each win and loss trial. At Session 2, participants were exposed to the same odor while they watched a compilation of funny scenes from the movie "Something About Mary." Selected film scenes were chosen on the basis of pretesting with four female volunteers who did not participate in the main experiment. The reason why different positive emotional manipulations were used at each session was because playing the game a second time would be less entertaining (than the first time) and would also be more likely to reveal that it was rigged. The game and the film clips both produced equivalent effects on positive affect (Mean pleasantness post game = 6.73, *SD* = 1.08; Mean pleasantness post film = 6.99, *SD* 1.61). Participants in Control Group i experienced the same mood manipulations at session 1 and 2 as the experimental group, but no ambient odor was present (no odor/mood). Participants in Control Group ii were exposed to the target odor in ambient air while they watched two different 15 min segments of a neutral nature documentary (National Geographic: "Jewels of the Caribbean Sea") at each session (odor/no mood). This documentary has been effectively used in past research to maintain neutral mood (Herz, 1999). Participants in Control Group iii sat in an odorless waiting room with various neutral local interest magazines available at both sessions (no odor/no mood). All procedures lasted approximately 15 min.

Mood Evaluations. Ratings of current mood were obtained using the Affect Grid (Russell et al., 1989) several times during the experiment. The Affect Grid is a 9x9 matrix with the horizontal axis corresponding to varying degrees of pleasure (extremely high - extremely low) and the vertical axis corresponding to varying degrees of arousal (extremely high - extremely low). Participants rate their current mood by placing an "X" at the appropriate location on the matrix. The Affect Grid yields two scores that range for -4 to +4, one for pleasantness and one for arousal. Baseline ratings were taken at the start of session 1. Subsequent mood ratings were obtained after each mood manipulation procedure, as well as at the start of sessions 3 and 4.

Odor Evaluation. Participants gave ratings of the target and anchor odor five times over the course of the experiment. After informed consent was obtained at the first session, participants gave their first hedonic ratings. After making these judgments, participants were given a set of distractor tasks to engage in for 15 min (word games) so that any perceptual effects from odor exposure would attenuate. Participants were then taken to a different room for the manipulation (associative learning) phase of the experiment, after which they returned to the first room to rate the odors for a second time, and were then dismissed. Participants returned on the next day for a second association session after which they gave odor ratings, they then returned 24 h later (session 3) and 5 days later (1 week from the start of the experiment = session 4) to make odor ratings only. Odor ratings always took place in a room separate from that in which the associative learning manipulations occurred, and there were no noticeable ambient scents in the odor rating room. As much as possible participants returned for each session at the same time of day.

Results

Analysis of variance (ANOVA) on the Affect Grid data with Group as the between subjects factor and Time as the within subjects factor showed that the computer game and film clips were effective at inducing positive emotion. Table 1 shows the mean ratings for mood pleasantness and arousal as a function of Group and Time. A main effect of Time was obtained for *mood pleasantness*, F (4, 104) = 3.32, $p < 0.05$. Posthoc comparisons showed that participants rated their mood as significantly less pleasant at baseline than at any other rating time. Tests of simple effects showed that the two groups who had experienced the positive emotional manipulations (Experimental and Control i) increased in mood pleasantness after the manipulation sessions while the other control groups fluctuated inconsistently over time (see Table 1). Similarly, a significant Group x Time interaction was obtained for *mood arousal*, F (12, 104) = 4.06, p < 0.01. Tests of simple effects showed that participants in the Experimental and Control i groups were significantly more aroused after the mood manipulation sessions than participants in the other two control groups.

Table 1

Affect Grid Responses.

EXPERIMENT 1: MOOD PLEASANTNESS (Mean ± SEM)

Group	Baseline	Mean Post-Manipulation	24 hrs	1 week
Experimental	5.60 ± 0.13	6.97 ± 0.35	5.73 ± 0.42	5.60 ± 0.45
Control i: Positive Experience/No Odor	6.00 ± 0.00	7.40 ± 0.66	7.00 ± 0.32	7.00 ± 0.32
Control ii: Neutral Experience/Odor	5.20 ± 0.49	6.20 ± 0.39	7.00 ± 0.45	6.40 ± 0.68
Control iii: Neutral Experience/No Odor	6.60 ± 0.93	6.60 ± 0.67	7.40 ± 0.40	6.80 ± 0.74

EXPERIMENT 1: MOOD AROUSAL (Mean ± SEM)

Group	Baseline	Mean Post-Manipulation	24 hrs	1 week
Experimental	4.67 ± 0.45	7.00 ± 0.35	5.87 ± 0.48	5.13 ± 0.42
Control i: Positive Experience /No Odor	5.00 ± 0.45	6.80 ± 0.59	5.40 ± 1.08	7.00 ± 0.55
Control ii: Neutral Experience/Odor	3.60 ± 0.68	3.40 ± 0.65	6.00 ± 0.55	5.40 ± 0.87
Control iii: Neutral Experience/No Odor	4.80 ± 0.37	4.80 ± 0.76	6.00 ± 0.89	5.00 ± .41

EXPERIMENT 2: MOOD PLEASANTNESS (Mean ± SEM)

Group	Baseline	Post-Manipulation	24 hrs	1 week
Group 1: Game + Odor	6.16 ± 0.39	4.08 ± 0.49	5.91 ± 0.40	6.33 ± 0.45
Group 2: Game + No Odor	5.75 ± 0.39	4.58 ± 0.49	6.41 ± 0.40	6.25 ± 0.44
Group 3: Magazines + Odor	6.58 ± 0.40	6.58 ± 0.49	6.41 ± 0.40	6.00 ± 0.45

EXPERIMENT 2: MOOD AROUSAL (Mean ± SEM)

Group	Baseline	Post-Manipulation	24 hrs	1 week
Group 1: Game + Odor	5.50 ± 0.49	4.00 ± 0.51	5.83 ± 0.51	5.83 ± 0.51
Group 2: Game + No Odor	4.83 ± 0.49	4.08 ± 0.51	5.83 ± .51	6.25 ± 0.51
Group 3: Magazines + Odor	6.25 ± 0.49	4.75 ± 0.51	6.17 ± 0.51	5.67 ± 0.51

Statistical analysis of the odor rating data from the three control groups showed that they were all equivalent and did not differ from each other over time; all *F*s < 1.00. The mean ratings obtained on each hedonic scale from the three control groups overall and at each rating time are shown in Tables 2 and 3. Because the control group participants all responded similarly, the data from these three groups were pooled into one Control Group ($n = 15$) and compared to the data obtained from the Experimental Group ($n = 15$). The four anchor odors (rose, vanilla, lemon, and peppermint) yielded equivalent hedonic ratings, therefore one group Mean Anchor rating was computed at each rating time. Mixed model ANOVA with Group as the between-subjects factor and Time as the within-subjects factor were conducted to answer the experimental questions. When posthoc comparisons were performed Newman-Keuls tests ($p < 0.05$) were used.

