# Sniff Before You Act: Exploration of Scent-Feature Associations for Designing Future Interactions

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**Abstract.** It has long been known that our sense of smell is a powerful one that affects emotions and behaviors. Recently, interest in the sense of smell has been growing exponentially in HCI. However, the potential of smell to inspire design is still underexplored. In this paper, we first investigated crossmodal correspondences between scents and selected features relevant for design (clustered in sensory, bodily, and qualitative features). Then, we created a set of cards (EssCards) to visually summarize the key findings to inspire designers. We carried out two preliminary design exploration sessions using the EssCards. Based on our findings, we discuss how to inspire and challenge design opportunities around the sense of smell and reflect upon applications for smell as inspirational material for designing future interactions and experiences.

**Keywords:** Sense of smell, scents, crossmodal correspondences, cross-sensory associations, multisensory design, design interaction, body image.


Figure 1. First, we asked participants to sniff and associate scents with features relevant for design (based on crossmodal correspondences). Then, we visualized the results through a set of cards (EssCards). Finally, we organized two preliminary design exploration sessions using the EssCards to ideate a multisensory garment.

## 1 Introduction

"Good design looks great, yes—but why shouldn't it also feel great, smell great and sound great" [33]. This is how the designer Lee Jinsop encourages design thinking that involves all five senses. In the past decades, the design of products and interactive systems has predominantly used limited sensory channels, with vision as a leading modality [11]. However, there is a growing awareness that the other senses also play an important role in making experiences more compelling [47]. Indeed, Schifferstein [46] has suggested that "designers who intentionally try to create specific experiences are more likely to succeed if they are aware of each sensory channel's contribution to the overall experience".

While there are growing efforts in designing for all the senses in HCI [40, 48], we have only recently started to understand the vastness of the design opportunities, especially when it comes to our sense of smell. Compared to other modalities, smell plays an important role in our emotions and memories and can evoke more emotionally loaded and vivid experiences [25]. Despite increasing efforts in the area of design, smell is often considered as an "add-on", rather than a starting point for design. One reason for the sense of smell being considered a secondary sense [48] lies in its complexity to work with (e.g., control over scent stimuli, subjective variability). In this paper, we explore the role of smell as inspirational material for designing future interactions (see in Figure 1).

As a first step in our investigation, we focused on the growing research in crossmodal correspondences, which refer to how "a sensory feature, or attribute, in one modality, can be matched (or associated) with a sensory feature in another sensory modality" [51]. We conducted a user study to explore crossmodal correspondences between different scents and selected sensory, bodily, and qualitative features, along with emotions, intensity, and verbal descriptors for each scent. We then summarized the key findings for each scent in a set of cards, called EssCards. The EssCards were designed with the aim of translating the findings into an accessible format that designers are familiar with and can use as inspiration for their design explorations. We organized two design exploration sessions to gain initial insights into the use of the EssCards in a design context. Based on our findings, we conclude by discussing emerging opportunities around designing future interactions based on smell.

Overall, the contribution of this work is three-fold. First, with our user study we revealed new insights into scent–feature associations (i.e., sensory, bodily, and qualitative features) advancing existing research on crossmodal correspondences to stimulate smell-inspired design. Second, we visualized our findings in the form of a set of cards (EssCards), as inspirational material for designers and anyone interested in the exploration of smell in the design of future interfaces. Our two design explorations exemplify possible uses of our study results using the EssCards. Third, we discuss future avenues for novel olfactory interaction and experience design.

Readers can find additional materials for each part of our work (from the scent–feature associations to the design explorations) in a dedicated Supplementary Material document that also includes the visualizations for all twelve EssCards.

## 2 Related Work

In this section, we review pertinent related work focused on the relevance of smell for HCI, multisensory design, and crossmodal correspondences (CCs) between scents and other senses and features relevant for design.

### 2.1 The Relevance of Smell in Design

Smell is a powerful sense that influences how we experience ourselves and the world around us [54, 56]. While smell is often considered a secondary sense [48], emerging research suggests that we use it more than we think. For example, previous work has shown that humans have scent-tracking abilities similar to dogs [42] and can detect emotions through the olfactory channel [59] (e.g., fear [14]). Moreover, prior studies show that scents not only regulate behavior [54] and evoke pleasant or unpleasant experiences [20], but also modulate mood [59], attention [29], stress [37], and memories [25].

Supported by this evidence, the sense of smell is gaining increasing attention in several design contexts. For example, in the context of wearable design [7, 22, 57], Essence [2] and Bioessence [1] are necklaces that release scents based on biometric or contextual data (e.g., heart rate and respiration). Most recently, Wang et al. [58] designed on-face olfactory wearable interfaces that are lightweight and can be adhered to the skin or attached to face accessories. These efforts are further extended towards multisensory design [46]. Most recently, Maggioni et al. [35] identified four key design features to guide smell-based experience design in HCI (i.e., chemical, emotional, spatial, and temporal features). This suggests that, in the imminent future, single-use case solutions and frameworks will become a rich ecosystem of smell-based applications and experience design. Those prior works demonstrate that smell is gaining increasing attention within HCI and the design community.

However, despite those efforts, smell is commonly considered as just an "add-on" to enhance and augment experiences, rather than inspirational material for designing future interactions and experiences. To guide smell-inspired design, we build upon the growing evidence in CC research, which has emerged from experimental psychology [51].

### 2.2 Smell and Crossmodal Correspondences

A growing body of research in experimental psychology and sensory science is showing that people exhibit consistent CCs between many stimulus-features in different sensory modalities. In this section, we provide an overview of previous work in CC research in relation to smell [52]. We have clustered the work according to the three features most relevant to the contribution made in this paper: sensory, bodily, and qualitative.

**Smell and Sensory Features.** Features including visual shapes, sound, temperature, and texture have previously been studied in relation to the sense of smell in CC research, and are recognized as relevant design targets in HCI [31].

*Visual Shapes*. Hanson-Vaux et al. [24] have found CCs between scents and visually displayed shapes. They presented participants with visual analogue scales (VAS) with spiky and rounded shapes as anchors and found that unpleasant and intense scents were associated with spiky shapes, while scents rated as pleasant and less intense were associated with rounded shapes. Kaeppler et al. [28] corroborated the same associations following the "kiki-bouba" paradigm [50]. Moreover, Jezler et al. [27] focused their work on the effect of scented materials on participants' physical creations, showing that lemon-scented sculptures have a higher number of spikes than vanilla-scented sculptures.

*Sound*. Belkin et al. [5] asked participants to match auditory stimuli that varied in high or low pitch with scents from different categories (e.g., citrus, woody, floral). Their results suggest that scent–sound associations are due to fragrance type and pleasantness. Later, Crisinel et al. [12] studied CCs between scents, four different musical instrument samples, and varying pitches. Their results show consistent CCs between scents, pitches, and musical instruments. For example, fruity scents were consistently associated with high pitch.

*Temperature*. Wnuk et al. [61] examined scent–temperature associations in three cultures (Maniq, Thai, and Dutch). Participants matched fifteen scents to temperature by touching cups filled with hot or cold water. The results show that some scents are associated to temperature but that there is a cultural variation in those associations, arguing against their universality. Brianza et al. [10] used VAS to explore associations between three scents and "hot" and "cold" words visually displayed as anchors. However, no significant results were found. Furthermore, Krishna et al. [32] have explored whether the congruence between scents and temperature enhances haptic perception and product evaluation. They found an interaction effect between temperature and scents, i.e., the scent rated as cold led to significantly more positive evaluations of a cold gel-pack than the scent rated as warm, and vice versa.

*Texture.* Demattè et al. [16] have assessed scent-texture associations. Participants were asked to rate the softness of fabric swatches while presented with three scents. They showed that fabric swatches were judged softer in the presence of a pleasant scent compared to an unpleasant scent. Meanwhile, Krishna et al. [32] have explored associations of smell and texture in relation to gender (i.e., masculinity–femininity). They found mutual agreement on rating smooth paper as feminine and rough paper as masculine. Moreover, for the smooth paper, the feminine scent was perceived as more congruent than the masculine scent, and vice versa.

**Smell and Bodily Features.** Recently, it has been shown that the perception of our own body can be influenced by smell [10, 60], which becomes increasingly relevant in the wider context of wearable design [7, 22, 57]. From prior work, we have selected two relevant features that explore the relationship between smell and the body: body silhouettes (i.e., 2D body silhouettes, thin–thick) and gender (i.e., masculinity–femininity).

*Body Silhouettes.* Brianza et al. [10] have studied the concept of body image perception (BIP) through the VAS paradigm by exploring CCs between lemon and vanilla scents and 2D body silhouettes as a visual representation of different body types. They found associations between lemon scent and thin body silhouettes and between vanilla scent

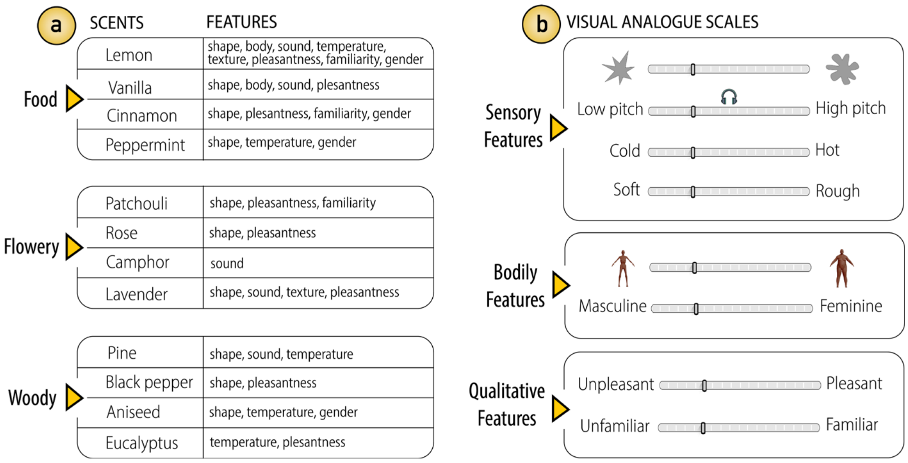


Figure 2. (a) Scents selected, based on prior CC research. (b) VAS employed in our study.

and thick body silhouettes. They also combined scents with sound to explore the relation between the same scents and the sound of participants' footsteps (increasing and decreasing pitch from low to high). They found that during the condition combining lemon scent and the sound of high-pitched footsteps, participants walked faster and felt lighter, in comparison with vanilla scent.

*Gender:* Kaeppler et al. [28] have explored associations between scents and gender-related features (masculinity–femininity) to investigate color–scent correspondences for fragrances marketed as masculine, feminine, or neutral. They have revealed that the way people think of a fine fragrance (i.e., masculine or feminine) influences the color associated to the fragrance. Moreover, Krishna et al. [32] have used the association between masculinity and femininity and scents to determine a possible association between smell and texture. They found that both scents and haptic experiences can have semantic associations in terms of gender, and the congruence of these semantic associations led to more positive perceptions.

**Smell and Qualitative Features.** Here, we review studies that account for the subjective experiences elicited by olfactory stimuli focused on two standard dimensions – pleasantness and familiarity. The perceived pleasantness and familiarity of an olfactory stimulus are mostly used to describe the subjective qualities of an odor [41].

Many studies have shown a variability in the ratings of those dimensions within and between participants for a given scent [18], and it has also been demonstrated that these dimensions are not independent [15]. Especially, a positive correlation between pleasantness and familiarity has been shown in prior literature [6, 18, 21, 45, 53]: the more familiar a scent is, the more pleasant it is rated. Indeed, studies previously cited for investigating different CCs also focused their research on familiarity with the scents [24, 28, 32, 63]. For example, in [12] it was found that the identification of the stimulus influences the ratings of familiarity and pleasantness: participants were better able to name the scents that they rated as more familiar. Correctly identified stimuli were also rated as more pleasant. This finding is in line with previous results concerning correlations between pleasantness and the familiarity ratings of scents (e.g., [18]).

**Summary and Opportunity for Extending Scent–Feature Associations.** The above subsections on CC research around sensory, bodily, and qualitative features highlight the growing interest and knowledge in associations between scents and other sensory features and attributes, including the expansion towards the body (bodily features) and the subjective dimensions of smell experiences (qualitative features).

While we can build on this existing CC research within HCI, there is, however, no comprehensive body of knowledge that has combined and studied all of the above-described sensory, bodily, and qualitative features with regards to a defined set of scent stimuli. Thus, we only have a fragmented picture of the scent–feature associations we could use to explore the role of smell in design applications. To overcome this limitation, we first conducted a systematic user study to establish a dataset on scent–feature associations, based on the features and scents identified in prior work (see an overview in Figure 2).

## 3 User Study on Scent–Feature Associations

To enrich the established set of scent–feature associations that already exists in the literature to possibly inspire future design interactions, we designed a user study to investigate CCs between a selection of scents (see Figure 2a) and a selection of features (see Figure 2b) described in the previous section. Thus, we aimed to extend prior work and create a more comprehensive set of CCs between scents and different features.

### 3.1 Selection of Scents and Features

We selected twelve scents for our study, identified through the review of prior works on CCs (see section 2.2). To facilitate future design choices, and influenced by the work of Belkin et al. [5] in which the stimuli were drawn from several fragrance categories (e.g., flowery, woody, citrusy), we wanted to cluster scents with similar features, as commonly done for other senses (e.g., environmental vs animal sounds, etc.).

