From Hate to Love: How Learning Can Change Affective Responses to Touched Materials

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Abstract. People display systematic affective reactions to specific properties of touched materials. For example, granular materials such as fine sand feel pleasant, while rough materials feel unpleasant. We wondered how far such relationships between sensory material properties and affective responses can be changed by learning. Manipulations in the present experiment aimed at unlearning the previously observed negative relationship between roughness and valence and the positive one between granularity and valence. In the learning phase, participants haptically explored materials that are either very rough or very fine-grained while they simultaneously watched positive or negative stimuli, respectively, from the International Affective Picture System (IAPS). A control group did not interact with granular or rough materials during the learning phase. In the experimental phase, participants rated a representative diverse set of 28 materials according to twelve affective adjectives. We found a significantly weaker relationship between granularity and valence in the experimental group compared to the control group, whereas roughness-valence correlations did not differ between groups. That is, the valence of granular materials was unlearned (i.e., to modify the existing valence of granular materials) but not that of rough materials. These points to differences in the strength of perceptuo-affective relations, which we discuss in terms of hard-wired versus learned connections.

Keywords: Haptics · Valence · Affect · Roughness · Granularity · Learning

1 Introduction

We constantly interact with various materials like plastic, fabric, or metal. Haptic perceptual properties of materials have been summarized by five different dimensions [1] that are softness (but cf. [2]), warmness, micro- and macro roughness, friction, and stickiness. In addition to the sensory properties that we experience while haptically exploring a material, we often also have an initial affective reaction to it. Moreover, the

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affective reactions that a material elicits might also influence the duration of our haptic interactions. For example, soft and smooth materials, which cause more pleasant feelings than rough and sticky materials [3–6], might be explored longer.

Previous research on the semantic structure of affective experiences postulates three basic affective dimensions [8]: valence, *arousal*, and *dominance,* where each dimension has two opposite poles [9]: arousal ranges from a very calm state and sleepiness (low) to vigilance, which is accompanied by excitement (high). Valence is a continuum from negative to positive and dominance ranges from dominant to submissive. Most of the research in haptic perception has focused on the connection between pleasantness (which can be equated with valence) and the perception of sensory dimensions. One key finding has been that smooth and soft materials are related to more pleasant feelings than rough materials [10], and that the rougher a material is rated, the more unpleasant it feels [10]. In a more recent study [11], all three basic affective dimensions and their relationship with materials' sensory characteristics have been systematically investigated: Drewing et al. [11] used a free exploration paradigm to study the sensory and affective spaces in haptics and tested the generalizability of their results to different participant groups. They found that arousal was related to the amount of perceived fluidity, that higher dominance as associated with increases in perceived heaviness and decreases in deformability, and that greater positive valence was associated with increased granularity and decreased roughness.

It is currently unknown to what extent such perceptuo-affective connections are due to learning experiences and to what extent they are hard-wired, innate mechanisms. Here we investigated directly whether existing relationships between sensory material properties and affective responses can be unlearned, and whether the extent of unlearning depends on the specific perceptuo-sensory relation, for two haptic perceptual dimensions: granularity and roughness. We speculate that hard-wired connections should be more resistant to unlearning than learned ones.

We ran a classical conditioning study that constisted of two phases: learning and experimental phases with two groups each (experimental and control). In the learning phase, participants haptically explored selected materials while watching affective images: In the experimental group rough materials were combined with positive images, granular materials with negative images and distractor materials with neutral images. In the control group participants learned instead associations of fibrous and fluid materials with arousal, which were however not subject of this paper and will not be further discussed. In the experimental phase, participants rated a representative set of 28 materials for 12 affective adjectives. We calculated perceptuo-affective correlations for valence-roughness and valence-granularity relationships per group and compared these correlations between groups. Lower correlations for the participants in the experimental group would indicate an unlearning of the relationship between valence and the respective perceptual dimension.

2 Methods

2.1 Participants

Sixty-six students (9 males; age 18–34 years, mean: 23.5 years) from Giessen University participated in our study. Four were excluded from analysis due to misunderstanding the task, technical error, or an increased threshold in the two-point touch discrimination (>3 mm at index finger). All participants were naïve to the aim of the experiment, spoke German at native-speaker level, and none reported relevant sensory, or motor impairments. All procedures were in accordance with the Declaration of Helsinki (2008), and participants provided written informed consent prior to the study.