Table 2
Experiment 1: Target Odor Hedonic Ratings By Control Group.

	TARGET ODOR (Mean ± SEM)		
Group	**Pleasantness**	**Familiarity**	**Intensity**
Control i: Positive Experience /No Odor	3.44 ± 0.46	3.52 ± 0.64	6.56 ± 0.50
Control ii: Neutral Experience/Odor	3.10 ± 0.46	3.56 ± 0.64	6.24 ± 0.50
Control iii: Neutral Experience/No Odor	3.20 ± 0.46	3.26 ± 0.64	5.82 ± 0.50

Table 3
Experiment 1: Target Odor Hedonic Ratings By Control Group over Time.

		TARGET ODOR (Mean ± SEM)				
		RATING TIME				
Rating Scale	**Group**	**Pre**	**Post 1**	**Post 2**	**24 hrs**	**1 wk**
Pleasantness	**Control i**	3.80 ± 0.67	3.40 ± 0.64	3.40 ± 0.39	3.60 ± 0.52	3.00 ± 0.63
	Control ii	3.40 ± 0.66	2.80 ± 0.63	2.90 ± 0.39	3.30 ± 0.52	3.10 ± 0.63
	Control iii	3.80 ± 0.66	2.90 ± 0.63	2.80 ± 0.39	3.30 ± 0.52	3.20 ± 0.63
Familiarity	**Control i**	3.20 ± 0.38	3.80 ± 0.74	3.40 ± 0.79	3.80 ± 0.82	3.40 ± 1.08
	Control ii	2.60 ± 0.38	3.00 ± 0.74	4.00 ± 0.79	4.00 ± 0.82	4.00 ± 1.08
	Control iii	2.80 ± 0.38	3.00 ± 0.74	3.50 ± 0.79	3.20 ± 0.82	3.80 ± 1.08
Intensity	**Control i**	6.20 ± 0.69	7.20 ± 0.77	6.80 ± 0.70	6.00 ± 0.65	6.60 ± 0.58
	Control ii	5.20 ± 0.69	6.20 ± 0.77	6.00 ± 0.70	6.80 ± 0.65	7.00 ± 0.58
	Control iii	5.20 ± 0.69	6.00 ± 0.77	6.50 ± 0.70	5.70 ± 0.65	5.70 ± 0.58

Did a PositiveEmotional Experience Paired with the Target Odor Elevate Produce Hedonic Evaluations? A main effect of Group was obtained for target odor *pleasantness* ratings, $F(1, 28) = 7.43$, $p < 0.01$ (see Figure 1). Posthoc comparisons showed that both groups rated the target odor similarly at premanipulation, but that at all postmanipulation evaluations the Experimental Group rated the target odor as significantly more pleasant than participants in the Control Group. This effect appears to be mainly due to decreasing pleasantness evaluations among Control Group participants. This trend is not statistically reliable as posthoc within-group comparisons were nonsignificant. No effect of Time and no interactions were observed; all Fs < 2.00; all ps > 0.10.

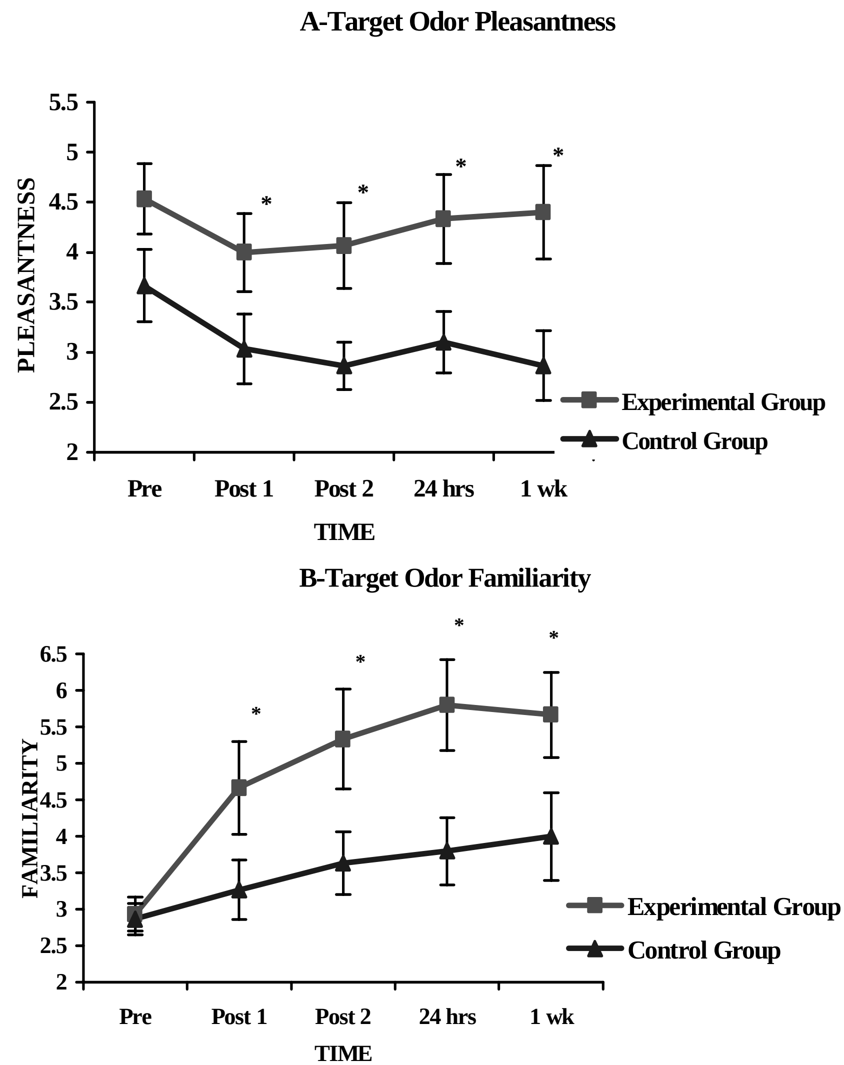

Figure 1. Target odor Evaluations: Experiment 1. A = Mean Pleasantness ratings (± SEM) to the Target odor for the Experimental Group and Control Group at 5 time intervals; premanipulation, after the first and second manipulation sessions, 24 h after manipulation, and 1 week from the first session. B = Mean Familiarity ratings (± SEM) to the Target odor for the Experimental Group and Control Group at 5 time intervals; premanipulation, post the first and second manipulation sessions, 24 h after manipulation, and 1 week from the first session.