We clustered each of the scents into one of three categories (i.e., food, flowery, and woody categories, with equal numbers of scents). Moreover, having more than one scent in each category enables the enrichment of personalization and customization in future design explorations (i.e., if one scent is disliked, another one from the same category can be selected). The scents of lemon, vanilla, cinnamon, and peppermint were clustered into food-related scents, while patchouli, rose, camphor, and lavender were grouped under flowery scents, and pine, black pepper, aniseed, and eucalyptus were clustered under woody scents. As scent stimuli, we used 100% undiluted natural essential oils from Holland & Barrett [3]. All the bottles containing the essential oils were anonymized for participants, and any link between the scents and their labels was removed.

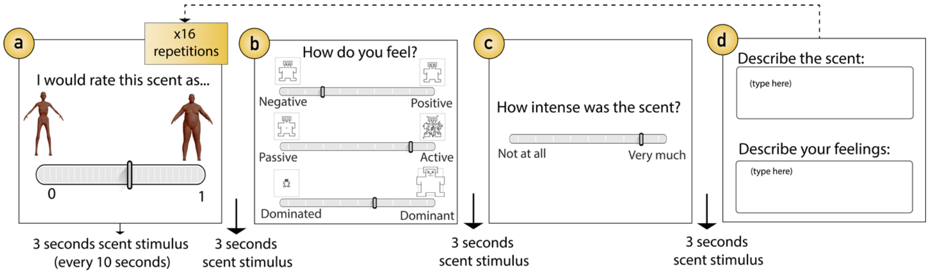


Figure 3. Measures used: (a) example of VAS. (b) SAM for emotion assessment. (c) Intensity assessment. (d) Open questions. Scent stimuli were presented for 3s, every 10s during the presentation of the VAS (a), and for 3s at the beginning of b-d.

It is worth noting that all the selected scents are considered pleasant. We did not consider unpleasant scents for this first attempt to explore the role of smell as inspirational material for designing future interactions and experiences. We wanted to create a pleasant initial experience to foster the potentials of smell in the wider context of multisensory design.

Eight bipolar features were clustered in sensory, bodily, and qualitative features, as shown in Figure 2b. As sensory features, we selected spiky versus rounded visual shapes [24, 27, 30], low- versus high-pitched sound [5, 12], cold versus hot temperature [32, 61], and soft versus rough texture [16, 32]. As bodily features, we selected thin versus thick body silhouettes [10] and masculine versus feminine gender [28, 32]. Finally, as qualitative features, we selected high versus low pleasantness [1, 7] and high versus low familiarity [24, 32].

### 3.2 Study Design

The study followed a within-participant design composed of two sessions that took place on two different days, in order not to overstimulate participants when presented with a total of twelve scents. In each of the two sessions, participants were presented with six of the twelve tested scents, counterbalanced across participants. Each session lasted 25 minutes and took place in a controlled study environment. Participants were provided with an information sheet and a consent form upon their arrival. The study was approved by the local university ethics committee. Below, we provide details on the measures used and the specific details on the study setup and procedure.

### 3.3 Measures

As shown in Figure 3, for each of the twelve scents, we assessed (a) CCs through the use of visual analogue scales (VAS); (b) the main three emotion dimensions (valence, arousal, dominance) using self-assessment manikin (SAM) scales [9]; (c) intensity using a Likert scale; and (d) subjective descriptors through open question boxes.

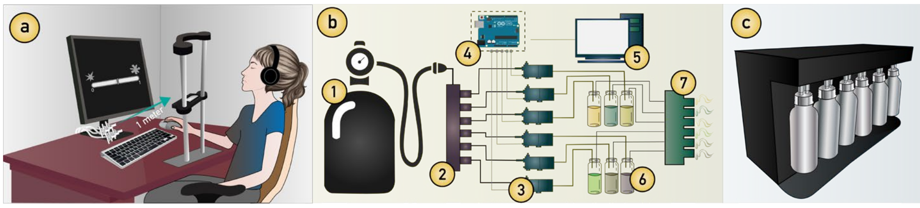

Figure 4. (a) Experimental setup. The distance between the output nozzle and each participant's nose was kept constant at 1m using a chinrest. (b) Structure of the scent delivery system: 1. air tank, 2. manifolds, 3. electric valves, 4 Arduino board, 5. PC, 6. bottles with the essential oils, 7. output nozzle with six individual channels; (c) Six bottles containing the essential oils.

**Visual Analogue Scale (VAS).** The VAS has been widely employed in the literature to study CCs [5, 10, 24, 36, 55]. In our study, it was presented on a screen and consisted of continuous scales ranging from 0 to 1 (step size of 0.005). Shapes were represented with visual illustrations following the "kiki-bouba" paradigm [50] as shown in Figure 2b. Similarly, body silhouettes were represented with body illustrations, following the study by Brianza et al. [10]. The remaining features were represented with words only (except for sound, we selected actual high-low pitch audio stimuli played via head-phones) [10]. Participants were asked to enter their answers by positioning the mouse on the desired point on a slider. The eight bipolar features were presented twice in a counterbalanced order, resulting in sixteen repetitions in total (see Figure 3a).

**Emotion Assessment.** Due to the important link between scents and emotions [20], we evaluated participants' emotional ratings for each scent using the 9-point SAM scale, commonly employed to study emotions [19, 36, 43] (see Figure 3b). It consists of a standardized measurement technique that includes valence (from negative to positive), arousal (from passive to active), and dominance (from dominated to dominant).

**Intensity Assessment.** Since intensity has been shown to significantly influence smell perception [24, 28]), we used a 9-point Likert scale, as in [10], to rate the intensity ("How intense was the scent?") from 1 "not at all" to 9 "very much" (see Figure 3c).

**Qualitative Descriptions.** To capture more qualitative insights about how the scent was perceived and the feelings towards the scent, we asked participants to answer two open questions at the end of the experiment, presented in random order: 1) "If you focus on the moment when you perceived the scent, how would you describe it?" and 2) "If you focus on the moment when you perceived the scent, how did it make you feel?". The aim was to capture subjective commonalities and differences among participants, following the work by Obrist et al. [41] suggesting that the way we describe a scent influences the overall smell experience.

### 3.4 Setup and Procedure

Participants sat in front of a desk while wearing headphones, as shown in Figure 4a. We delivered the scent stimuli through a 3D-printed nozzle (with six independent channels for each scent) that was positioned at 1m distance from each participant's nose [10]. Throughout the study, participants were asked to place their chin on a chinrest to keep the distance consistent across trials and participants. The delivery device (shown in Figure 4b-c) was developed to automatically deliver scents with time precision. The device is composed of six electrovalves that regulate the air passage (on–off) from a tank of compressed air (Figure 4b). The tank supplies airflow through plastic pipes linked through electrovalves, which open six aluminum bottles that contain 2.5 ml of six undiluted natural essential oils (Figure 4c). The delivery device was hidden from participants' view. The scent stimuli were automatically delivered throughout the experiment, using an Arduino board to control the delivery device. The scent was delivered every 10 seconds during the VAS task, three seconds (fixation cross on-screen) before the SAM task, and three seconds (fixation cross on-screen) before the open questions, as shown in Figure 3. The pressure was constant at 1 Bar during the whole study.

### 3.5 Participants

We recruited twenty-one participants (10 male, 11 female, Mage=27.96, SD=±6.08). They reported having normal or corrected-to-normal vision and no olfactory impairments (e.g., allergies, cold, flu), tested by the Olfactory Assessment Test [39].

### 3.6 Results

Here, we present the results of our analysis of the collected data. First, we ran normality tests to check if any of our quantitative data violated the assumption of normality. In the Shapiro-Wilk test, skewness and kurtosis did not show any significant departure from normality. Then, it being a within-participants study, we ran several repeated measures analyses of variance (ANOVAs), which enabled exploration of the factor interactions across dependent variables. Below, we summarize our main results [49]. In addition, mean scores, standard deviations (SD), and significant pairwise comparisons of the full set of features for each scent are included in the Supplementary Material.

**Scent–Feature Associations.** With the data collected from the VAS, we ran a repeated-measures ANOVA. Sphericity was assumed for all the variables, apart from temperature and sound. We found no significant results for gender. However, we found statistically significant differences ($p<.05$) for the features listed below. Post hoc analysis, with Bonferroni correction was applied.

- Visual shapes: $F(11, 209) = 3.9$, $p<.001$
- Sound: $F(11, 209) = 3.67$, $p<.01$
- Temperature: $F(11, 209) = 3.33$, $p<.01$
- Texture: $F(11,209) = 2.83$, $p<.01$

- Body silhouettes: $F(11,209) = 5.12$, $p<.001$
- Pleasantness: $F(11,209) = 4.52$, $p<.001$
- Familiarity: $F(11,209) = 7.87$, $p<.001$

In summary, we found that peppermint and eucalyptus are the scents most significantly associated with a spiky shape, high-pitched sound, coldness, and a thin body silhouette. On the contrary, rose is the scent predominantly associated with a rounded shape, low-pitched sound, soft texture, and thick body silhouette. Concerning familiarity and pleasantness, lemon was rated as having high familiarity and high pleasantness. On the contrary, rose and pine were rated as having low familiarity and low pleasantness. Figure 5 shows the results on the scent–feature associations for the twelve different scents grouped by features.

**Emotion Ratings of Scents.** With the data collected from the SAM scale, we ran a repeated-measures ANOVA. Sphericity was assumed for all the variables. The results show a statistically significant effect ($p<.05$) for the features listed below. Post hoc analysis with Bonferroni correction were applied.

- Valence: $F(11,220) = 4.246$, $p<.001$
- Arousal: $F(11,220) = 2.267$, $p<.05$
- Dominance: $F(11,220) = 2.407$, $p<.01$

In summary, concerning valence, we found that peppermint and lemon were rated as significantly more positive than rose and pine. Concerning arousal, we found that peppermint, eucalyptus, lemon, camphor, and black pepper were rated as significantly more arousing than rose, lavender, vanilla, and patchouli. Concerning dominance, lemon was rated as more dominant than rose. Mean scores of emotion ratings are included in the Supplementary Material (Figures S2 and S3).

**Intensity Ratings of Scents.** With the data collected on perceived scent intensity using a 9-point Likert scale, we ran a repeated-measures ANOVA. Sphericity was assumed for the variable. The results showed a statistically significant effect ($p<.05$) for intensity, $F(11,220)=16.357$, $p<.001$. Post hoc analysis, with Bonferroni correction, showed that the weakest scents were vanilla, rose, and patchouli, and the strongest scents were peppermint, eucalyptus, lavender, black pepper, and cinnamon. Mean scores of intensity ratings are included in the Supplementary Material (Figure S4).

**Qualitative Descriptions of Scents.** Scents are not always easy to describe and label [15, 41]. With the two open questions at the end of our experiment, we captured participants' descriptions and feelings elicited by the presented scents. Two researchers read through the responses individually first, and then together in order to identify commonalities and differences across participants. We noticed that scents rated as more familiar were described more coherently than unfamiliar scents. For example, lemon was always correctly identified ("lemon" or "citrus" labels) and, as personal feelings, described as

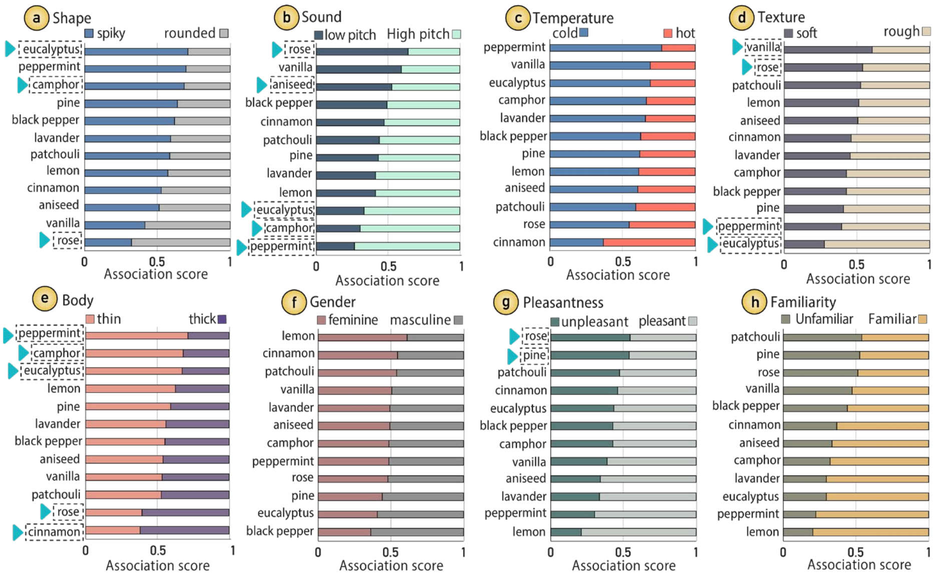


Figure 5. Results on the associations between scents and bipolar sensory (a-d), bodily (e-f), and qualitative (g-f) features using the VAS scores. Dashed boxes and ▶ highlight the new scent–feature associations we identified in our study, thus extending existing literature on CCs.

"sweet", "pleasant", "nice", "fresh". When participants did not recognize the scent at all, the descriptions were more mixed and diverging. For example, patchouli was never correctly identified ("confused" or "strong") and in terms of feelings, it was described as "sharp" or "curious". To facilitate visual inspection, we created word clouds for each scent using the R word cloud package (see Figure 6 as an example of a word cloud included in the EssCards).

## 3.7 Summary of Key Findings

Our results from the user study not only confirm previous associations between scents and other sensory features but also contribute new knowledge on CCs to the literature. Below, we summarize the new key findings for each of the three investigated groups of features, highlighted with dashed boxes in Figure 5.