2.2 Setup, Material, and Adjectives

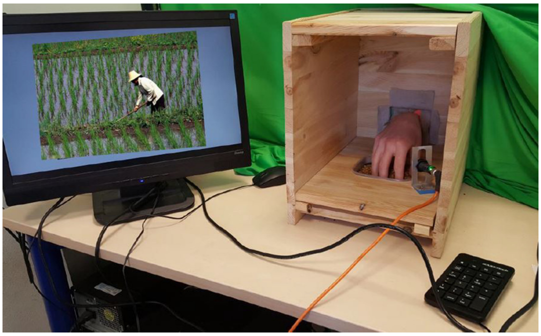

Fig. 1. Experimental setup from the experimenter's viewpoint.

Participants sat at a table in front of a big wooden box with a hand opening. Materials were presented in the box (see Fig. 1). Participants reached the materials through the hand opening, which was covered with linen to hinder participants to look inside the box. On a monitor (viewing distance about 60 cm) we presented images (visual angle 14.2°) and adjectives to the participant. Earplugs and active noise cancelling headphones (Beyerdynamic DT770 PRO, 30 O) blocked the noises that can occur from exploring the materials. All materials were presented in 16 × 16 cm plastic containers embedded in the bottom of the box. A light sensor in the box signaled when the participant's hand was on the front edge of the container, allowing to start picture presentation simultaneously to haptic exploration. Participants gave responses using a keyboard. The experimenter sat on the other side of the table in order to exchange materials guided by information presented on another monitor.

For the learning part of the experimental group, we selected materials from [11] which had a high factor value on one of the target sensory dimensions (either granularity or roughness) but did not show high factor values in any of the other dimensions (fluidity, fibrousness, heaviness, deformability). Bark and sandpaper were selected for roughness, and salt and lentils for granularity. In the control group other materials were used (jute, wadding, water, shaving foam). Additionally, for both groups (experimental and control) we added four distractor materials, which did not have high factor values on the manipulated dimensions: cork, chalk, paper, and polystyrene. We also the sensory and affective adjectives were obtained from [11]; one to two representative adjectives per sensory dimension (rough, granular, moist, fluffy, heavy and light, deformable and hard). In the learning phase, sensory ratings served to draw the participant's attention to the materials.

For establishing affective-sensory associations we used images from the International Affective Picture Systems (IAPS). The IAPS database includes 1196 colorful images of various semantic contents, that have been rated according to valence, and arousal [12, 13]. For the experimental group, we selected sixteen images with high negative valence (<2.5) and sixteen images with high positive valence (>7.5), and as diverse content as possible (excluding drastic injury images). For the control group, we used images with high or low arousal instead. We also selected 32 distractor images, which have average valence and arousal values (between 4.5 and 5.5).

In the experimental phase, participants rated 28 materials (plastic, wrapping foil, aluminum foil, fur, pebbles, playdough, silicon, paper, styrofoam, paper, sandpaper, velvet, jute, silicon, stone, bark, flour, metal, cork, polish stone, oil, shaving foam, soil, hay, chalk, salt, lentil). We assessed affective responses via adjectives and selected four high loading adjectives per affective dimension: *valence* (pleasant, relaxing, enjoyable, and pleasurable), *arousal (*exciting, boring, arousing, and attractive) and *dominance* (dominant, powerful, weak, and enormous/tremendous).

2.3 Design and Procedure

Participants were randomly assigned to either the experimental or the control group. In the learning phase of the experimental group, we coupled the exploration of the two very rough materials with positive images and the granular materials with negative images, in order to manipulate valence. In the control group, different materials were explored and coupled with different images.

The learning phase consisted of 64 trials: in the experimental group, each of the two granular materials was presented eight times coupled with one of the 16 negative images, and each of the two rough materials was coupled 8 times with one of the positive images. Also, each of the four distractor materials (cork, chalk, polystyrene, and paper) was presented eight times with a distractor image. Both, the assignment of corresponding images to materials and the order of presentation, were random.