Main effects of Group $F(1, 28) = 5.57$, $p < 0.05$, and Time $F(4, 112) = 10.94$, $p < 0.01$, were obtained for *familiarity* ratings, and a Group x Time interaction was observed, $F(4, 112) = 2.42$, $p = 0.05$. Figure 1B shows, and it was confirmed by posthoc comparisons, that Control and Experimental participants rated the target odor equivalently at premanipulation, but at subsequent evaluations participants in the Experimental Group rated the target odor as increasingly more familiar, whereas participants in the Control Group remained relatively flat in their subsequent evaluations. A main effect of Time was obtained for *intensity* ratings, $F(4, 112) = 4.39$, $p < 0.01$. Posthoc comparisons showed that all participants rated the target odor as significantly less intense at premanipulation than at all other rating times (see Table 4).

Table 4
Intensity Ratings for Target and Anchor odors in Experiment 1.

TARGET ODOR (Mean ± SEM)						
Rating Scale	**Group**	**Pre**	**Post 1**	**Post 2**	**24 hrs**	**1 wk**
Intensity	Experimental	4.73 ± 0.50	5.47 ± 0.36	5.93 ± 0.41	5.87 ± 0.47	6.07 ± 0.46
	Control	5.53 ± 0.39	6.47 ± 0.44	6.43 ± 0.39	6.17 ± 0.37	6.43 ± 0.34
ANCHOR ODORS (Mean ± SEM)						
Rating Scale	**Group**	**Pre**	**Post 1**	**Post 2**	**24 hrs**	**1 wk**
Intensity	Experimental	6.15 ± 0.26	6.63 ± 0.21	6.75 ± 0.21	6.55 ± 0.19	6.70 ± 0.23
	Control	6.42 ± 0.27	6.71 ± 0.28	6.48 ± 0.31	6.61 ± 0.31	6.66 ± 0.25

How LongLasting was the Effect of Odor-Associative Learning? What was the Shape of the Time Function? Figure 1 shows that postmanipulation ratings of target odor pleasantness and familiarity were consistently higher in the Experimental Group than in the Control Group and showed no evidence of declining over one week. Thus, it appears that the effects of odor-associative learning can be longlasting. Posthoc comparisons showed that postmanipulation ratings were not significantly different from each other within Group. Thus, once an association to an odor had been made to an emotional event, hedonic perception was immediately altered and thereafter remained stable.

Did Ratings for the Anchor Odors Remain Sable Between Groups and over Time? No significant main effects or interactions were obtained for *pleasantness* or *familiarity* ratings to the anchor odors (see Figure 2); all Fs < 1.50; all ps > 0.79. However, a main effect of Time was found for anchor odor *intensity*, $F(4, 112) = 3.41$, $p < 0.05$. Posthoc comparisons showed that, as with the target odor, participants perceived the anchor odors as significantly less intense at premanipulation than at any other time (see Table 4).

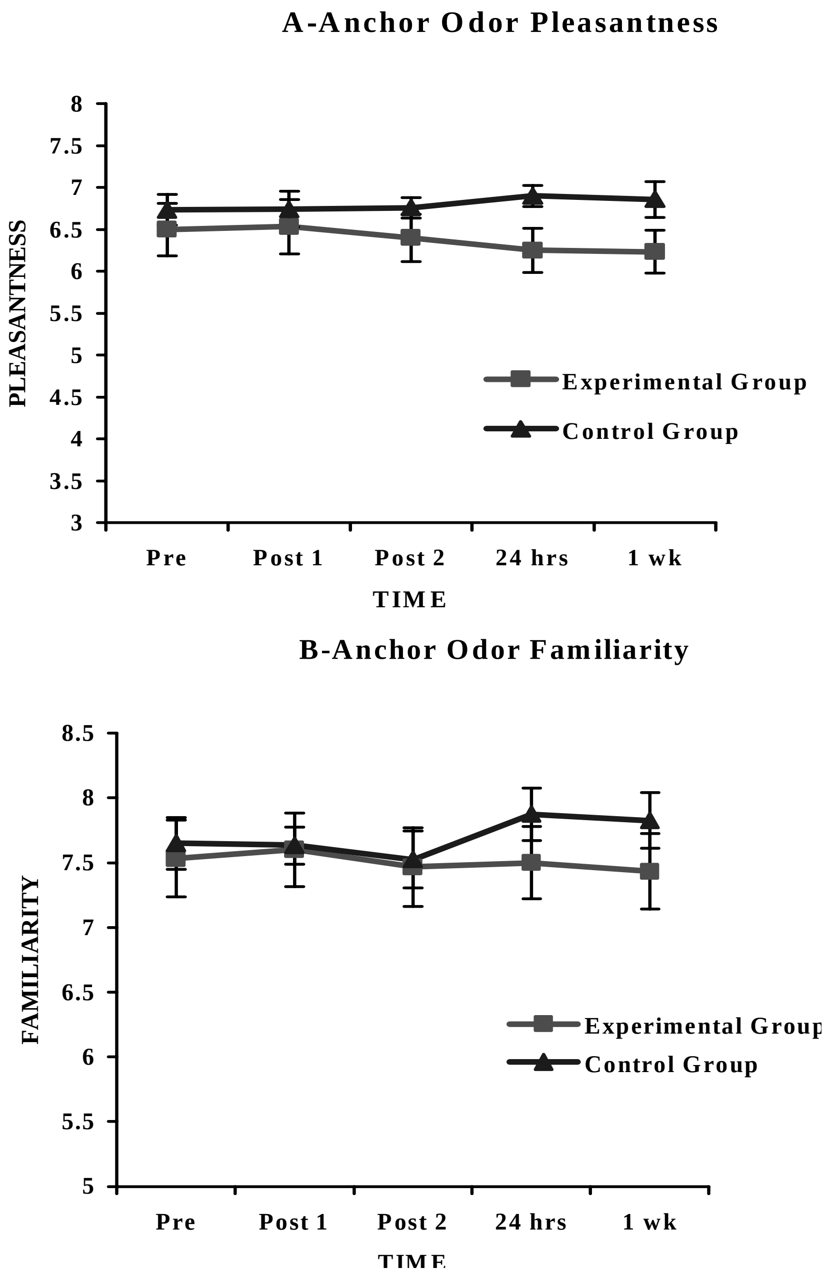

Figure 2. Anchor Odor Evaluations: Experiment 1. A = Mean Pleasantness ratings (± SEM) to the Anchor Odor for the Experimental Group and Control Group at 5 time intervals; premanipulation, after the first and second manipulation sessions, 24 h after manipulation, and 1 week from the first session. B = Mean Familiarity ratings (± SEM) to the Target odor for the Experimental Group and Control Group participants at 5 time intervals; premanipulation, after the first and second manipulation sessions, 24 h after manipulation, and 1 week from the first session.