**Findings on Smell and Sensory Features.** Concerning scent-shape associations, our findings are in line with prior work [10, 24, 27, 28]. We also found new associations for the added scents. For example, rose was associated with rounded shapes while eucalyptus and camphor with spiky shapes. Concerning sound, we confirmed previously tested associations [10], but we further found that peppermint, camphor, and eucalyptus were associated with a high pitched sound, while rose and aniseed with a low pitched sound. With regards to the associations between scents and soft or rough textures, we did not confirm the findings of Dematte' et al. [16]. Indeed, our study showed strong associations between vanilla and rose and soft textures, and lemon and peppermint and rough textures. This could be due to the selection of pleasant scents only.

**Findings on Smell and Bodily Features.** We confirmed prior findings that link lemon with a thin body silhouette and vanilla with a thick body silhouette [10]. In addition, we found even stronger associations between peppermint, camphor, and eucalyptus and a thin body silhouette, and between rose and cinnamon and a thick body silhouette. For scent–gender associations, our findings were not significant, which could be due to the primary focus on scent–gender association without any additional features (as tested in [28, 32]). Further studies are needed to verify this assumption.

**Findings on Smell and Qualitative Features.** Finally, with regards to familiarity and pleasantness, we found that lemon and peppermint were rated as the most pleasant and familiar scents. On the contrary, rose and patchouli were rated as the least pleasant and familiar scents. With regards to the emotion assessment, we found that peppermint and lemon were rated as significantly more positive than rose and pine, even though we selected only pleasant scents. Concerning arousal, in line with prior work [10], we found that peppermint, lemon, and black pepper were rated as significantly more arousing than rose, lavender, vanilla, and patchouli. We also found new associations for the added scents (e.g., camphor and eucalyptus rated as high arousing). Concerning dominance, as previously shown in [10], lemon was rated as more dominant than rose. With regards to the intensity rating, as shown in [24, 28], we found that scents rated with high intensity were perceived as more familiar and pleasant (e.g., lemon and peppermint). Familiarity also played a role in the subjective descriptions participants provided

# 4 EssCards & Design Explorations

The findings from our user study open up a range of future research directions to explore scent–feature associations. However, those results alone may not change the way designers approach scent–feature associations to create multisensory experiences. Hence, with the ambition to inspire the design of future interactions, we wanted to make our findings more engaging and accessible. Thus, we created the so-called EssCards – a set of cards that captures the key findings obtained in our user study. Below, we first describe the creation of the EssCards and then showcase their use in two design explorations.

## 4.1 Creation of the EssCards

To design the EssCards, we took inspiration from prior attempts to facilitate creativity through the use of design cards [23, 62]. The abstract frameworks into something more operational and tangible. As stated in [8], there are different types of design cards (e.g., exertion game design [38], tangible design [26], playful design [34]) but a common

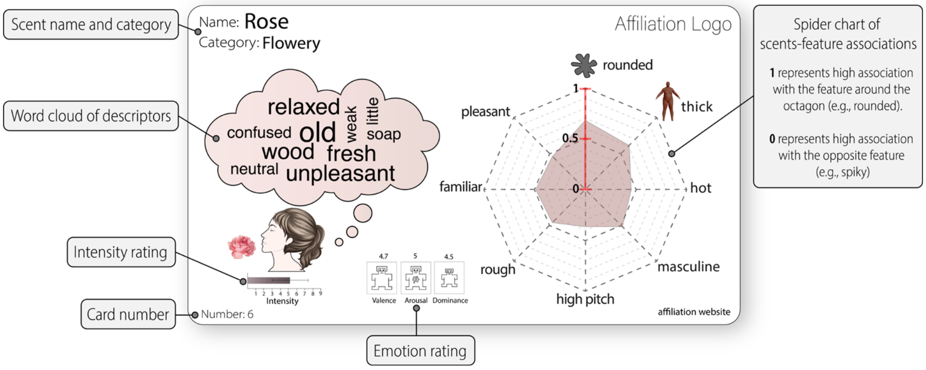


Figure 6. Example of the EssCard for the rose scent, highlighting its main elements.

denominator is that they can facilitate design activity through keywords, pictures, and collaborative settings.

We adopted the card format as it is easy to use, printable, and easily shared and used online. Figure 6 shows an example EssCard for the scent of rose (the complete set of twelve cards is included in the Supplementary Material, section S.3). The EssCards set also includes an explanation card that describes the included data for first-time use. Each EssCard includes the following elements:

1. Scent name and category (food, flowery and woody).
2. Scent-specific generated word clouds based on participants' most frequently employed words to describe both the scent and the feelings associated with the scent
3. Intensity rating of the scent on a 9-point scale.
4. Emotion ratings of valence, arousal, and dominance for the scent (mean values of the 9-point SAM scale and the corresponding manikin for visual representation).
5. Spider chart of bipolar scent–feature associations for the scent, where "1" (outer layer of the chart) refers to a high association with the labelled feature (e.g., rounded) and "0" (in the center of the chart) refers to a high association with the opposite feature (e.g., spiky). In the shown example, we can see that rose is associated with a rounded shape (> 0.5), thick body silhouette (> 0.5), and low-pitched sound (< 0.5).

To exemplify the possible use of the EssCards, we organized two exploratory design sessions – a group and an individual session. Both sessions are only meant to exemplify the possible use of the EssCards and collect some early-stage feedback from designers.

### 4.2 Design Explorations: Overall Approach and Design Brief

Using the EssCards, we organized two design exploration sessions to gain some initial insights into how scent–feature associations could inspire designers given a specific design brief ("*design a multisensory fashion garment that makes the wearers feel good about themselves*"). Below, we report a brief summary of both explorations to exemplify the possible use of our user study results in design. We do not provide detailed explanations of the design explorations and outcomes as these do not constitute the

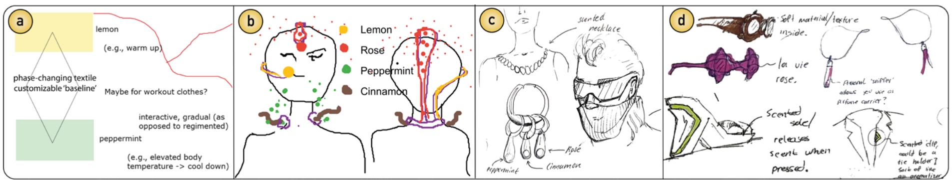


Figure 7. Design outcomes from Group 1 (a) and Group 2 (b) during design exploration 1. Design outcomes from Designer 1 (c) and Designer 3 (b) during the individual design exploration 2.

primary contribution of this paper, and further data collection is required. However, we hope to inspire through these initial explorations.

The original intention was to run in-person design workshops with designers. However, due to the COVID-19 pandemic and social distancing restrictions, we adapted our approach and moved the design explorations into an initial online group session, followed up with a second individual session at home. We recruited a total of seven designers from our personal professional network.

As these sessions are meant as initial steps from research to design, we selected a sub-set of the EssCards (four out of twelve) as inspirational material for both sessions. We focused on the scents of peppermint, lemon, cinnamon, and rose. Our work has shown that peppermint and lemon are associated with a thin body silhouette and cinnamon and rose with a thick body silhouette (see section 3.6), and thus may induce different design outcomes around our brief. Moreover, those four scents can be easily sourced in home environments to accompany the design activities

Overall, we focused on gaining some preliminary insights on how designers use the information displayed on the EssCards (shared in PDF format via email), alongside sniffing the scented objects (real objects representing each of the four selected).

### 4.3 Design Exploration – Group Session

The group session involved four designers (two male, two females, M age=34.25, SD= ±8.42), all of whom, apart from one, had prior experience working with scents. The exploration consisted of two main parts: (1) a questionnaire to collect designers' educational and professional background, and (2) a two-hour online group session using Zoom as platform. The EssCards were shared via email before the group session. For the online group session, two subgroups were created. The designers were first invited to sniff the scented objects and focus on their own experiences and feelings for each of the scents. Then, they discussed and brainstormed ideas for the given design brief.

We collected comments and feedback, pictures of the scented objects, and design sketches made by the designers (see Figure 7a-b). We noticed that the EssCards were consulted at the beginning without being explicitly reused again. This is in accordance with the study by Bornoe et al. [8], in which design cards were used as an initial source of inspiration and then put away for the rest of the design session.

In the final discussion with all designers, they all agreed that the EssCards would have been of great help during an in-person workshop as something tangible to work with ("I think if the workshop was not online, they could have helped just having them in hands") and they reported that having someone close by to share thoughts, comments, ideas with would have been nice. The affordances in an online design workshop were limited. Participants could have printed the EssCards, but it would not have been the same, as cards are often passed amongst designers to stimulate discussion and reflection.

However, despite this limitation, we can see traces of EssCard information in the designers' creations, such as in the use of scent–feature associations. For example, one group ideated a workout t-shirt made of fabrics with micro-capsules to spread scents based on wearers' body temperature during the workout ("…garments for workout made of phase changing material that you can program with temperature"). The designers described their approach as follows: "we are talking about lemon as a more uplifting and active scent and peppermint a bit more calming (..) so delivering lemon when the temperature increases and people are more active and peppermint to cool down, for stretching." (see Figure 7a). Concerning the other group, the location of the devices on the body and the link between location, scent, and intensity of the scent flow (see Figure 7b), can be seen as a reminder of the emotion and intensity data displayed in the EssCards (see Figure 7b).

Based on our observations and designers' feedback, we further noticed that a key limitation was the online setting and the limited time available to define the problem, brainstorm, and create design ideas. Thus, we endeavor to adjust the setup and method to gain further insights on the use of the EssCards, this time using an individual design approach, carried out offline and spread over two weeks.

### 4.4 Design Exploration – Individual Session

Based on the lessons learnt from our first group exploration session, we refined our approach and gave designers more time to engage with the EssCards, scented objects, and design brief. The individual approach was chosen to enable an extended design exploration while still complying with the COVID-19 restrictions.

This second design exploration involved three designers (two male, one female, M age= 37.6, SD= ± 8.31), who had no prior experience with working with scents. The exploration consisted of two main tasks (Sniff & Act) carried out at home by each individual:

- Task 1 (Sniff): We asked each designer to sniff the scented objects and complete online forms to collect their scent–feature associations through the same set of measures used in our user study (see section 3.3). The aim of this task was to familiarize the designers with the scent–feature associations visualized in the EssCards.
- Task 2 (Act): We shared with the designers the set of four EssCards via email and they were given seven days to work on the design brief. They were invited to share any outcome from their design process and to annotate their design choices and thoughts. Once completed, we organized a final individual interview via Zoom.

The results from Task 1 matched the data visualized in the EssCards. Thus, we can confirm that the designers' scent–feature associations match our findings from the user study (described in section 3.6).

Concerning Task 2, similar to the group session and prior work [8], all designers said that they used the EssCards at the beginning without explicitly reusing them again throughout the design session. As with the previous exploration, in the final interviews of the individual session the need for physical cards was confirmed. Each designer emphasized the usefulness of the cards as a physical object. However, we had to face constraints due to the continuous COVID-19 restrictions and remote design exploration. Future work can address this problem shipping to all participants a printed set of EssCards. Despite the limited use of the EssCards, we could again trace the information presented in the cards in the designers' outcomes, particularly in terms of shape and texture. For example, designers ideated goggles made of soft textile inspired by cinnamon, high heels with spiky shapes inspired by lemon, and rounded glasses inspired by rose (see Figure 7c-d). All the sketches are included in Figures S8 and S9 in our Supplementary Material.

Overall, both the group and the individual design exploration sessions provided us with some initial opportunities to translate the findings of our user study into a design context. Despite the unusual setup in the form of online and remote design explorations, we received encouraging feedback from all designers on the use of scents and the EssCards, which opens new avenues for future interaction and experience design.

## 5 Discussion

Although recently designing olfactory interfaces and smell experiences has gained attention in the HCI community, there is still a lack of understanding of how smell can be used as a source of inspiration for designers. We focused on expanding the existing knowledge around CCs, running a user study to explore new scent–feature associations, and "translating" our findings into something that designers can easily engage with (EssCards). Here, we discuss how we can think of scent–feature associations as inspirational material for designing future interactions and of the differences between "scent-inspired design" and "designing with scents".

### 5.1 Smell as Inspirational Material for Designing

It has long been known that the optimal design of products, systems, and experiences benefits from the broad consideration of all the senses [59]. Building on CC research allows us to think beyond single sensory stimulation and promotes the use of cross-sensory associations in design. Not only did we provide a detailed review of design features in relation to selected scents, but we also found novel scent–feature associations (see section 3.7 for a summary of our findings).

We designed the EssCards to summarize and visualize the research findings. We observed that, in both design explorations, the use of the EssCards was limited to the beginning of the design activity. Hence, we can hypothesize that the EssCards are inspirational material during the design activity. Moreover, we noticed traces of the information represented in the cards within designers' outcomes, which makes us believe that they played an active role in the design explorations (e.g., high heels with spiky shapes inspired by lemon).

All designers mentioned that they would have liked to touch the cards and, if tangible, would have used them more. It remains to be studied how the physical use of the cards in in-person workshops would change the engagement as well as the outcomes.

Overall, we propose the EssCards as general profiles and summations of collected data on scent–feature associations and related emotion and intensity ratings that can be used to inspire designers easily and effectively.

