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Learning to (dis)like: The effect of evaluative conditioning with tastes and faces on odor valence assessed by implicit and explicit measurements

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HIGHLIGHTS

- It is still not fully understood how food preferences are formed or may be influenced.
- We employed two evaluative conditioning paradigms, using tastes and faces.
- We were able to induce negative hedonic changes for previously neutral odors.
- Concomitant cardiovascular changes were measured.
- There was no shift in the positive direction.

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ABSTRACT

Evaluative conditioning may be an important mechanism for learning food preferences and aversions; however, in both real life and experimental settings it has not been consistently successful. The current study aimed to gain more insight into which underlying factors may contribute to a successful outcome of olfactory evaluative conditioning. Two groups of 18 participants came in on three consecutive days, and were repeatedly exposed to four novel, neutral odors (CS) coupled to varying disliked, neutral, liked, or no stimuli (taste and/or pictures, US), following a 50% reinforcement schedule, leading to 40 odor presentations per session. Liking ratings, as well as changes in the autonomic nervous system were assessed before, during and after conditioning. We were able to induce negative, but not positive, affective changes by pairing neutral odors with tastes and pictures differing in valence. Negative as well as multimodal stimuli appear to be more potent US, since they may be considered more salient. Lastly, results of the current study imply that heart rate is responsive to changes in valence of olfactory stimuli, and perhaps even more sensitive than explicit ratings of liking.

1. Introduction

Besides sensory properties (such as smell, taste and sight), previous experience greatly determines the formation of food preferences, and therefore plays an important role in shaping eating behavior. However, it is at present not fully understood how these preferences are formed and how the acquisition of likes and dislikes may be influenced or manipulated.

Associative learning is the process by which one stimulus comes to be linked to another through experience. Associative learning can occur through classical conditioning, in which a conditioned stimulus (CS) comes to signal the occurrence of a second stimulus, the unconditioned stimulus (US) [1], or through operant conditioning, in which reinforcement or punishment is employed to alter the behavioral response to a stimulus [2,3]. A hedonic form of classical conditioning is evaluative conditioning, which refers to a change in the valence of a stimulus (CS) that is due to the pairing of that stimulus with another positive (US+) or negative (US−) valenced stimulus. A large body of research on evaluative conditioning exists (see reviews by [4,5]), demonstrating effects using a wide variety of stimuli and procedures. When it comes to food preferences, two commonly used paradigms of evaluative conditioning are flavor–flavor (or odor–taste) learning, and observational learning. Flavor–flavor learning depends on the association between a neutral or novel flavor and a familiar or already liked flavor, resulting in a positive shift in preference for the first flavor (*e.g.* [6,7]). Observational conditioning occurs

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through observing the behavior of others; for instance seeing a model drinking a beverage and facially expressing his/her like or dislike may change the valence of that product for the observer [8,9]. Evaluative conditioning is thus a possible manner in which likes and dislikes can be learned and may explain human perceptual and behavioral responses to foods, tastes and smells (*e.g.* [10–12]).

Whereas basic taste hedonics are fairly stable [13], odor preferences are considered to be subject to change. Various studies have shown the impact of visual or verbal information on the perception and pleasantness of odors [14–17]. Also, cultural differences can affect familiarity, identification and pleasantness ratings for odors *e.g.* wintergreen [18–20], indicating that previous experiences shape how we perceive and evaluate odors.

Since olfactory cues are a key factor in the anticipation of food consumption [21], they can have an important role in modulating food preferences. Though ample studies have looked at hedonic effects of evaluative conditioning before (see reviews by [4,5]), only a subset of those have used olfactory stimuli [7,22–31] to gain insight into the acquisition of preferences and aversions related to eating behavior, and with varying results. While an initial study [28], showed promising results for flavor–flavor conditioning, in that flavored herbal teas increased in pleasantness when they had been previously paired with sucrose (liked, sweet taste), this could not be confirmed by other groups [24,25,29]. Only recently, Yeomans and colleagues were able to replicate the increase in liking for flavors paired with sweet tastes, but only in a subset of participants (*e.g.* sweet likers, disinhibited participants, or in a hungry state) [7,26,27]. Moreover, review papers have by now questioned the practical validity and occurrence of evaluative conditioning in humans, in real life and lab settings [32,33]. Given the important role that evaluative conditioning might play in shaping ones' eating behavior, it is vital to understand if and how this works in various settings, and subsequently, which underlying factors, such as type and novelty of the CS, liking of the US, or temporal contiguity, may contribute to a successful outcome.