Discussion

Experiment 1 showed that all participants evaluated the odors similarly prior to the emotional association procedures. However, postmanipulation, pleasantness ratings to the target odor by participants in the Experimental Group remained consistently neutral, while a trend toward decreasing pleasantness evaluations was observed in the Control Group. Notably, familiarity ratings significantly increased to the target odor in the Experimental Group while Control Group ratings showed no change over time. The variables of pleasantness and familiarity are highly positively correlated (Moskowitz, 1979; Ayabe-Kanamura et al., 1997). Familiar odors are generally perceived as more pleasant than unfamiliar odors and pleasant odors tend to be evaluated as more familiar than unpleasant odors. Given the conceptual relatedness of pleasantness and familiarity in odor hedonic perception, we propose that the factors of pleasantness and familiarity can together be viewed as denoting odor hedonic acceptability. Thus, Experiment 1 showed that simultaneously pairing a novel unpleasant scent (target odor) with positive emotional experiences improved subsequent hedonic acceptability of that odor compared to participants who did not experience this pairing. This demonstrates that emotional associative learning can directionally alter odor hedonic perception. As expected, no changes in odor perception were observed to familiar odors that were not directly associated to mood manipulations (anchor odors).

Pleasantness and familiarity ratings to the target odor among Experimental Group participants did not show any signs of diminishing after one week. In keeping with the extended duration of episodic odor memory (Engen & Ross, 1973; Lawless, 1978) it appears that the effects of emotional associative learning on odor perception are long lasting. It also appears that the time function of hedonic evaluation after associative learning is stable. The observed positive changes to the target odor can not be explained by greater exposure to the target odor, as participants in Control Group ii who were also exposed to the target odor during the manipulation sessions did not show any enhanced evaluations. Moreover, no pleasantness or familiarity changes to ratings of the anchor odors were observed over time, therefore repeated testing can not be responsible for the effects. The observed increase in intensity ratings from baseline to postmanipulation evaluations for all participants and all odors, suggests that an odor sensitization effect may be occurring (Wysocki et al., 1989). This could be due to the experimental context or increased selective attention to the specific odorants presented. It is also possible that odor sensitization is especially tractable with female participants (Dalton et al., 2002).

Experiment 2

Experiment 1 showed that associating a positive emotional experience with an unfamiliar and initially unpleasant odor was able to alter subsequent hedonic perception of that odor such that it became more acceptable and this effect showed no evidence of diminishing after one week. Odors that were not explicitly associated to the emotional association procedure were unchanged in evaluation. Thus, it appears that responses to odors can be altered through emotional associative learning. Experiment 2 was conducted to verify and extend the odor-associative learning effects observed in Experiment 1 by addressing the converse scenario; whether hedonic evaluations of a novel pleasant odor could be made unpleasant after pairing with a negative emotional experience. Experiment 2 also aimed to broaden the generalizability of the findings by testing both male and female participants and expanded upon several procedural parameters to obtain a better methodological treatment.

Method

Participants. Twenty male and 19 female participants selected on the basis of the same prescreening criteria described in Experiment 1 were tested at session 1. Two males and one female did not return to complete testing, therefore statistical analyses were performed on 36 subjects (mean age 19.94 years). Participants were individually tested and received course credit as compensation.

Design and Procedures. The design and procedures were similar to Experiment 1, with alterations as follows. Two target odors were used. The two odors were selected based on pretesting with an independent group of 10 participants (5 males and 5 females) who evaluated them for pleasantness and familiarity (9-point Likert scales). The target odors were prepared by AromaSys for this research and thus would never have been previously experienced by the participants. Pretest ratings showed that both odors were judged as moderately unfamiliar (Target odor 1, $M = 4.22$; Target odor 2, $M = 4.45$) and moderately pleasant (target odor 1, $M = 6.42$; target odor 2, $M = 6.75$). The reason for including two target odors was to attenuate possible confounds due to idiosyncratic responding that might occur to the characteristics of one particular odor. The anchor odors and presentation of odors for hedonic evaluation and in ambient air were the same as in Experiment 1. The previously described procedures for mood assessment were followed, and the general method for odor-associative learning was the same except that only one emotional manipulation session (rather than two) was used, as it became apparent during pretesting that one negative association was sufficient to alter hedonic perception.

The participants (18 males, 18 females) were randomly assigned to three groups ($n = 12$, sex matched in each group): Group Experimental: target odor + frustrating mood manipulation; Group Control i: no odor + frustrating mood manipulation; and Group Control ii: target odor + neutral mood manipulation. Half of the participants in each group (3 males and 3 females) evaluated target odor 1, and the others evaluated target odor 2. For participants in Groups Experimental and Control ii, the target odor they evaluated was also present in ambient air during the mood manipulation.

Mood Manipulations and Evaluation. To induce a negative mood state a computer game was developed similar to that used in Experiment 1. As in Experiment 1, participants began with $ 2.50 and were told that they could double their money or lose it all. However, this game was rigged to be frustrating to play, to end in a loss ($ 0.00), and to have annoying accompanying sound effects. The neutral mood experience involved sitting in the test room with various neutral local interest magazines available. Participants rated their target odor and the four anchor odors four times during the experiment: (1) at the start of the first session (premanipulation); (2) after the mood manipulation at Session 1 (postmanipulation); (3) at Session 2 (24 h later); and (4) at Session 3 (1 week from the first session). As before, anchor odor ratings were pooled as a group mean for each assessment. Mood ratings were obtained using the Affect Grid at the start of session 1 (baseline rating 1), after the mood manipulation in session 1 (postmanipulation), and at the start of session 2 (24 h) and session 3 (1 week).