### 5.2 Scent-Inspired Design and Designing with Scents

Based on previous work in HCI and on our observations in both design exploration sessions, we noticed two ways of thinking about scents: "scent-inspired design" and "designing with scents". While we are aiming to advocate the first with our work, the second is the dominant way of thinking about smell and design in HCI. Indeed, "designing with scents" reflects the approach when using the sense of smell as an "add-on” and involves the creation of wearable artefacts able to deliver scents (e.g., Essence [2]). An example collected from our design explorations is a t-shirt that delivers scents (see Figure 7a). On the contrary, "scent-inspired design" is embedded in the creation of the EssCards. While scents were not necessarily embedded in all the design outcomes collected from both design exploration sessions, they were present through characteristics of the outcomes based on the associations between the sensory features and scents. For example, rounded goggles inspired by cinnamon demonstrate the influence of scent–shape associations conveyed in the EssCards (see Figure 7d). In other words, "scent-inspired design" does not need to result in the actual use and delivery of scents in the design outcome. Indeed, we imagine the use of the EssCards alongside with or even as a possible replacement of actual scents. Future work is needed to explore and compare designers’ creations and experiences under different conditions with and without real scent stimulation.

It has been suggested that "smell is the Cinderella of our senses" [4] as it has acquired a poor reputation due to its subjectivity and difficulty to work with. However, increasing research is demonstrating the power of smell, and growing efforts are underway to establish the sense of smell in HCI for inspiring designers and designing olfactory interfaces. Our paper contributes to these efforts, showing that scent–feature associations can be a powerful source of inspiration as well as material to design with.

## 6 Limitations and Future Work

Despite the growing knowledge on the sense of smell in HCI, extended through our work, we also need to acknowledge limitations that require further investigation.

First, concerning the user study, we applied the VAS paradigm, visually presenting all the features with the exception of sound. We aim to conduct further studies with physical representations of the features, such as temperature (e.g., Peltier modules), texture (e.g., fabric swatches), or self-body representations (e.g., avatars in VR) to establish more fine-granular insights on scent–feature associations.

Second, digitalizing the set of cards allows us to add more information and, at the same time, designers to zoom in and out of the cards and enable a richer space of exploration. We also aim to improve the layout of the EssCards.

Third, future cross-cultural work could extend our findings on scent–feature associations to understand potential cultural differences around olfactory perception and scent–feature associations. Moreover, more qualitative data would be desirable to create a shared language around smell. We believe that the use of in-depth interview techniques such as micro-phenomenology can further enrich the EssCards information.

Fourth, it would be interesting to run more design explorations, in-person and online, with and without the EssCards and the scented objects, giving new design briefs. A set of EssCards can be shipped to designers to collect feedback on the layout, insights on the need of physicality, and discussion around their use during the design activity.

Fifth, although we explored how our EssCards can be applied in a design context, we believe that our results can also be used for other purposes to reach a broader HCI audience. For example, researchers could explore the use of the EssCards as an evaluation tool to engage with various categories of customers or as a teaching aid to share insights about multisensory and crossmodal association [13, 17, 44]. To facilitate these and other future explorations, including the study of further scent–feature associations, we have included a blank template of our EssCards in the Supplementary Material - section S.3.

## 7 Conclusion

Smell is a powerful sensory modality to inspire creativity and imagination, even though we are only starting to unlock its full potential. In this paper, we explored scent–feature associations relevant for designing future interactions and experiences. First, we ran a user study and established empirical evidence on novel scent–feature associations advancing existing knowledge on CCs. Second, we designed a visualization of our findings in form of a set of cards (EssCards). Then, we organized two preliminary design explorations to exemplify the use of the EssCards and obtain some initial feedback from designers. Finally, we discussed how future work can explore more systematically the role of smell in design practice.

## 8 Acknowledgments

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# Sniff Before You Act: Exploration of Scent-Feature Associations for Designing Future Interactions

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## SUPPLEMENTARY MATERIAL

This supplementary material contains: (1) details on statistical comparisons from the user study on scent-feature associations, emotional ratings and perceived intensity, (2) the most frequent words employed by participants to describe both the scents and their feelings towards them, (3) the full set of twelve EssCards representing the results from each scent tested in the user study, a cover card with the explanation of each scale, an empty card (templated) that can be used to collect more data with different scents and features; and (4) the sketches created by designers during both design explorations.

### S.1 Statistic Comparison from the User Study

**a Sensory Features**

Shape

| Spiky | Mean [±SD] | Rounded | Mean [±SD] | *p* value |
|---|---|---|---|---|
| Peppermint | 0.28 [0.27] | Rose | 0.68 [0.20] | <.01 |
| Eucalyptus | 0.32 [0.27] | Rose | 0.68 [0.20] | <.05 |
| Pine | 0.36 [0.24] | Rose | 0.68 [0.20] | <.01 |
| Camphor | 0.32 [0.23] | Rose | 0.68 [0.20] | <.01 |
| Black pepper | 0.38 [0.26] | Rose | 0.68 [0.20] | <.01 |
| Peppermint | 0.28 [0.27] | Vanilla | 0.55 [0.18] | <.01 |

Sound

| High pitch | Mean [±SD] | Low pitch | Mean [±SD] | *p* value |
|---|---|---|---|---|
| Peppermint | 0.72 [0.27] | Rose | 0.38 [0.21] | <.05 |
| Eucalyptus | 0.66 [0.26] | Rose | 0.38 [0.21] | <.05 |
| Peppermint | 0.72 [0.27] | Vanilla | 0.42 [0.15] | <.05 |

Temperature

| Cold | Mean [±SD] | Hot | Mean [±SD] | *p* value |
|---|---|---|---|---|
| Peppermint | 0.22 [0.27] | Cinnamon | 0.61 [0.20] | <.01 |
| Eucalyptus | 0.35 [0.27] | Cinnamon | 0.61 [0.20] | <.05 |
| Camphor | 0.36 [0.23] | Cinnamon | 0.61 [0.20] | <.01 |

Texture

| Rough | Mean [±SD] | Soft | Mean [±SD] | *p* value |
|---|---|---|---|---|
| Eucalyptus | 0.73 [0.17] | Rose | 0.48 [0.24] | <.05 |
| Eucalyptus | 0.73 [0.17] | Vanilla | 0.41 [0.22] | <.05 |
| Eucalyptus | 0.73 [0.17] | Patchouli | 0.45 [0.22] | <.01 |

**b Bodily Features**

Body

| Thin | Mean [±SD] | Thick | Mean [±SD] | *p* value |
|---|---|---|---|---|
| Peppermint | 0.27 [0.19] | Rose | 0.63 [0.16] | <.01 |
| Eucalyptus | 0.35 [0.22] | Rose | 0.63 [0.16] | <.05 |
| Pine | 0.41 [0.19] | Rose | 0.63 [0.16] | <.05 |
| Lemon | 0.37 [0.20] | Rose | 0.63 [0.16] | <.05 |
| Camphor | 0.32 [0.19] | Rose | 0.63 [0.16] | <.01 |
| Black pepper | 0.43 [0.22] | Rose | 0.63 [0.16] | <.05 |
| Peppermint | 0.27 [0.19] | Cinnamon | 0.60 [0.24] | <.001 |

**c Qualitative Features**

Familiarity

| Unfamiliar | Mean [±SD] | Familiar | Mean [±SD] | *p* value |
|---|---|---|---|---|
| Pine | 0.46 [0.23] | Peppermint | 0.79 [0.18] | <.05 |
| Patchouli | 0.43 [0.22] | Peppermint | 0.79 [0.18] | <.01 |
| Black pepper | 0.53 [0.19] | Peppermint | 0.79 [0.18] | <.05 |
| Pine | 0.46 [0.23] | Lemon | 0.82 [0.15] | <.05 |
| Patchouli | 0.43 [0.22] | Lemon | 0.82 [0.15] | <.01 |
| Black pepper | 0.53 [0.19] | Lemon | 0.82 [0.15] | <.05 |
| Rose | 0.49 [0.29] | Lemon | 0.82 [0.15] | <.01 |
| Vanilla | 0.52 [0.26] | Lemon | 0.82 [0.15] | <.01 |
| Pine | 0.46 [0.23] | Lavender | 0.72 [0.19] | <.05 |
| Patchouli | 0.43 [0.22] | Lavender | 0.72 [0.19] | <.05 |

Pleasantness

| Unpleasant | Mean [±SD] | Pleasant | Mean [±SD] | *p* value |
|---|---|---|---|---|
| Rose | 0.44 [0.26] | Lemon | 0.80 [0.22] | <.01 |
| Pine | 0.43 [0.23] | Lemon | 0.80 [0.22] | <.01 |
| Cinnamon | 0.50 [0.27] | Lemon | 0.80 [0.22] | <.05 |

Figure S1. Mean scores, standard deviations, and significant pairwise comparisons for sensory (a), bodily (b) and qualitative (c) features.

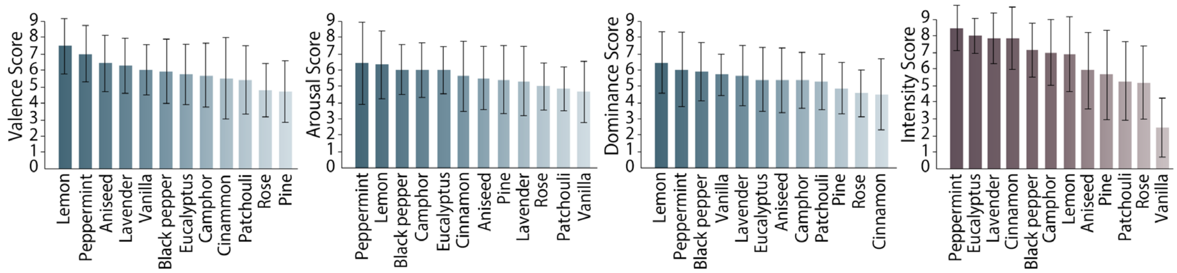


Figure S2. Mean scores of emotions (valence, arousal and dominance) and intensity ratings. Error bars represent ± SD.

**Emotion Ratings**

| | Negative | Mean [±SD] | Positive | Mean [±SD] | *p* value |
|---|---|---|---|---|---|
| Valence | Rose | 4.79 [1.63] | Peppermint | 7.03 [1.71] | <.05 |
| | Pine | 4.71 [1.87] | Peppermint | 7.03 [1.71] | <.01 |
| | Rose | 4.79 [1.63] | Lemon | 7.47 [1.69] | <.01 |
| | Pine | 4.71 [1.87] | Lemon | 7.47 [1.69] | <.01 |
| | **Active** | **Mean [±SD]** | **Passive** | **Mean [±SD]** | ***p* value** |
| Arousal | Peppermint | 6.42 [2.52] | Rose | 5.00 [1.44] | <.05 |
| | Peppermint | 6.42 [2.52] | Lavender | 5.33 [2.12] | <.05 |
| | Peppermint | 6.42 [2.52] | Vanilla | 4.67 [1.88] | <.05 |
| | Peppermint | 6.42 [2.52] | Patchouli | 4.86 [1.35] | <.05 |
| | Eucalyptus | 6.00 [1.44] | Rose | 5.00 [1.44] | <.05 |
| | Eucalyptus | 6.00 [1.44] | Vanilla | 4.67 [1.88] | <.05 |
| | Eucalyptus | 6.00 [1.44] | Patchouli | 4.86 [1.35] | <.05 |
| | Lemon | 6.33 [2.08] | Vanilla | 4.67 [1.88] | <.01 |
| | Lemon | 6.33 [2.08] | Patchouli | 4.86 [1.35] | <.05 |
| | Camphor | 6.00 [1.67] | Vanilla | 4.67 [1.88] | <.05 |
| | Camphor | 6.00 [1.67] | Patchouli | 4.86 [1.35] | <.01 |
| | Black pepper | 6.05 [1.53] | Rose | 5.00 [1.44] | <.05 |
| | Black pepper | 6.05 [1.53] | Vanilla | 4.67 [1.88] | <.05 |
| | Black pepper | 6.05 [1.53] | Patchouli | 4.86 [1.35] | <.05 |
| | **Dominated** | **Mean [±SD]** | **Dominant** | **Mean [±SD]** | ***p* value** |
| Dominance | Rose | 4.57 [1.43] | Lemon | 6.47 [1.88] | <.05 |

Figure S3. Mean scores, standard deviations, and significant pairwise comparisons for emotion ratings.