In each trial of the learning phase (Fig. 2), an initial beep sound signaled the participant to insert the hand in the box and to start exploring the material. When participant's hand started the exploration, an image was displayed on the screen. Participants explored the materials while looking at the images for five seconds. Another beep sound signaled participants to end the exploration, and a randomly chosen sensory adjective appeared on the screen. Participants rated how much the adjective applied to the material (1*: not at all*, 4: *maybe*, 7: *very*) using a keyboard. Finally, a multiple-choice question about the main content of the image was posed. The experimenter exchanged the stimuli between trials. In total, the learning phase took about 30 min.

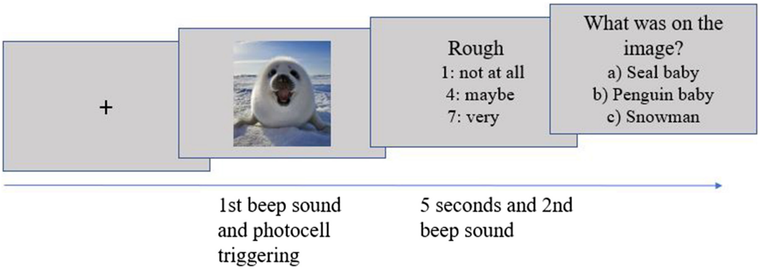

Fig. 2. Time course of one trial of the learning phase.

The experimental phase consisted of 336 trials (28 materials × 12 adjectives). Each trial started with a fixation cross on the screen (Fig. 2). Then participants reached in the box with their dominant hands and explored the material. During exploration each of the 12 affective adjectives appeared on the screen (in random order), and participants had to rate how much each adjective applied to the material (1–7). The hand was retracted, and the material exchanged after the all twelve adjectives were evaluated. The total duration of the experiment including learning phase, instructions, preparation, pauses for cleaning hands and debriefing was about 2–2.5 h.

2.4 Data Analysis

We first assessed the number of correct responses from the multiple-choice questions of the learning phase. With an average of 96.2% correct (individual minimum: 84.4%), we could verify that all participants had attended to the images as they should. Next, we used the affective ratings from the experimental phase in a covariance-based principal component analysis (PCA) with Varimax-rotation (for all adjective ratings across all materials and participants) in order to extract underlying affective dimensions. Before doing so, we assessed whether the PCA was suitable by a) checking the consistency across participants by calculating Cronbach's alpha for each affective adjective (separately for experimental and control group), b) computing the Kaiser-Meyer-Olkin (KMO) criterion, c) using Bartlett's test of sphericity [11].

Lastly, in order to test a potential unlearning of the perceptuo-affective relationships valence-roughness and valence-granularity, we determined material-specific individual factor values of the valence dimension. We calculated individual correlations of these values with previously observed average granularity and roughness values across materials (taken from Exp. 2 in [11]), and used two independent samples t-tests in order to compare the two perceptuo-affective Fisher-z transformed correlations of experimental and control group.

3 Result

3.1 PCA on Affective Dimensions

Cronbach's alpha was higher than .80 per adjective and participant group, indicating good consistency between participants. Bartlett's test of sphericity was statistically significant, □2(66, $N = 28$) = 12868.897, $p < .001$, and the KMO value, which has a range from 0–1, was 0.86 [14]. Given these results we proceeded with the PCA.

The PCA extracted three components according to the Kaiser criterion, explaining 73.1% of the variance in total. After the varimax-rotation, the first component explained 31.8% variance with the highest component loads obtained from the adjectives pleasant (score: 1.8), relaxing (1.8), enjoyable (1.5), and pleasurable (1.8). Thus, we identified this component as *valence*. The second component explained 22.4% variance with high loads from adjectives dominant (1.6), powerful (1.6), weak (−1.1), and enormous/tremendous (1.6); consequently, we called this component dominance. The last component explained 18.9% variance with high loads from exciting (1.4), boring (1.5), arousing (0.7), and attention-attracting (1.5), and therefore we labeled it arousal. All other component loads of any adjective had an absolute value below 0.7 and where thus not considered in the interpretation.