Results

Table 1 shows the mood ratings obtained on the Affect Grid. ANOVA with Group and Sex as the between subject factors and Time as the within-subjects factor revealed a significant Group x Time interaction for *mood pleasantness,* $F(8, 120) = 3.47$, $p < 0.01$. Posthoc comparisons showed that all groups were equivalent in pleasantness at baseline, but in both groups who played the game there was a significant drop in pleasant affect postmanipulation. At subsequent mood ratings (24 h, 1 week) all groups were in equivalent pleasantness states. ANOVA performed on the *mood arousal* ratings showed a main effect of Time, $F(4, 120) = 7.81$, $p < 0.01$. All groups were in a significantly less aroused state after the manipulation procedure than at baseline, and all groups had returned to baseline arousal when tested at 24 h and 1 week. There were no effects or interactions with subject Sex observed in any of the analyses, all *F*s < 1.00; all *p*s > 0.32.

Mixed model Analyses of Variance (ANOVA) with Group and Sex as the between subjects factors and Time as the within subjects factor were conducted to answer the experimental questions.

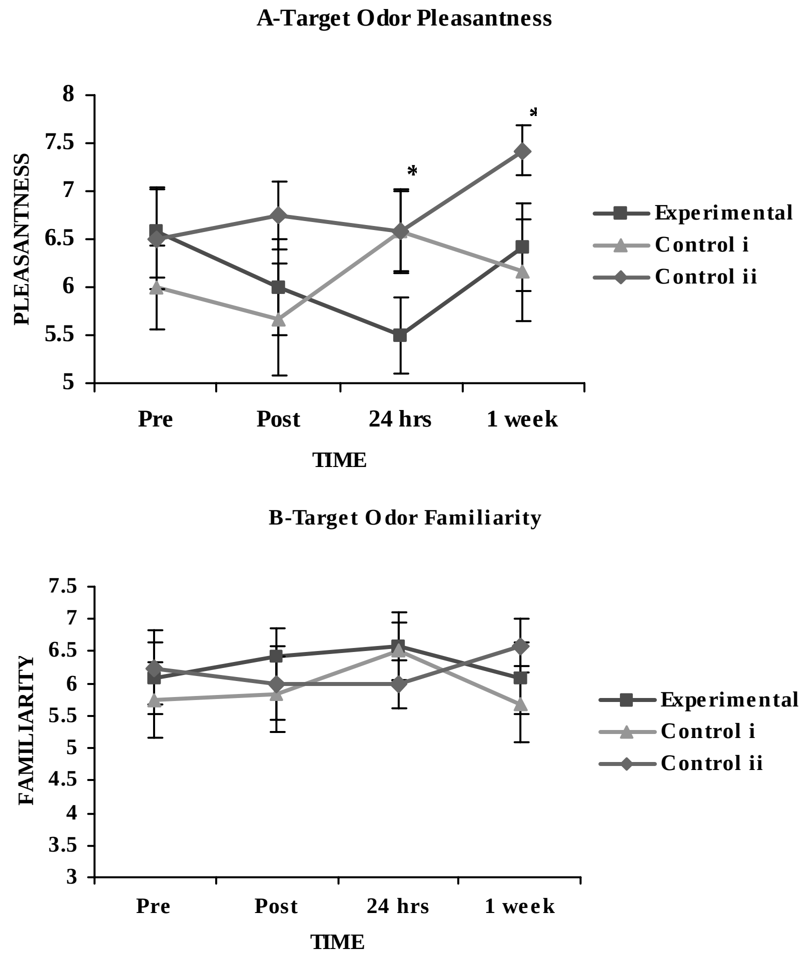

Figure 3. Target odor Evaluations: Experiment 2. A = Mean Pleasantness ratings (± SEM) to the Target odor for Experimental (Game + Odor), Control i (Game + No odor) and Control ii (Magazines + Odor), at 4 time intervals; premanipulation, after the manipulation, 24 h after manipulation, and 1 week from the first session. B = Mean Familiarity ratings (± SEM) to the Target odor for Group Experimental (Game + Odor), Control i (Game + No odor) and Control ii (Magazines + Odor), at 4 time intervals; premanipulation, after the manipulation, 24 h after manipulation, and 1 week from the first session.

Did a Negative Emotional Experience Paired with the Target Odor Decrease Hedonic Evaluations? A significant Group x Time interaction was obtained for target odor *pleasantness* ratings, $F(6, 99) = 2.17$, $p < 0.05$. As Shown in Figure 3A, and confirmed by posthoc comparisons, ratings of target odor pleasantness were similar at premanipulation and at the first rating postmanipulation among all groups, but after 24 h participants in Group Experimental (game + odor) rated the target odor as significantly more unpleasant than participants in the other two groups. At 1 week, participants in Group Experimental were still rating the target odor as less pleasant than participants in Group Control ii (magazine + odor), but were now comparable with participants in Group Control i (game + no odor). No effects or interactions with Sex were found; all *F*s < 1.50; all *p*s > 0.26.

No main effects or interactions with Group, Time, or Sex were observed for target odor *familiarity* ratings; all *F*s < 0.10; all *p*s > 0.50. Note that all ratings were at the moderately familiar level (overall Mean = 6.14 ± 0.29).

A main effect of Time was obtained for *intensity* ratings, $F(3, 99) = 3.03$, $p < 0.05$. Posthoc comparisons showed that all participants rated the target odor as significantly less intense at premanipulation than at all other rating times (see Table 5).

Table 5
Intensity Ratings for Target and Anchor odors in Experiment 2.

TARGET ODOR (Mean ± SEM)

Rating Scale	Group	Pre	Post 1	24 hrs	1 wk
Intensity	**Experimental:** Game + Odor	6.17 ± 0.37	6.67 ± 0.31	6.42 ± 0.43	6.08 ± 0.36
	Control i: Game + No Odor	6.17 ± 0.29	6.33 ± 0.46	6.33 ± 0.45	6.33 ± 0.45
	Control ii: Magazines + Odor	4.92 ± 0.40	6.50 ± 0.43	6.00 ± 0.49	6.17 ± 0.41

ANCHOR ODORS (Mean ± SEM)

Rating Scale	Group	Pre	Post 1	24 hrs	1 wk
Intensity	**Experimental:** Game + Odor	6.75 ± 0.39	7.08 ± 0.21	6.77 ± 0.33	6.83 ± 0.25
	Control i: Game + No Odor	7.00 ± 0.30	6.94 ± 0.34	7.05 ± 0.32	7.00 ± 0.29
	Control ii: Magazines + Odor	6.64 ± 0.27	7/03 ± 0.26	7.11 ± 0.23	6.89 ± 0.35

How LongLasting was the Effect of OdorAssociative Learning? What was the Shape of the Time Function? Figure 3A shows that 24 h after experiencing the target odor in conjunction with a negative emotional experience the perceived pleasantness of that odor was significantly reduced in Group Experimental. One week later Group Experimental participants were still rating the target odor as less pleasant than participants in Control ii, but not differently than they had rated it at premanipulation or than participants who played the game but who did not experience concomitant odor exposure (Control i). Note that changes in hedonic response were not observed immediately postmanipulation in Group Experimental, but took 24 h to develop. Figure 3A also shows a non-significant trend of increased odor pleasantness ratings over time in Control ii. These findings are more variable than the time function observed in Experiment 1. Further discussion and possible explanations for the differences in the shape of the time function for associative effects between Experiment 1 and 2 are offered in the General Discussion.