## Intensity Ratings

| Negative | Mean [±SD] | Positive | Mean [±SD] | *p* value |
|---|---|---|---|---|
| Peppermint | 8.47 [1.36] | Rose | 5.19 [2.20] | <.001 |
| Peppermint | 8.47 [1.36] | Pine | 5.64 [2.69] | <.001 |
| Peppermint | 8.47 [1.36] | Lemon | 6.90 [2.25] | <.05 |
| Peppermint | 8.47 [1.36] | Aniseed | 5.90 [2.30] | <.01 |
| Peppermint | 8.47 [1.36] | Camphor | 7.00 [1.97] | <.01 |
| Peppermint | 8.47 [1.36] | Vanilla | 2.48 [1.77] | <.001 |
| Peppermint | 8.47 [1.36] | Patchouli | 5.29 [2.36] | <.001 |
| Peppermint | 8.47 [1.36] | Black pepper | 7.14 [1.62] | <.01 |
| Rose | 5.19 [2.20] | Eucalyptus | 8.00 [1.04] | <.001 |
| Rose | 5.19 [2.20] | Lemon | 6.90 [2.25] | <.05 |
| Rose | 5.19 [2.20] | Lavender | 7.85 [1.52] | <.01 |
| Rose | 5.19 [2.20] | Camphor | 7.00 [1.97] | <.05 |
| Rose | 5.19 [2.20] | Vanilla | 2.48 [1.77] | <.001 |
| Rose | 5.19 [2.20] | Black pepper | 7.14 [1.62] | <.01 |
| Rose | 5.19 [2.20] | Cinnamon | 7.86 [1.87] | <.01 |
| Eucalyptus | 8.00 [1.04] | Pine | 5.64 [2.69] | <.01 |
| Eucalyptus | 8.00 [1.04] | Aniseed | 5.90 [2.30] | <.01 |
| Eucalyptus | 8.00 [1.04] | Vanilla | 2.48 [1.77] | <.001 |
| Eucalyptus | 8.00 [1.04] | Patchouli | 5.29 [2.36] | <.001 |

| Negative | Mean [±SD] | Positive | Mean [±SD] | *p* value |
|---|---|---|---|---|
| Eucalyptus | 8.00 [1.04] | Black pepper | 7.14 [1.62] | <.05 |
| Pine | 5.64 [2.69] | Lavender | 7.85 [1.52] | <.01 |
| Pine | 5.64 [2.69] | Vanilla | 2.48 [1.77] | <.001 |
| Pine | 5.64 [2.69] | Black pepper | 7.14 [1.62] | <.05 |
| Pine | 5.64 [2.69] | Cinnamon | 7.86 [1.87] | <.01 |
| Lemon | 6.90 [2.25] | Vanilla | 2.48 [1.77] | <.001 |
| Lemon | 6.90 [2.25] | Patchouli | 5.29 [2.36] | <.05 |
| Lavender | 7.85 [1.52] | Aniseed | 5.90 [2.30] | <.01 |
| Lavender | 7.85 [1.52] | Vanilla | 2.48 [1.77] | <.001 |
| Lavender | 7.85 [1.52] | Patchouli | 5.29 [2.36] | <.01 |
| Aniseed | 5.90 [2.30] | Vanilla | 2.48 [1.77] | <.001 |
| Aniseed | 5.90 [2.30] | Patchouli | 5.29 [2.36] | <.01 |
| Camphor | 7.00 [1.97] | Vanilla | 2.48 [1.77] | <.001 |
| Camphor | 7.00 [1.97] | Patchouli | 5.29 [2.36] | <.01 |
| Vanilla | 2.48 [1.77] | Patchouli | 5.29 [2.36] | <.001 |
| Vanilla | 2.48 [1.77] | Black pepper | 7.14 [1.62] | <.001 |
| Vanilla | 2.48 [1.77] | Cinnamon | 7.86 [1.87] | <.001 |
| Patchouli | 5.29 [2.36] | Black pepper | 7.14 [1.62] | <.01 |
| Patchouli | 5.29 [2.36] | Cinnamon | 7.86 [1.87] | <.001 |

Figure S1. Mean scores, standard deviations, and significant pairwise comparisons for perceived intensity.

**S.2 Smell Descriptors (Frequency of Words)**

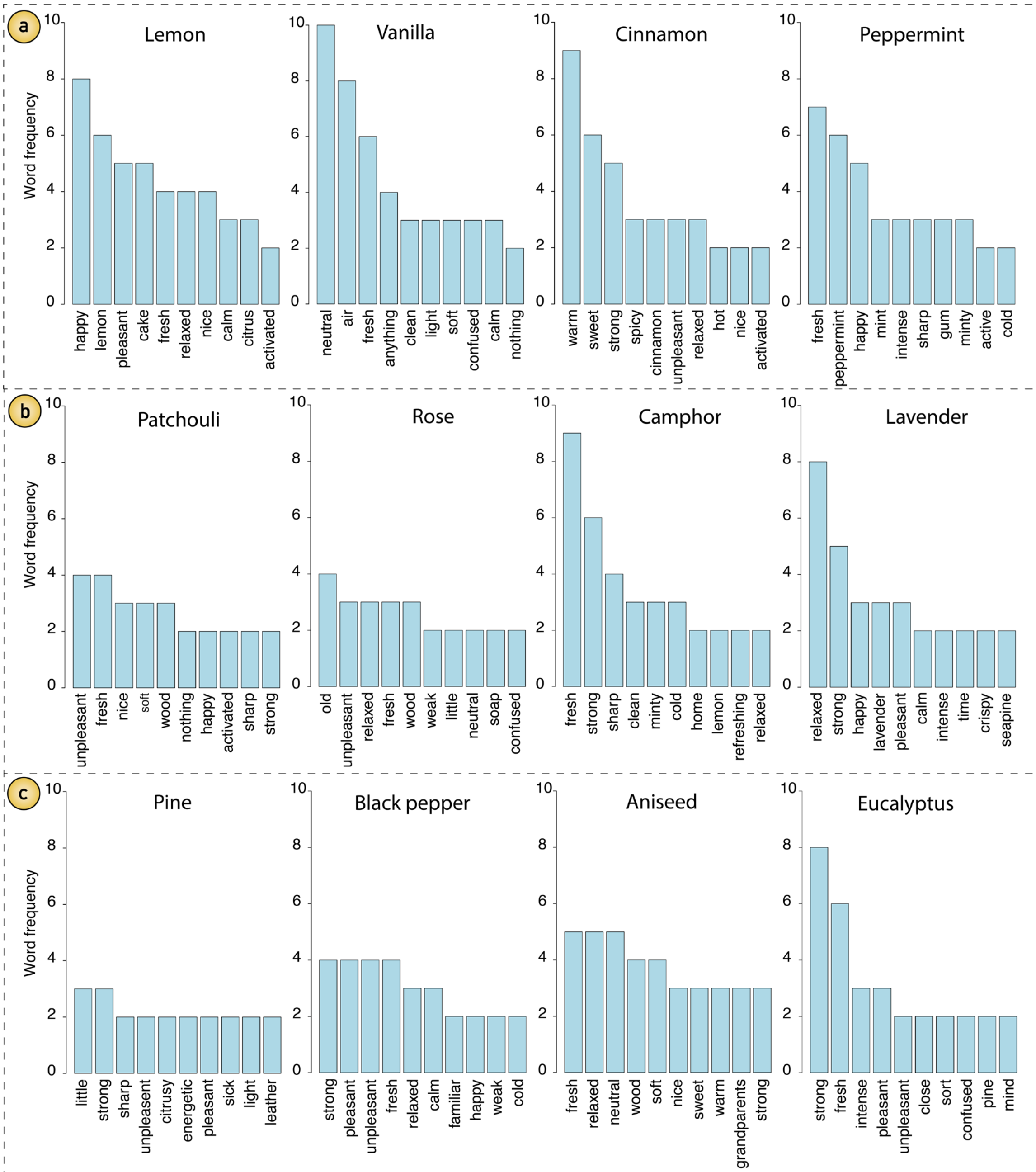


Figure S4. Frequency of words used by participants to describe both the scents and their feelings during scent exposure, grouped by category: food (a), flowery (b) and woody (c).

### S.3 EssCards

SCHI LAB
Multisensory Experiences

# EssCards

Sniff before you act

https://multi-sensory.info/

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SCHI LAB
Multisensory Experiences

## EssCards

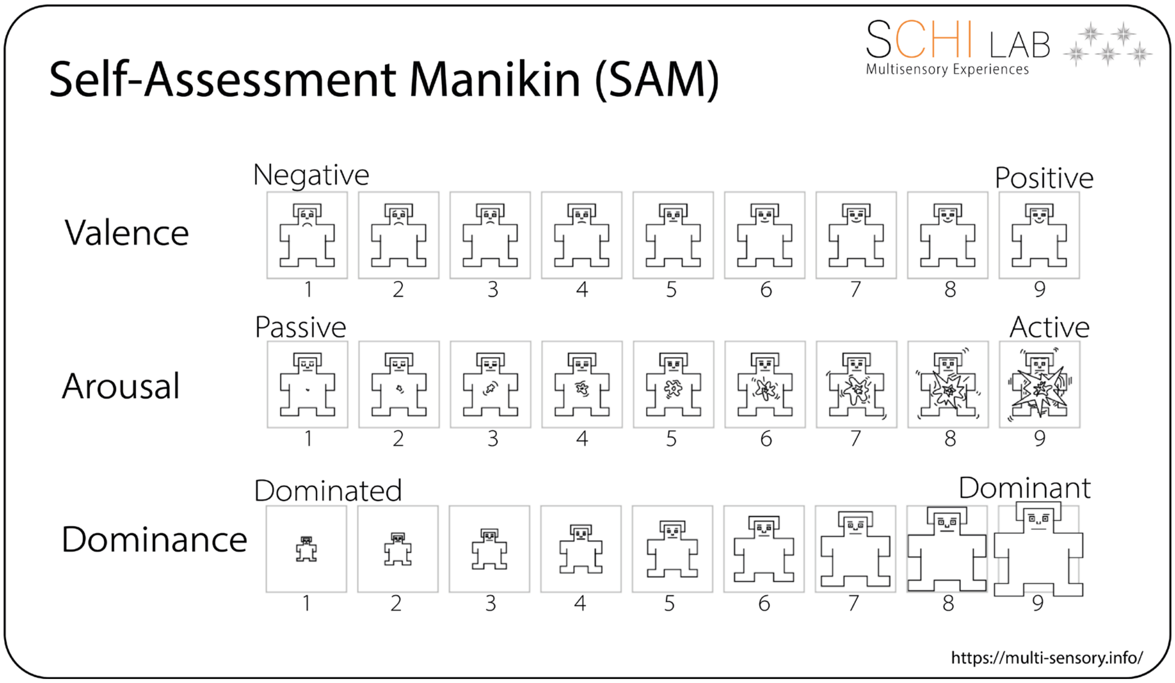
Each card includes graphical representations for each of the twelve tested scents:

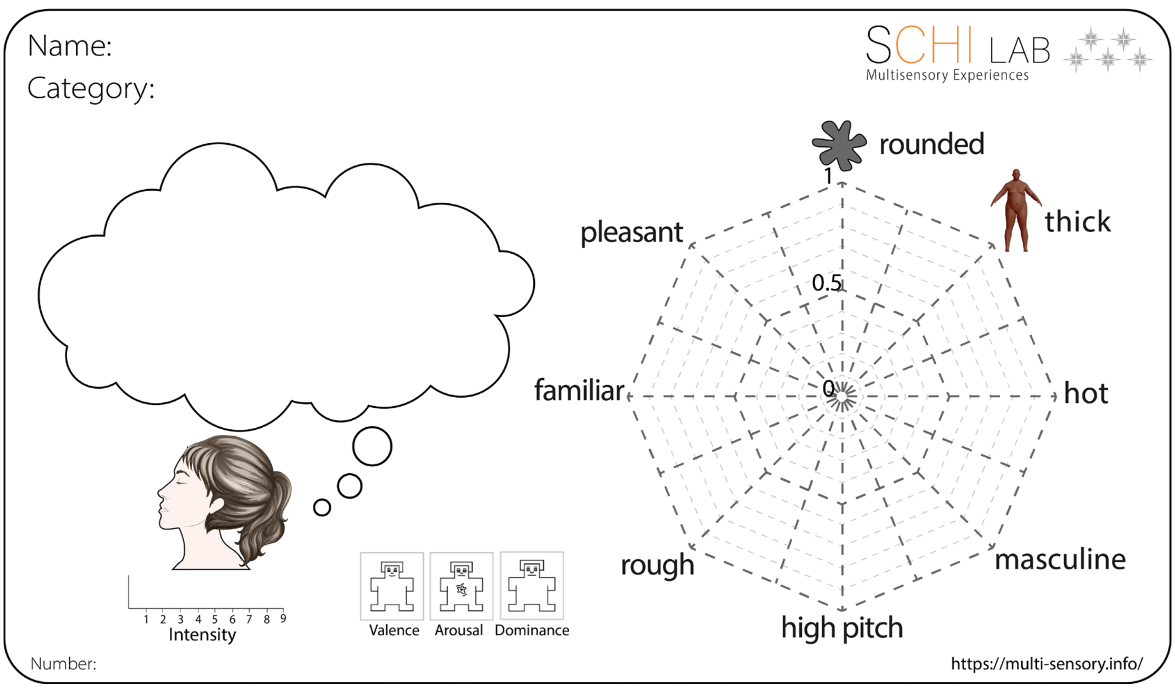
1. Scent name, scent number (from 1 to 12), scent category (food, flowery, and woody).
2. Octagon of bipolar sensory, bodily, and qualitative features associations:
   - Sensory features: shape, sound, texture, and temperature.
   - Bodily features: gender and body silhouettes.
   - Qualitative features: familiarity and pleasantness.

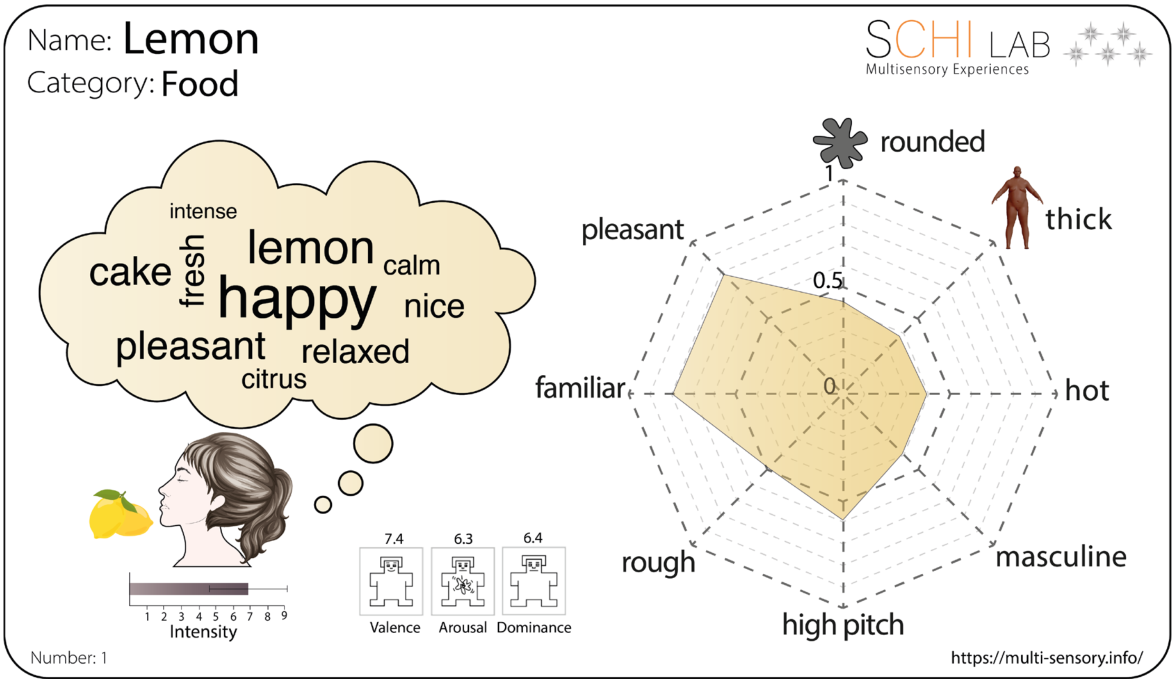
   1 refers to a high association with the adjective on the perimeter (e.g., high pitch).
   0 refers to a high association with the opposite adjective (e.g., low pitch).
3. Word cloud based on subjects responses on two open questions:
   - "If you focus on the moment when you perceived the scent, how would you describe it?"
   - "If you focus on the moment when you perceived the scent, how did it make you feel?"
4. Intensity ratings (captured on a 9-point Likert scale).
5. Emotions ratings: Valence, Arousal and Dominance (captured on a 9-point SAM scale).