The current study is aimed to gain more insight in the factors and study parameters involved in olfactory evaluative conditioning, by using repeated exposure of novel, (initially) neutral odors coupled to varying disliked, neutral or liked stimuli, under strictly (time-)controlled circumstances and a selected group of participants. Furthermore, since previous studies have shown that odors of different valence or arousal are able to elicit differential responses by the autonomic nervous system [34,35], both implicit measures of liking, such as concomitant (unconscious) changes in the autonomic nervous system and explicit measures of liking will be assessed to be able to measure even subtle hedonic changes.

2. Materials and methods

2.1. Study design

The study was designed to measure changes in hedonics of odor stimuli after repeated exposure coupled to aversive, neutral or appetitive stimuli, or without reinforcement (mere exposure) as control condition. This was achieved by using an olfactory version of an evaluative conditioning paradigm, in which a neutral stimulus (the conditioned stimulus (CS)) acquires valence due to the repeated pairing with another valenced item (the unconditioned stimulus (US)). The current study employed two conditioning methods that differed in the kind of unconditioned stimuli used (taste stimuli *versus* taste and visual stimuli combined).

On the first day, testing consisted of a pre-conditioning and conditioning session. The second testing day consisted of a conditioning session only. On the third day, testing consisted of a conditioning and post-conditioning session, followed by de-briefing.

Explicit liking scores, preference ranking, and implicit physiological measures (sniff magnitude, instantaneous heart rate (HR), electrodermal activity (EDA), and skin temperature) were collected during, before and after conditioning to examine changes in olfactory hedonics of the CS within each experimental method.

2.2. Stimuli

2.2.1. Odor stimuli

Odor stimuli were carefully selected to be relatively novel and neither particularly pleasant nor unpleasant before conditioning (see Tables 1 and 2), in order to maximize the possibility to become positive or negative after conditioning. Furthermore, odor concentrations, presented as a percentage of the full-strength extract, were set at a low but detectable level to further increase novelty and, based on preceding pilot work, were approximately matched for intensity. The selected odor stimuli were: Aloe Vera (0.4% v/v), Chinotto (0.2% v/v), Coriander (0.2% v/v), Honeysuckle (0.4% v/v), Oolong tea (0.2% v/v), Sanddorn (0.04% v/v), White tea (4% v/v), and Woodruff (0.2% v/v) (International Flavors and Fragrances, Hilversum, the Netherlands). White tea and Aloe Vera were diluted in propylene glycol, all other odors in water. Per subject, a subgroup of 4 odors that were individually rated as neutral (*i.e.* a score of >-2 and <2 on a 9-point scale ranging from -4 "extremely unpleasant" to 4 "extremely pleasant") was used in the experiment.

2.2.2. Taste stimuli

Taste stimuli consisted of a liked sweet solution (individually selected from five concentrations of sucrose dissolved in water, ranging between 1.8 and $5.6 \cdot 10^{-2}$ M), a disliked bitter solution (individually selected from five concentrations of quinine monohydrochloride dehydrate dissolved in water, ranging between $1 \cdot 10^{-3}$ and $1 \cdot 10^{-5}$ M), and a neutral control stimulus (water). The concentrations of sweet and bitter solutions were individually determined based on subjects' pleasantness and intensity ratings. Concentrations were chosen that were most similar in hedonic strength (*i.e.* strength of response irrespective of positive or negative direction) and intensity.

2.2.3. Visual stimuli

Visual stimuli consisted of pictures of facial expressions taken from the Karolinska Directed Emotional Faces (KDEF) collection [36]. Based on preceding pilot work, a total of 60 pictures were selected that best conveyed liked, neutral, and disliked attitudes, 20 for each category.

Table 1
Liking scores before and after conditioning for odors coupled with positive, neutral, or negative US or without reinforcement (mere exposure) for the "Odor-Taste" and "Odor-Picture-Taste" method. Significant changes ($p < 0.05$) are highlighted in bold.

	Odor–Taste				Odor–Picture–Taste			
	Liking scores (mean ± SD)		rm-ANOVA		Liking scores (mean ± SD)		rm-ANOVA	
	Pre-conditioning	Post-conditioning	F	p	Pre-conditioning	Post-conditioning	F	P
Mere exposure	51.4 ± 18.5	49.1 ± 16.9	.68	.42	56.8 ± 13.8	58.9 ± 12.8	.34	.57
Positive	60.8 ± 10.4	59.9 ± 17.3	.07	.80	59.8 ± 15.9	59.9 ± 15.6	.002	.97
Neutral	57.8 ± 14.7	58.0 ± 14.9	.005	.95	54.2 ± 19.3	54.4 ± 17.6	.002	.97
Negative	62.2 ± 12.0	57.5 ± 15.5	2.78	.11	**56.5 ± 13.8**	**50.1 ± 15.5**	**4.73**	**.04**