Did ratings for the anchor odors remain stable among participants and between groups? No significant main effects or interactions were obtained for *pleasantness, familiarity* or *intensity* ratings of the anchor odors (see Figure 4 and Table 5). All *F*s < 2.00; all *p*s > 0.08. Thus, hedonic perception of common odors that were not associated to an emotional experience were unchanged.

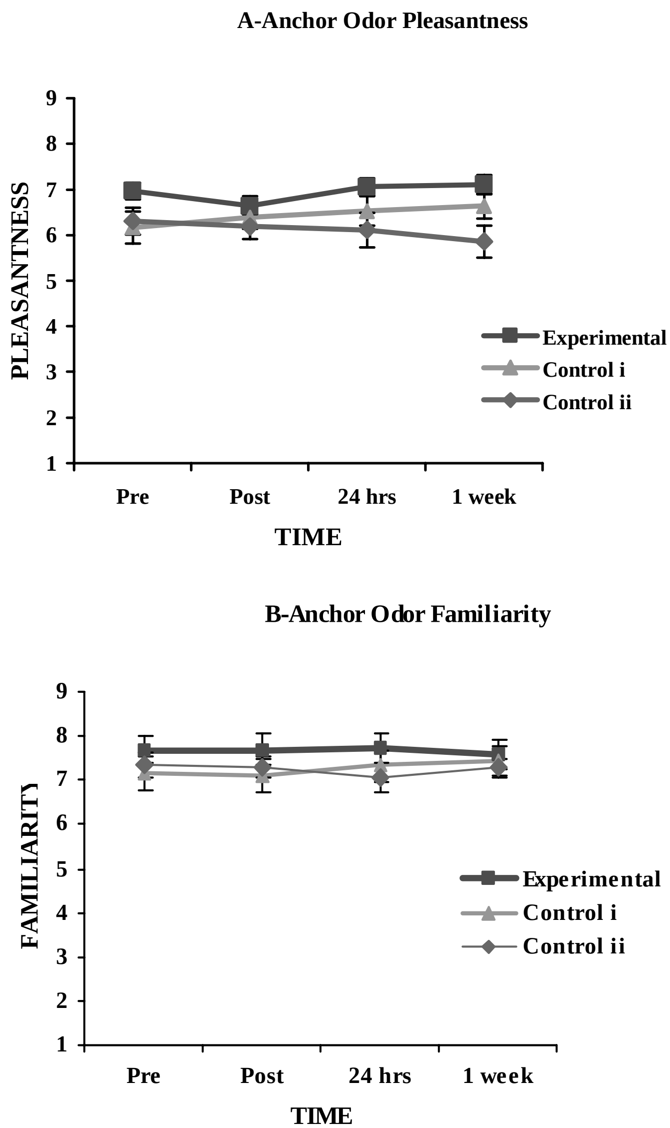

Figure 4. Anchor odor Evaluations: Experiment 2. A = Mean Pleasantness ratings (± SEM) to the Anchor odors for Group Experimental (Game + Odor), Group Control i (Game + No odor) and Group Control ii (Magazines + Odor), at 4 time intervals; premanipulation, after the manipulation, 24 h after manipulation, and 1 week from the first session. B = Mean Familiarity ratings (± SEM) to the Anchor odors for Group Experimental (Game + Odor), Group Control i (Game + No odor) and Group Control ii (Magazines + Odor), at 4 time intervals; premanipulation (= baseline), after the manipulation, 24 h from the first session, and one week from the first session.

Discussion

The data from this experiment showed that an unfamiliar pleasant odor could subsequently become perceived as significantly less pleasant as a function of being paired with a negative emotional experience. Specifically, the target odor was rated as more unpleasant 24 h after association with the negative game and this decline was still evident one week later when compared to Group Control ii (magazines + odor). Participants who did not experience the negative emotion + odor pairing did not show any significant changes in their odor hedonic ratings over one week. In terms of the time course for the development and duration of associative learning it is interesting that no effects were seen immediately postmanipulation, suggesting that some incubation period may be necessary for the target odor to take on a negative association. Moreover, one week after training, evaluation of the target odor was significantly lower in the experimental group than in Group Control ii but not Group Control i. This difference appears to be primarily due to an increase in pleasantness evaluations in Group Control ii at one week; though this increase was not statistically reliable. The magazine association to the odor (Group Control ii) was intended to be neutral in affect, however, it may have become a positive association over time. Another possibility is that experiencing the target odor in ambient air solidified its familiarity and the trend towards increased pleasantness was due to correlated familiarity effects.

In light of the comments just made for the neutral mood-odor association is the problem that familiarity ratings were unchanged in any group by the manipulations. However, familiarity evaluations may have been confounded in this experiment. The target odors used in this experiment were selected to be pleasant yet unfamiliar. Despite pretesting that indicated that the target odors were unfamiliar, it is likely that because the odors were perceived as pleasant and due to the positive relationship that exists between familiarity and pleasantness, that familiarity ratings may have been artificially elevated. This possibility confounds interpretation of the familiarity data. Nevertheless, the finding that emotional associative learning still occurred for odors that may have been perceived as moderately familiar suggests that this phenomenon can be observed under less than optimal empirical conditions (e.g., Baeyens & Wrzesniewski, 1996)

Intensity ratings to the target odor followed the same pattern as observed in Experiment 1, further supporting the suggestion that increased odor exposure leads to an odor sensitization effect (Wysocki et al., 1989). However, no changes in anchor odor ratings were observed here which may suggest that exposure sensitization is more potent with less familiar or less frequently encountered odors. Males and females did not differ in their emotional responses or ratings of the odorants. Odors that were not directly paired with the manipulation (anchor odors) were unaffected in every group.