3.2 Learning Effects on Materials

For the control group ($N = 30$), correlations between roughness and valence, $r = -.37$, $p < .001$ and granularity and valence, $r = .25, p < .001$ were statistically significant after Bonferroni correction, confirming the basic perceptuo-affective relations previously observed in [11]. In order to test the effect of unlearning perceptuo-affective relationship, we compared the Fisher-z-transformed correlations of the two groups (Fig. 3).

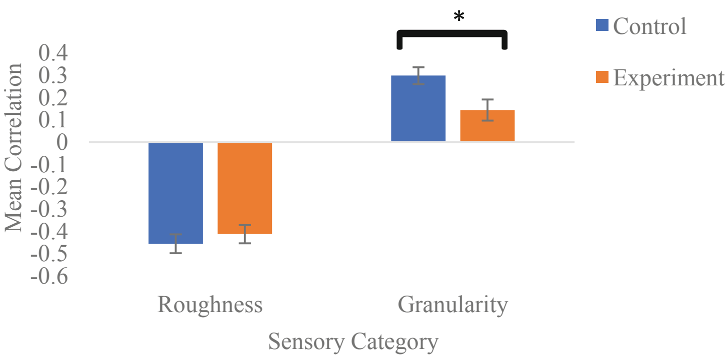

Fig. 3. Relationship between sensory category and valence for experimental (orange) and control group (blue). It shows mean correlations (inverse of average Fisher z-transforms) as a function of sensory category (roughness and granularity). Error bars show 1 ± standard errors (*Significant $p < .05$ level). (Color figure online)

There was not a statistically significant difference between experimental ($M = -.41$, $SD = .21$) and control ($M = -.46$, $SD = .23$) groups, t (60) = .763, $p = .449$ for the valence-roughness correlation. However, there was a statistically significant difference between control ($M = .30$, $SD = .23$) and experiment ($M = .14$, $SD = .26$) groups, t (60) = −2.461, $p = .017$ for the valence-granular correlation.

4 Discussion

People experience rougher materials as more unpleasant, and more granular materials as more pleasant [11]. Here we investigated whether brief learning experiences can influence the affective assessments of these two material properties. Our aim was to modify previously found affective responses towards granular and rough materials, and we found, that the perceptuo-affective correlation between granularity and valence was lowered through learning in the experimental group compared to control group. However, the valence-roughness relation was not significantly different in experimental and control group, suggesting that this connection could not be unlearned. We suggest that these results demonstrate different strengths in the perceptuo-affective connections, which relate to the degree to which connections are learned during lifetime vs being evolutionary prepared to serve a biological function.

Studies on fear conditioning suggest that some classes of stimuli are phylogenetically prepared to be associated with fear responses, while others can be hardly learned. For example, it has been shown that lab-reared monkeys easily acquire fear of snakes by observing videos of the fear that other monkeys had shown - even if they had never seen snakes before in their lives [15]. When these videos were reproduced to create similar fear against toy snakes, crocodiles, flowers, and rabbits, lab-reared monkeys showed fear against snakes and crocodiles, but not flowers and rabbits [16]. Because these monkeys had never been exposed to the stimuli before, this can be taken as evidence for a phylogenetic basis of selective learning. Furthermore, in humans, researchers observed superior fear conditioning to snakes when compared to guns with loud noises [17], which also supports the idea of phylogenetically based associations for snakes and fear.

Natural rough materials, such as rocks or barks, could be harmful because of their surface structure they could potentially break the skin. Therefore, an association of those materials with feelings of unpleasantness could be prepared in our nervous system, which would make it difficult to associate those materials with positive valence. In contrast, granular materials that are present in our environment such as sand, generally do usually not pose a danger. Thus, their associations with valence are probably not evolutionary driven. This might explain why we seem to be more flexible in associating granularity with positive or negative valence than associating roughness with positive valence. This flexibility is evident in our results since participants in the experimental group learned to associate granular materials with negative valence. We conclude that even brief learning experiences can change perceptuo-affective connections depending on the source and strength of the relationship. In the current case, the valence of granular materials was unlearned but not that of rough materials. This might mean that perceptuo-affective connections for granular materials are learned, yet for rough materials they might be hard-wired or at least prepared.

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