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Odor-associative Learning and Emotion: Effects on Perception and Behavior

Rachel S. Herz

Department of Psychology, Brown University, Providence, RI 02912, USA

Correspondence to be sent to: Rachel S. Herz, e-mail: rachel_herz@brown.edu

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Introduction

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. It has been proposed that associative learning principles can explain human perceptual and cognitive–behavioral responses to odors (Engen, 1991; Herz, 2001). Specifically, it is hypothesized that odor hedonic perception and odor-related behavior results from a learned association between an odor and the emotional context in which that odor was first encountered. The process is proposed to operate and produce effects as follows: (i) the emotion paired with an odor becomes associated to the odor and imbues it with meaning, thus influencing hedonic perception; and (ii) an odor can elicit the emotion associated with its prior exposure and have a general impact on mood and mood-related behavior. Thus, emotional odor-associative learning can explain both how odors come to be liked or disliked as well as how their presence can elicit emotion and influence thinking and behavior.

A number of studies have shown that hedonic responses to odors are learned through specific experiences. Mennella and colleagues (Mennella and Beauchamp, 1991; Mennella *et al.*, 1995) 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. Among adults, physiological fear responses were elicited by the scent of eugenol in participants who were afraid of the dentist but not fearless patients (Robin *et al.*, 1998). Moreover, there are no empirical examples of cross-cultural consensus on odor heodonic evaluation among adults (Ayabe-Kanamura et al., 1998). A striking example is how in recent research 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 *et al.*, 1999).

These examples illustrate that olfactory hedonics are learned on the basis of experience. A comparison of two studies shows how emotion is critically involved in this process. 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 and Johnson, 1978). Included in both studies was the odorant methyl salicylate (wintergreen). In the British study, wintergreen was given one of the lowest pleasantness ratings, whereas, in the US study it was given the highest. The reason for this difference is explained as follows. 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 US, the smell of wintergreen is exclusively a candy mint smell and one that only has positive connotations. Neuroanatomy further supports the proposition that our olfactory system is especially prepared to learn the significance of odors. The orbitofrontal cortex, in addition to processing olfaction, is the area of the brain critical for assigning affective value to stimuli; in other words, assigning hedonic meaning. Furthermore, the amygdala which synapses directly with the olfactory nerve is critical for emotional associative learning (Davis and Whalen, 2001).

Current experimental evidence

To test the hypothesis that olfactory hedonic responses are acquired through associative learning with emotion, we conducted two experiments that varied with regard to whether a novel ('target') odor was pre-experimentally pleasant or unpleasant and the emotional association that was linked to it was positive or negative (Herz *et al.*, 2004). Note that odor novelty prior to associative learning is important because if an odor is already familiar, it necessarily has been associated to past experiences.

In each experiment, participants were randomly assigned to an experimental group (odor + emotional association) and various control groups. Evaluations of the target odor and several 'anchor odors' (familiar odors that were not explicitly part of the association procedures) were made several times throughout the study: (i) prior to the manipulation; (ii) post-manipulation; (iii) 24 h after the manipulation; and (iv) 1 week from the start date. The results from both experiments showed that evaluation of the target odor by all participants was comparable prior to the manipulations 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 group and showed that odor perception had changed in accord with the emotional valence of the associated experience. When an 'unpleasant' target odor was paired with a positive emotional experience, subsequent evaluations of that odor were more favorable and when a 'pleasant' target odor was paired with a negative emotional experience, subsequent evaluations of that odor were more unpleasant. No such effects were seen in the control groups. These findings show that when a novel odor is paired with an emotional event, hedonic perception of that odor is altered in accord with the associated emotion. Although our study can not rule out the possibility of innate responding to odors, together with past empirical work and developmental and cross-cultural data it appears that emotion in conjunction with odor exposure is a powerful manipulator of subsequent odor preference.

In order to investigate how emotional associative learning to odors can induce mood consistent changes in behavior we first examined children (Epple and Herz, 1999). In Epple and Herz (1999), 5-year-olds were subjected to a failure–frustration manipulation in the presence of an unfamiliar ambient odor. Facial expressions at the end of the manipulation were judged as predominantly negative, thus it was inferred that the failure–frustration task had induced negative affect. After a 20 min break in an unscented area, the children were given a test of motivated behavior in the presence of either the same odor, a different odor or no odor. The test 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, or no-odor). Results revealed that performance of participants in the different-odor and no-odor groups was the same. However, children who performed the task in the presence of the same odor circled significantly fewer puppies (had lower performance scores) than participants in any other group. This decrement in test scores was presumed to be due to decreased motivation elicited by the odor–mood connection among children in the same-odor group and not a decrement in ability, as the children were randomly allocated to group and were of comparable intellectual ability. This study provided support for the hypothesis that emotional experiences can become associated to odors and when re-presented influence behavior in a mood consistent manner. However, several questions concerning the relationship between olfaction, emotional associative learning and behavior remained.

To validate the findings of Epple and Herz (1999) and explore the mechanisms involved we conducted two experiments with adults (Herz *et al.*, 2005). In experiment 1, participants experienced a frustration mood induction in the presence of an unfamiliar ambient odor and later worked on word puzzle tests in a room scented with the same odor, a different odor, or no odor. Motivation to work on the puzzles was assessed by the time participants took to complete the tests (no time limits were imposed). Puzzle accuracy was also examined. Results showed that participants in the same-odor group spent significantly less time working on the tests than participants in the other groups. Puzzle accuracy did not vary between groups. The lack of puzzle accuracy differences across conditions was predicted on the basis of the similar intellectual ability of the participants and their experience of taking tests under less than ideal mood states. However, it poses a problem for interpreting the time data as reflecting decreased motivation. To clarify the findings, experiment 2 included a puzzle-test-only control group and an emotionally neutral same-odor group. Additionally, time spent on each question of the puzzle tests was analyzed as a function of the response made to the question (correct, incorrect, left blank). It was hypothesized that the time taken on questions that participants ended up leaving blank would be most susceptible to motivational level and, hence, ambient odor condition. Experiment 2 showed that puzzle accuracy performance was independent of the manipulations, and that all participants were at ceiling. More importantly, results confirmed that the effects were due to the specific presence of an odor that had previously been associated to frustration, and not simply over-exposure. Only participants in the negative same-odor group spent less time on the tests. Moreover, the decreased time spent by participants in the negative same-odor group was restricted to difficult test problems that were ultimately left blank and thus not efficiency. In other words, lowered motivation on the puzzle tests was produced by the emotional association acquired to the ambient odor.

In sum, past studies and current empirical work provide strong experimental evidence to support the hypothesis that odor hedonic perception and odor-related behavior result from a learned association between an odor and the emotional context in which the odor was first encountered. Further research exploring the full range of emotional associations, the situations in which they can be expressed and a detailed analysis of the classical conditioning mechanisms involved in odor-associative learning are now needed.

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