General Discussion

The goal of the present study was to test the associative learning hypothesis for odor hedonic perception. Two experiments showed that when an odor was paired with an emotional event, hedonic perception of that odor was altered in accord with the associated emotion. This effect did not transfer to odors that were not directly associated with an emotional manipulation (anchor odors); did not occur from the emotional association when unpaired with the target odor; and did not occur from simple prolonged exposure to the target odor. Affect Grid analyses confirmed that the mood manipulations in both experiments resulted in significantly altered mood in the expected directions. Our findings are therefore taken as empirical support for the hypothesis that liking or disliking of odors develops from emotional associative learning (Bartoshuk, 1991; Engen, 1991; Herz, 2001). Additionally, changes in hedonic perception appeared to endure for at least one week in Experiment 1. Clinical and anecdotal evidence suggests that emotional responses trigged by odors can last a lifetime (Vermetten & Bremner, 2003; Proust, 1928). Further research to investigate the longevity of olfactory perceptual changes that occur through emotional learning should now be undertaken.

The present study can not rule out innate responding to odors. However, together with past empirical work (Hvastja & Zanuttini, 1989; Baeyens & Wrzesniewski, 1996; Robin et al., 1998) it appears that emotion experienced in conjunction with odor exposure is a powerful manipulator of subsequent hedonic perception. Moreover, the finding that different target odors could elicit the same effects support the proposition that it is the association of a specific emotional state with an odor, and not the specific odor itself (e.g., Black, 2001), that leads to the observed change in odor hedonics. In other words, the emotional effects of odors are not intrinsic to the odorants themselves but rather are due to the hedonic or emotional responses that have been associated to them.

The results from Experiment 1 and 2 demonstrated that a different time function for odor-associative learning developed depending upon whether the target odor was pre-experimentally pleasant or unpleasant and the paired emotional experience was positive or negative. In Experiment 1, when an unpleasant odor was associated to a positive emotional experience, positive hedonic effects occurred immediately and persisted for at least one week. However, in Experiment 2, when a pleasant odor was associated to a negative emotional experience, changes in olfactory perception were not observed until 24 h after the association had been made and were weaker after one week. This observation suggests that different mechanisms may underlie stimulus-association interactions as a function of the initial emotional salience of an odor and an associated event.

A possible explanation for why the hedonic responses in Experiment 1 were more consistent over time than in Experiment 2 is that participants in Experiment 1 had more association time with the target odor (two association sessions rather than one) which may have produced a more durable hedonic change. Another consideration is that the target odors in Experiment 2 were perceived as more familiar (less novel) than the target odor in Experiment 1, and thus may have been less susceptible to associative learning which could account for the observation of an incubation period (24 h) and weakened endurance. Finally, we can not overlook the fact that our sample sizes were not very large and thus some of the effects obtained could have been artifactual. A replication of this study and further experiments to address the issues discussed above should be undertaken.

Evaluative conditioning is a topic that is conceptually similar to the present research. Evaluative conditioning is an extrapolation of classical conditioning where sensory stimuli such as odors or tastes serve as conditioned stimuli and emotional or hedonic experiences serve as the unconditioned stimuli (Baeyens et al., 1990; Martin & Levey, 1978). For example, when a positive taste such as sweetness was paired with a neutral flavor, the flavor was subsequently perceived as more pleasant (Zellner et al., 1983). Reviews of this research, however, have noted that obtaining evaluative conditioning effects in the laboratory is both difficult and elusive (De Houwer et al., 2001; Rozin et al., 1998). Methodological issues appear to account for many of the inconsistencies obtained in evaluative conditioning research. As our work is similar to the paradigms involved in evaluative conditioning, and in light of the methodological issues raised from the present study we present a brief analysis of the development of our methods in hopes of assisting future researchers in this area.

During prestesing for Experiment 1, we observed that the positive emotional manipulation we had developed was not sufficient to produce changes in hedonic response to the target odor when presented only once. Thus, we tried two positive pairing sessions with the target odor and found this to be effective for altering hedonic perception. Notably the two pairing sessions were not repeats but involved two different experiences (game and film clips); this was done to prevent the development of negative effects from multiple exposures to the game. The spacing of 24 hours between emotional manipulation sessions was the first interval attempted and was chosen primarily for logistical reasons. We found it to be effective and did not explore alternate time spacing. However, whether positive associations could have been formed with the two sessions spaced over less or more time is unknown and could be an area of future inquiry. When pretesting Experiment 2 we found that one negative emotional manipulation was sufficient for odor perception to be affected. This fits with the asymmetrical potency of positive and negative emotional experiences. It has been well documented that negative emotion tends to be more potent and more motivating than positive emotion (Baumeister et al., 2001; Rozin & Roysman, 2001). Herz and Cupchik (1993) also found that it was easier to manipulate evaluations of positive paintings by a negative odor context than to manipulate evaluations of negative paintings by a positive odor context. However, the specific emotional potency of the associated experience (unconditioned stimulus) is something that should be explored in itself. One could imagine that only one pairing of a very positive unconditioned stimulus, such as a back message, with ambient odor might form a more durable association than pairing with a moderate negative stimulus, such as an annoying computer game. Further work to examine the potency of the unconditioned stimulus in conjunction with its hedonic valence for establishing a conditioned association and determining its duration in odor-associative learning would now be important. The reason why an interactive computer game was developed as the main emotional manipulation for this research is because self-involving emotional experiences tend to have a deeper and more intense influence on mood than passive mood inductions (Gerrards-Hesse et al., 1994) and because positive and negative variants of the experience were possible. Both the negative and positive versions of the computer games were extensively pre-tested and modified for maximum mood effectiveness prior to beginning this study.

In terms of classical conditioning issues, a further consideration is that this study did not conform to standard classical conditioning paradigms where an un-paired control group would have also occurred. That is, there is no way to verify in the present study that backwards conditioning was not a factor in the results or that non-associative effects due to the stimuli themselves could have produced the present findings. Future studies on this topic should control for the presentation of the conditioned (target odor) and unconditioned (emotional manipulation) stimuli in an unpaired fashion to unambiguously demonstrate that it is the temporal pairing of the target odor with the emotional manipulation that produces hedonic changes in target odor perception.