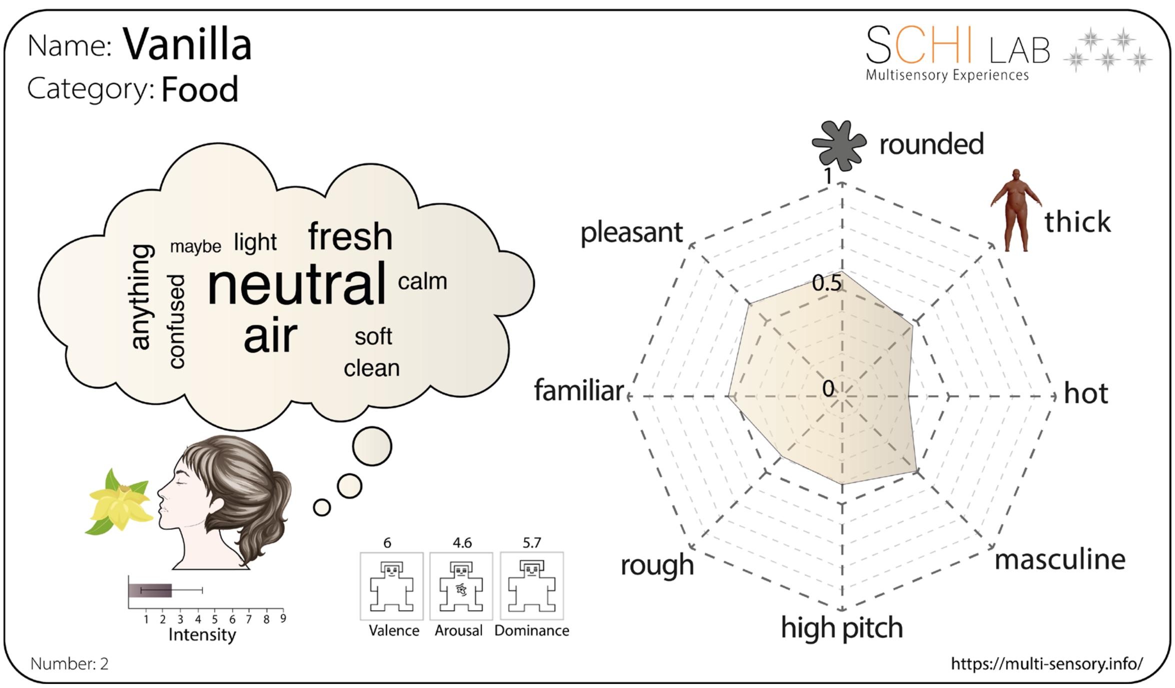
Intructions

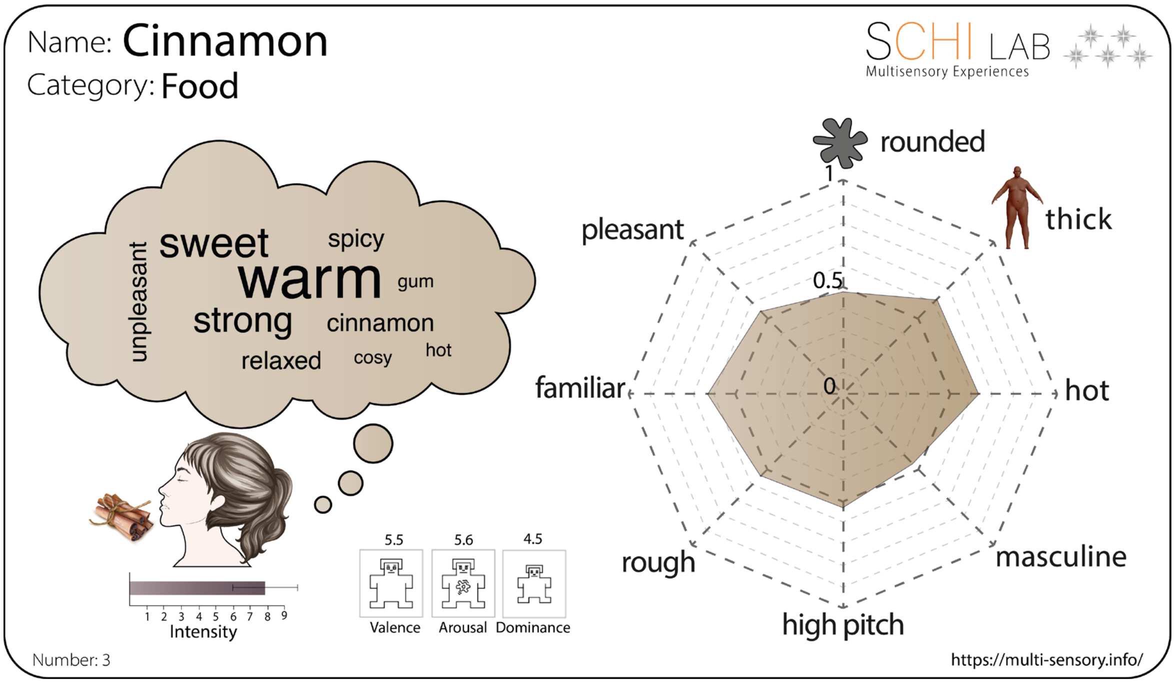
https://multi-sensory.info/

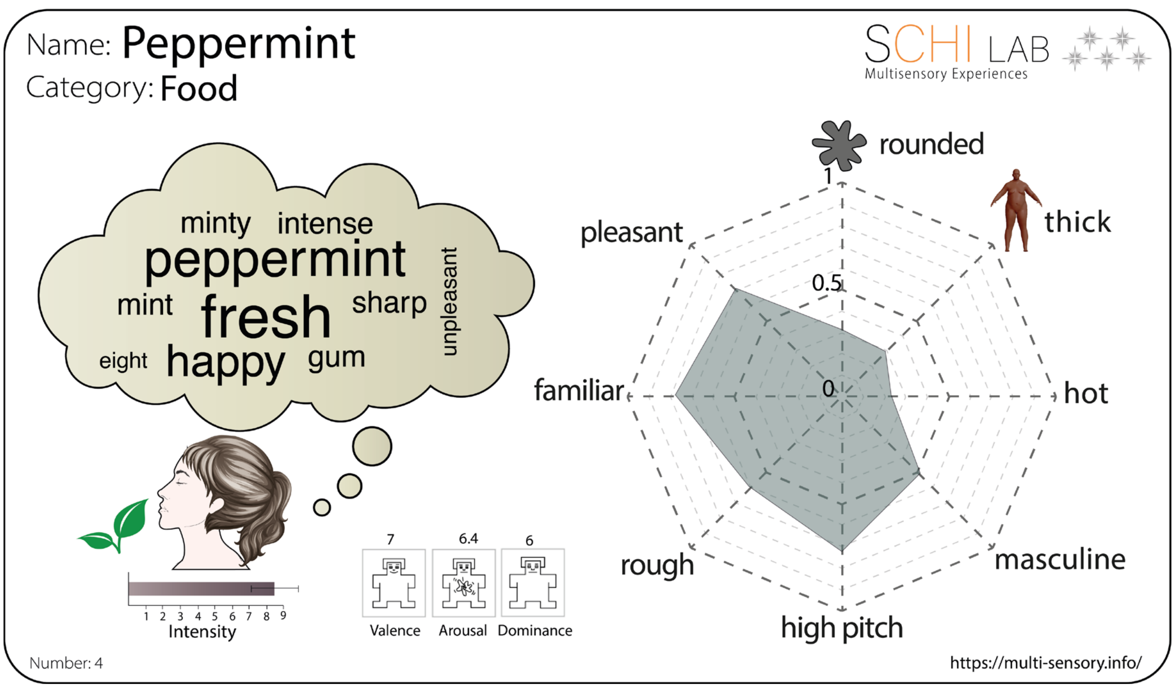

SCHI LAB
Multisensory Experiences
Self-Assessment Manikin (SAM)
Valence
Negative
Positive
1 2 3 4 5 6 7 8 9
Arousal
Passive
Active
1 2 3 4 5 6 7 8 9
Dominance
Dominated
Dominant
1 2 3 4 5 6 7 8 9
https://multi-sensory.info/

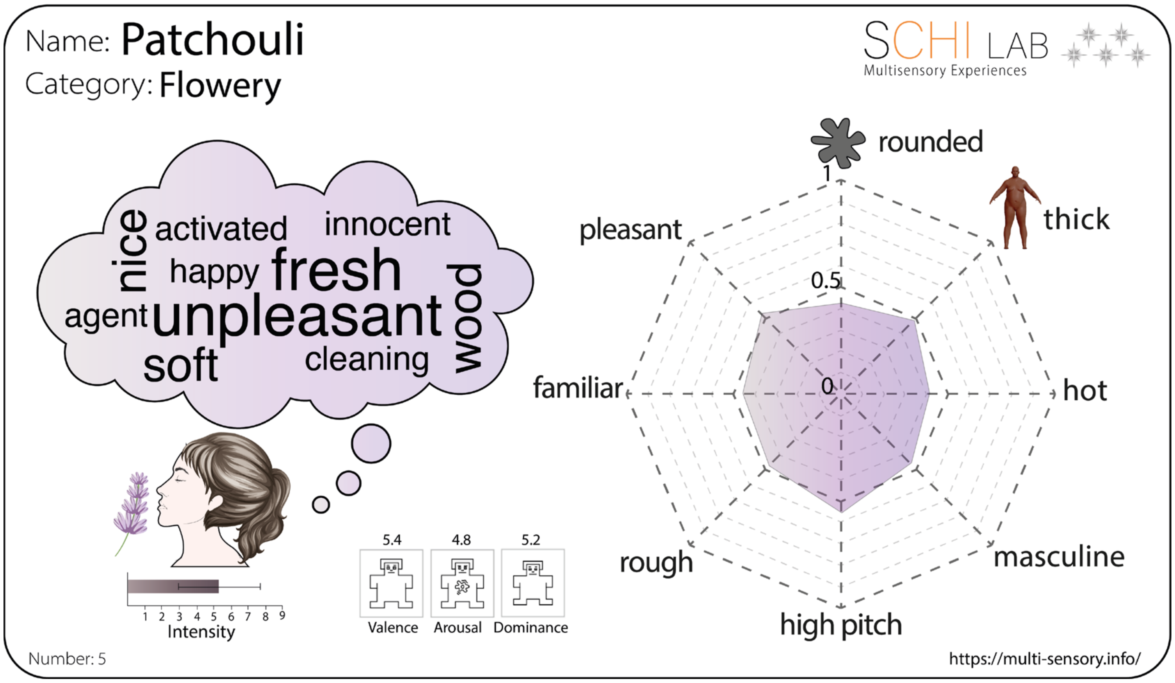

Name:
Category:
SCHI LAB
Multisensory Experiences
1 2 3 4 5 6 7 8 9
Intensity
Valence
Arousal
Dominance
rounded
thick
hot
masculine
high pitch
rough
familiar
pleasant
1
0.5
0
Number:
https://multi-sensory.info/