Another methodological issue that emerged during pretesting was that the target odor needed to be presented as the first item in the rating sequence. Initially we randomly ordered the target odor with the anchor odors for hedonic evaluations, however, we noted that the target odor elicited different responses depending upon what the preceding odorant had been. For example, if the target odor was presented first it received different hedonic ratings than if vanilla immediately preceded it which was different again from the case where rose and lemon had preceded it. We surmised that this might be due to at least two factors, cross-adaptation and expectation. Cross-adaptation is a sensory phenomenon that develops when, due to the chemical properties of the odorants in question, the first odorant sniffed interferes with perception of a subsequent odor. In addition, cognitive factors such as expectation could have been at play and the target odor may have been perceived as more or less pleasant depending upon the number of preceding pleasant-familiar scents that had just been evaluated. Presenting the target odor before any of the anchor odors eliminated cross-adaptation and expectation confounds and was found to alleviate inconsistent rating, thus this procedure was adopted for the present experiments. The order of anchor odor presentation was not an issue but remained constant for every rating trial for consistency.

Finally, an important consideration for the present study was that the emotional experiences and ambient odors were not conceptually related. That is, the smell in the air had nothing to do with the games. The fact that the associations between odor and events were arbitrary as opposed to being causally linked, as would be the case if the odor emanated from the source of the emotional experience (e.g., the perfume of an emotionally significant person, or the smell of fire in a burning house), may have implications for the way in which odor associations are learned. Attention to this issue is further substantiated by the animal literature showing that not all arbitrary pairings between a particular sensation and associated experience will result in classical conditioning (Garcia & Koelling, 1966; Domjan, 1983). Specifically, when a rat experiences a sweet flavor paired with nausea this induces learned taste aversion for that particular flavor (notably in only one trial of association) much more readily than if electric shock is paired with the same sweet flavor. This is because nausea is more experientially related to flavor/food than shock is (but see, Krane & Wagner, 1975). Such questions of "belongingness" and differences between associations made to odors that are based on a causal versus chance co-occurrence should be addressed in future human research.

The goal of the present study was to provide support for the proposition that human hedonic responses to odors are learned through emotional associations. Evidence for this hypothesis was behaviorally shown by our results and extends previous experimental, development and cross-cultural findings that are consistent with this claim. The associative learning hypothesis for odor perception is also theoretically supported by an evolutionary analysis contrasting the goals and requirements of animals that are generalists versus those that are specialists. Specialists are animals that are restricted to specific habitats, and thus can often only eat a few foods and have particular local predators (Rozin, 1976); the eucalyptus-exclusive diet of the panda bear is an extreme example. Thus, for specialists having hard-wired responses to particular odors is adaptive. Innate odor responses have been empirically demonstrated for many specialist species. For example, both lab-reared and wild-reared California ground squirrels show a discriminative defensive response to their natural predator, Pacific rattlesnakes, as compared to Pacific gopher snakes, when first exposed to them, and this discrimination has been shown to be made on the basis of subtle olfactory cues that differentiate them (Coss et al., 1993; Poran & Coss, 1990). The same type of specificity in responding has also been demonstrated for food sources.

In contrast to specialists, generalists (humans, rats, cockroaches) can exploit any habitat. The available resources and potential predators and dangers, however, differ drastically across environments. Therefore, it is not adaptive to have predetermined olfactory responses to potential prey or predators, but rather to be especially prepared to learn associations on the basis of their significance when encountered. The best natural example of the potency of odor learning is the case of taste aversions. Rats and humans can be made to avoid a novel flavor by being made sick after consumption. For example, presenting a rat with a sweet tasting banana smelling drink and then injecting it with lithium causes avoidance of this smell thereafter (Garcia & Koelling, 1966). Similarly, children who have experienced chemotherapy after ingesting a novel ice cream flavor subsequently show clear avoidance of that flavor (Bernstein, 1978). Bartoshuk (1989) has made it clear that it is the smell, not the taste, of the substance that is responsible for the conditioned aversion response. A *tabula rasa* olfactory system also accounts for the neophobia that human infants display to most new smells until they have determined their meaning (Frank & Kalisewicz, 2000). From an evolutionarily perspective, it is therefore adaptive that the olfactory system of generalists is not predisposed to like or dislike any particular odors, but rather is especially prepared to learn and remember what to approach and what to avoid based on experience.

An important aside here is how olfaction and emotion are fundamentally related in terms of approach and avoidance mechanisms. Olfactory information is inherently about what is good to approach or bad to avoid. Emotions also tell mammals, particularly humans, what is good to approach and what is bad to avoid. Just as odors impart information critical to survival (e.g., prey, predator, kin, etc.), positive emotions, such as joy, are appetitive and are ultimately correlated with greater reproductive success, whereas negative emotions such as fear lead to avoidance and hopefully not to the end of reproductive success! The fact that both olfaction and emotion have the same functional significance, in tandem with the uniquely direct neuroanatomical connection between the olfactory system and the amygdala (Aggleton & Mishkin, 1986) suggests that there is a fundamental linkage between emotion and olfaction that no other sensory system shares.

At least two caveats to the assertion that all olfactory hedonic responses are learned must be mentioned. One is the issue of trigeminal stimulation. Trigeminal stimulation is responsible for the tactile (burning, cooling) and irritating component of odor perception. Although the trigeminal system is separate from the olfactory system, subjective experience is not distinct and thus it is often very difficult to dissociate the olfactory from the trigeminal aspects of a scent (e.g., gasoline). Odors vary greatly in the degree to which they stimulate the trigeminal nerve and in many cases this aspect is negligible (Doty et al., 1978). However, trigeminal odors may elicit immediate avoidance responses on the basis of their irritation. A question for further research is whether a nontrigeminal odor such as phenyl ethyl alcohol (synthetic rose scent) can be made unpleasant merely by adding a nonodorous trigeminal stimulant such as CO_2.

A second consideration is the individual variability that may exist in specific genes and pseudogenes for olfactory perception across individuals. It is known that of the 1,000 identified genes coding for olfactory receptors, only a subset of them are functional (between 300-400). It is quite likely given the variability in the number of functional genes reported that there is also variability between individuals in what those functional genes are. Thus, it may be the case that a person who likes the smell of skunk does so in part because they are missing receptors for detecting some of the more pungent volatiles, while another who is repulsed by this scent is endowed with a greater number of receptors that are keenly attuned to the mercaptan and sulphide aspects of this bouquet. Future research should investigate individual genetic differences in olfactory sensitivities as a covariate to susceptibility for odor-associative learning.

The results of our research have shown that olfactory hedonic responses can be changed through emotional associative learning. A number of new questions have been raised by this research, including a number of important methodological issues. Our study presents a first step towards a viable training and testing procedure for studying how emotional experience can modify the value of odors through conditioning. It is hoped that this research will provide a starting point both methodologically and theoretically for further exploration of the role of emotion in odor associative learning.

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Received May 23, 2003.
First revision received October 6, 2003.
Second revision received November 10, 2003.
Accepted December 29, 2003.