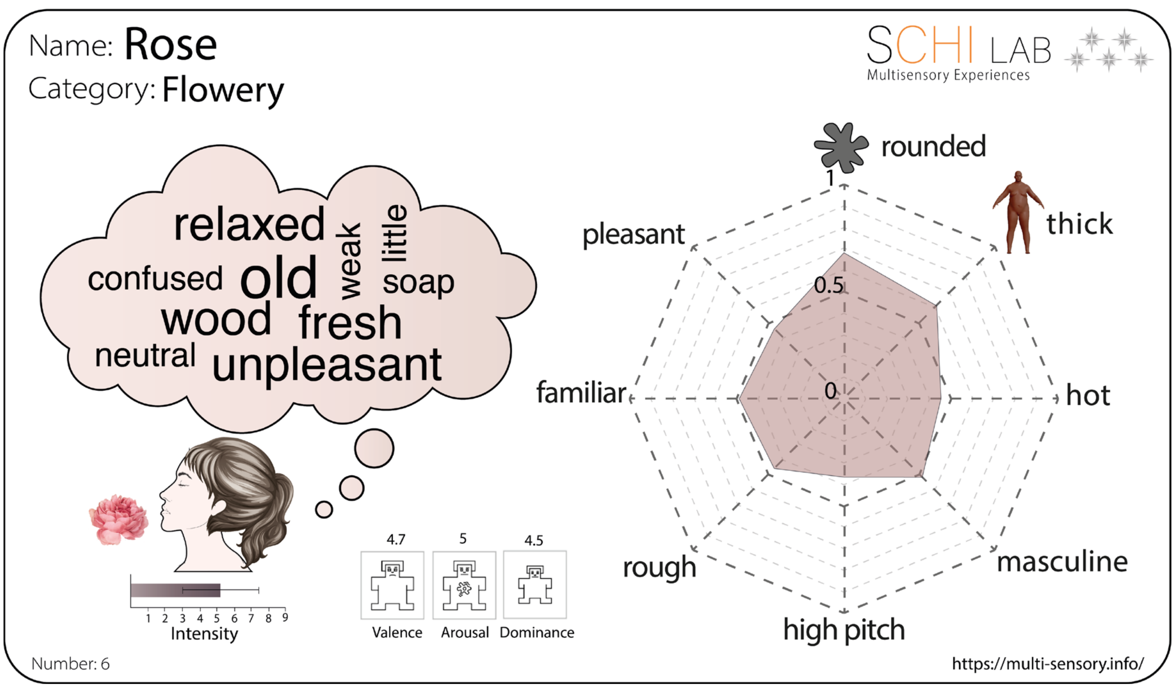

Name: Lemon
Category: Food
SCHI LAB
Multisensory Experiences
intense
cake
fresh
lemon
calm
happy
nice
pleasant
relaxed
citrus
Intensity
7.4
6.3
6.4
Valence
Arousal
Dominance
rounded
1
thick
pleasant
0.5
familiar
0
hot
rough
masculine
high pitch
Number: 1
https://multi-sensory.info/

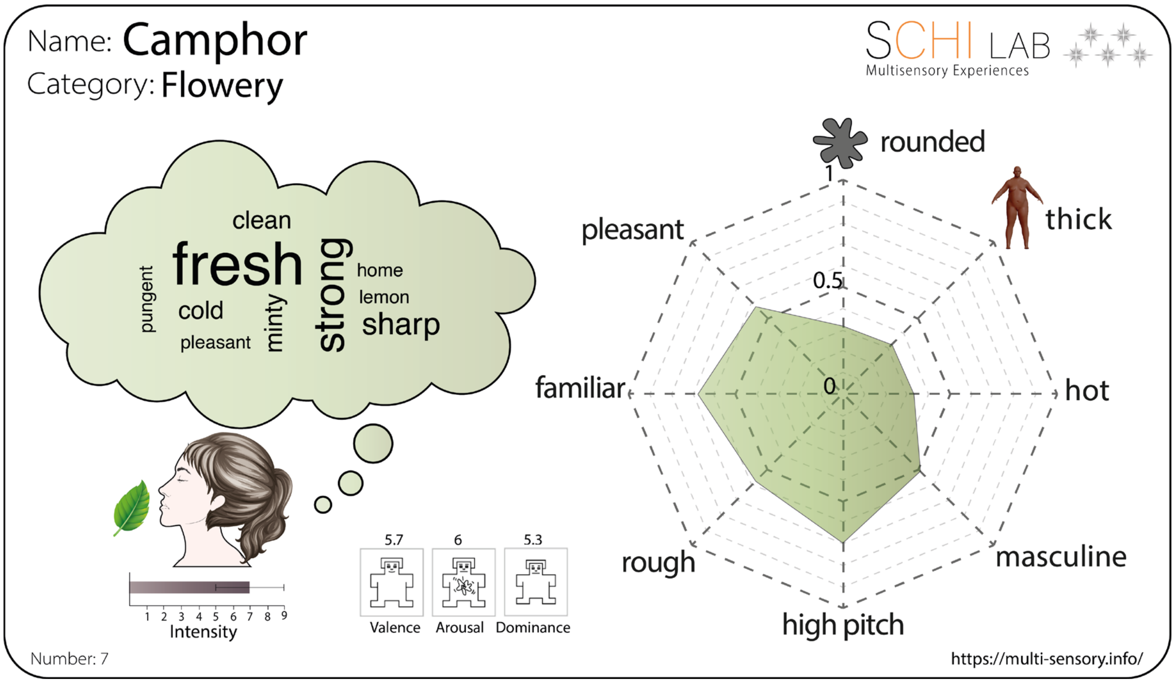

Name: Vanilla
Category: Food
SCHI LAB
Multisensory Experiences
anything
confused
maybe
light
fresh
neutral
calm
air
soft
clean
Intensity
6
4.6
5.7
Valence
Arousal
Dominance
rounded
1
thick
pleasant
0.5
familiar
0
hot
rough
masculine
high pitch
Number: 2
https://multi-sensory.info/

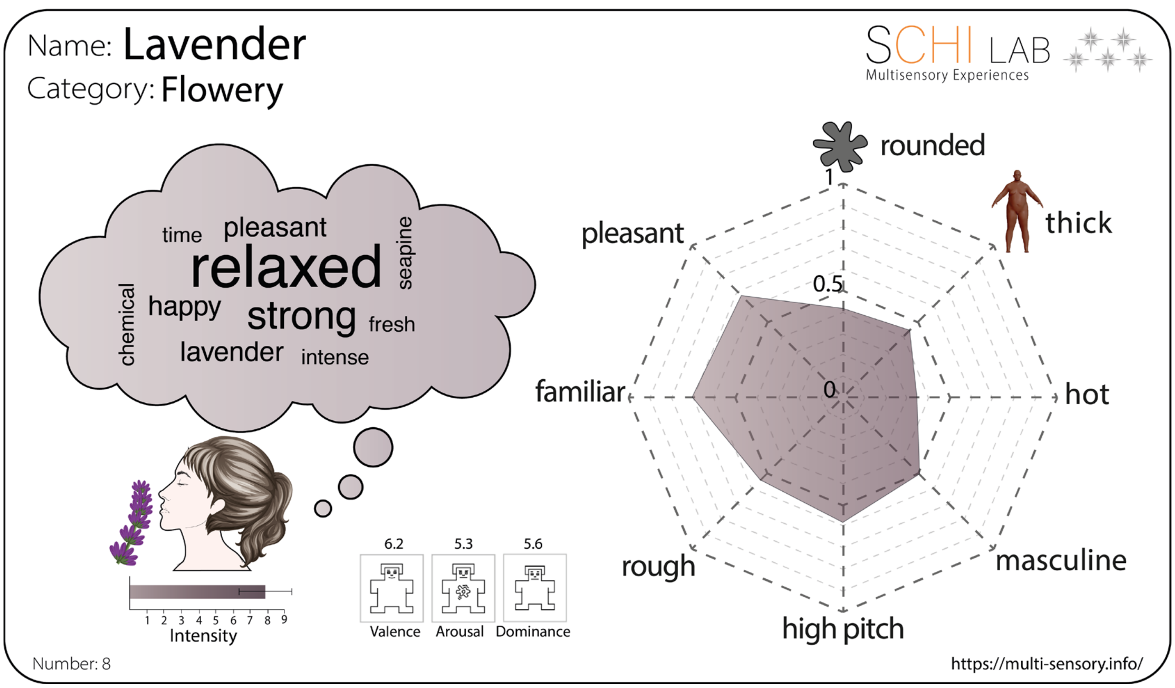

Name: Cinnamon
Category: Food
SCHI LAB
Multisensory Experiences
unpleasant
sweet
spicy
warm
gum
strong
cinnamon
relaxed
cosy
hot
1 2 3 4 5 6 7 8 9
Intensity
5.5
5.6
4.5
Valence
Arousal
Dominance
rounded
thick
pleasant
hot
familiar
masculine
rough
high pitch
1
0.5
0
Number: 3
https://multi-sensory.info/

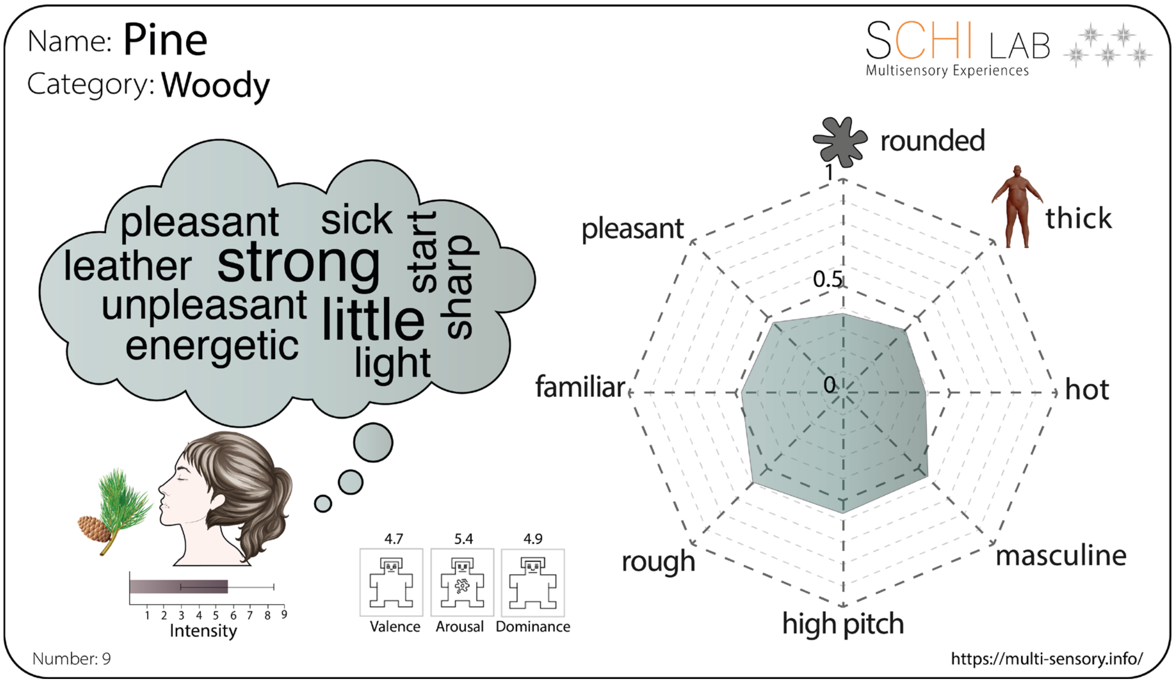

Name: Peppermint
Category: Food
SCHI LAB
Multisensory Experiences
minty
intense
peppermint
mint
fresh
sharp
unpleasant
eight
happy
gum
1 2 3 4 5 6 7 8 9
Intensity
7
6.4
6
Valence
Arousal
Dominance
rounded
thick
pleasant
hot
familiar
masculine
rough
high pitch
1
0.5
0
Number: 4
https://multi-sensory.info/

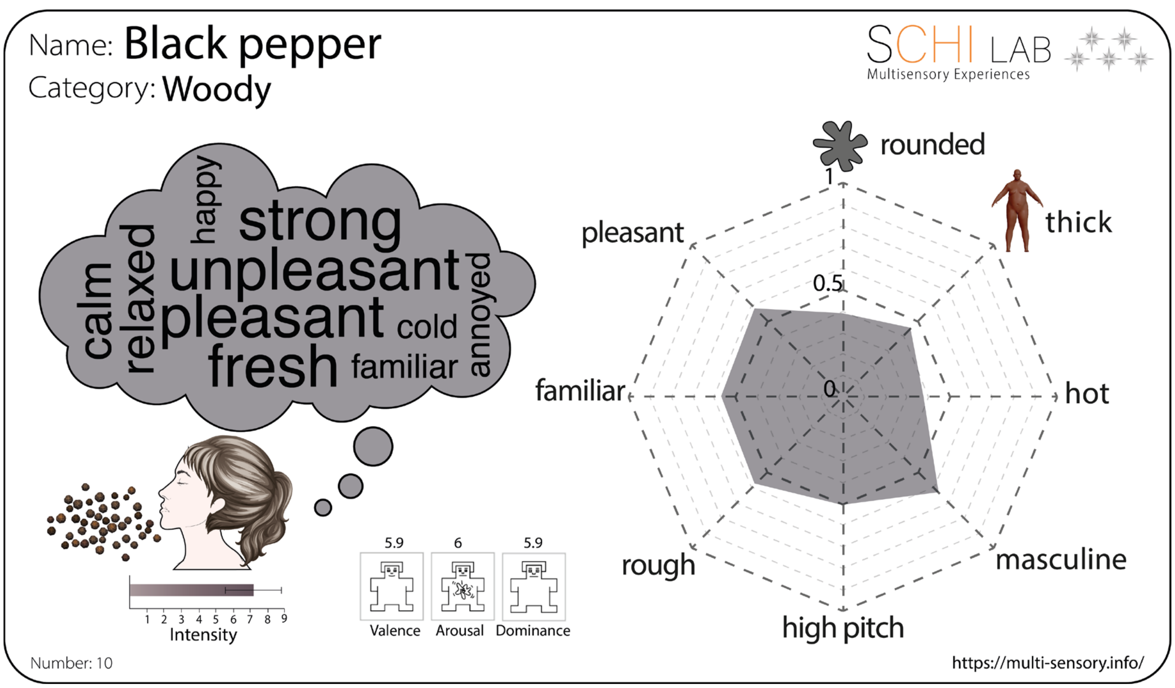

Name: Patchouli
Category: Flowery
SCHI LAB
Multisensory Experiences
nice
activated
innocent
happy
fresh
wood
agent
unpleasant
soft
cleaning
1 2 3 4 5 6 7 8 9
Intensity
5.4
4.8
5.2
Valence
Arousal
Dominance
rounded
thick
pleasant
0.5
1
0
familiar
hot
rough
masculine
high pitch
Number: 5
https://multi-sensory.info/

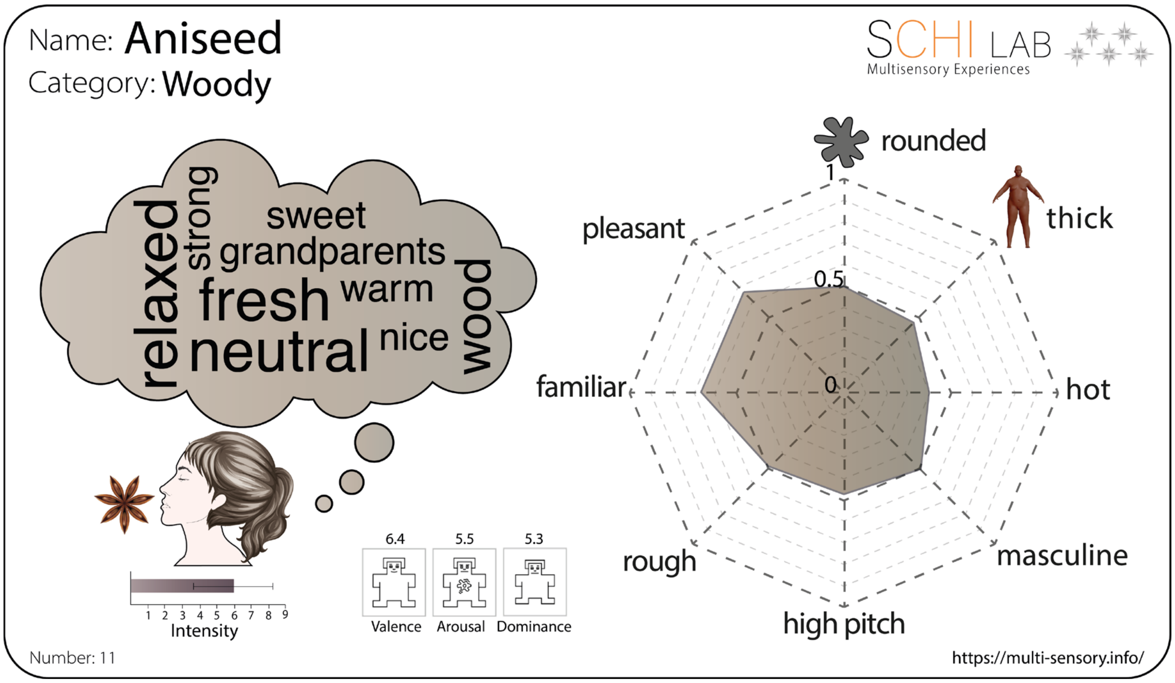

Name: Rose
Category: Flowery
SCHI LAB
Multisensory Experiences
relaxed
weak
little
confused
old
soap
wood
fresh
neutral
unpleasant
1 2 3 4 5 6 7 8 9
Intensity
4.7
5
4.5
Valence
Arousal
Dominance
rounded
thick
pleasant
1
0.5
0
familiar
hot
rough
masculine
high pitch
Number: 6
https://multi-sensory.info/

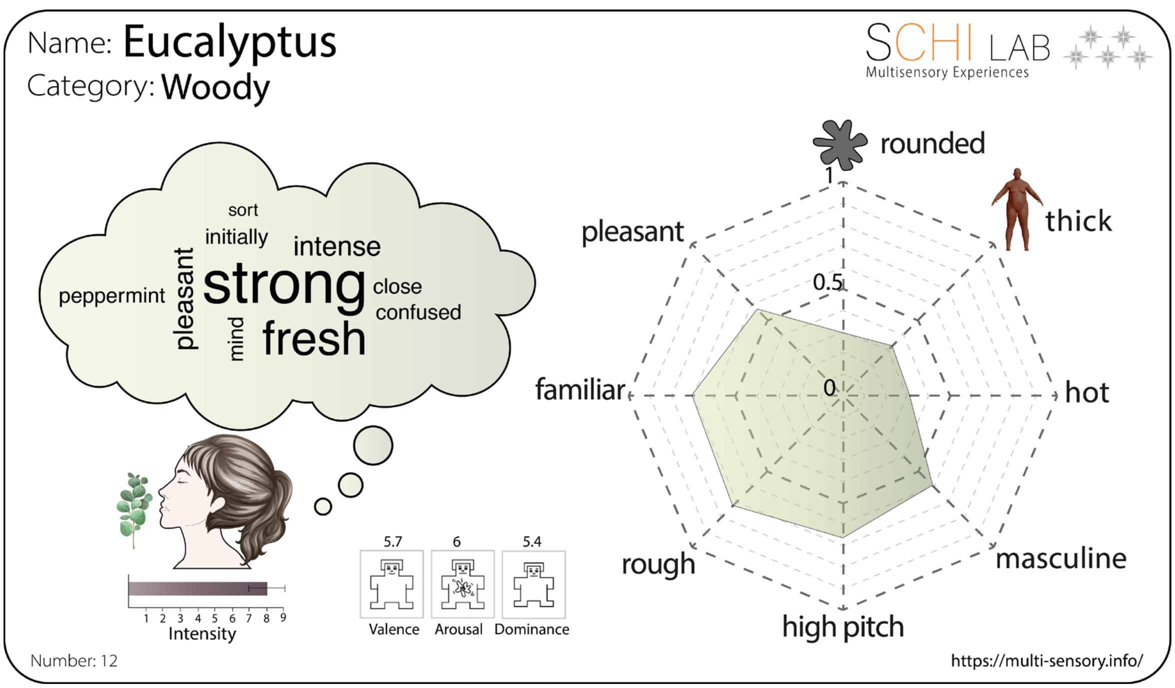

Name: Camphor
Category: Flowery
SCHI LAB
Multisensory Experiences
clean
fresh
pungent
cold
pleasant
minty
strong
home
lemon
sharp
Intensity
1 2 3 4 5 6 7 8 9
5.7
6
5.3
Valence
Arousal
Dominance
rounded
thick
hot
masculine
high pitch
rough
familiar
pleasant
1
0.5
0
Number: 7
https://multi-sensory.info/


Name: Lavender
Category: Flowery
SCHI LAB
Multisensory Experiences
time
pleasant
seapine
relaxed
chemical
happy
strong
fresh
lavender
intense
Intensity
1 2 3 4 5 6 7 8 9
6.2
5.3
5.6
Valence
Arousal
Dominance
rounded
thick
hot
masculine
high pitch
rough
familiar
pleasant
1
0.5
0
Number: 8
https://multi-sensory.info/


Name: Pine
Category: Woody
SCHI LAB
Multisensory Experiences
pleasant
sick
leather
strong
start
sharp
unpleasant
little
energetic
light
rounded
thick
pleasant
familiar
hot
rough
masculine
high pitch
1
0.5
0
4.7
5.4
4.9
Valence
Arousal
Dominance
1 2 3 4 5 6 7 8 9
Intensity
Number: 9
https://multi-sensory.info/


Name: Black pepper
Category: Woody
SCHI LAB
Multisensory Experiences
happy
strong
calm
relaxed
unpleasant
pleasant
cold
annoyed
fresh
familiar
rounded
thick
pleasant
familiar
hot
rough
masculine
high pitch
1
0.5
0
5.9
6
5.9
Valence
Arousal
Dominance
1 2 3 4 5 6 7 8 9
Intensity
Number: 10
https://multi-sensory.info/


Name: Aniseed
Category: Woody
SCHI LAB
Multisensory Experiences
relaxed
strong
sweet
grandparents
fresh
warm
neutral
nice
wood
rounded
thick
pleasant
hot
familiar
masculine
rough
high pitch
1
0.5
0
6.4
5.5
5.3
Valence
Arousal
Dominance
1 2 3 4 5 6 7 8 9
Intensity
Number: 11
https://multi-sensory.info/


Name: Eucalyptus
Category: Woody
SCHI LAB
Multisensory Experiences
sort
initially
intense
peppermint
pleasant
strong
close
confused
mind
fresh
rounded
thick
pleasant
hot
familiar
masculine
rough
high pitch
1
0.5
0
5.7
6
5.4
Valence
Arousal
Dominance
1 2 3 4 5 6 7 8 9
Intensity
Number: 12
https://multi-sensory.info/

## S.4 Smell-Inspired Sketches

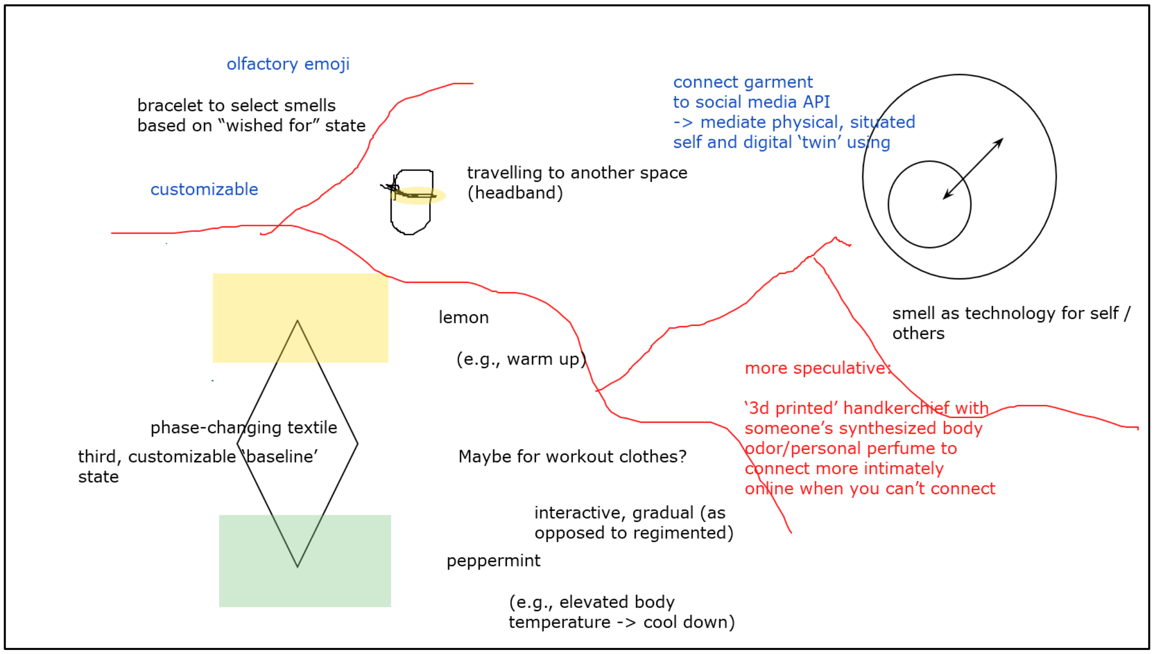



Figure S5. Sketches from Group 1 created during design exploration 1 (*group* session).

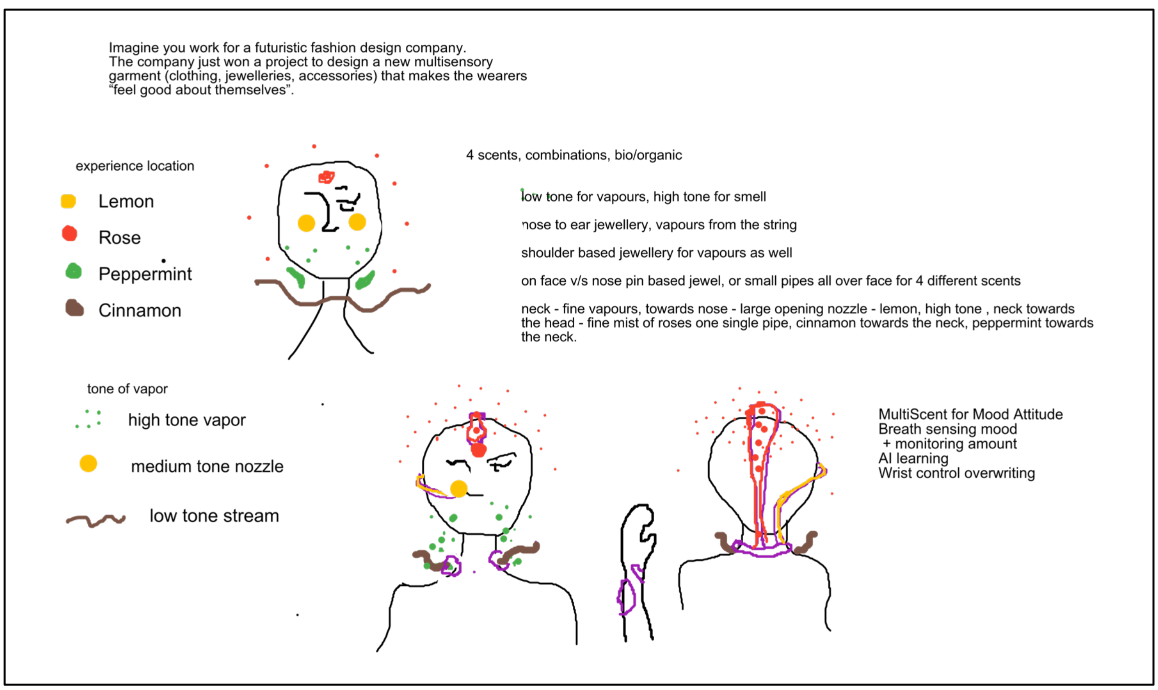



Figure S6. Sketches from Group 2 created during design exploration 1 (*group* session).

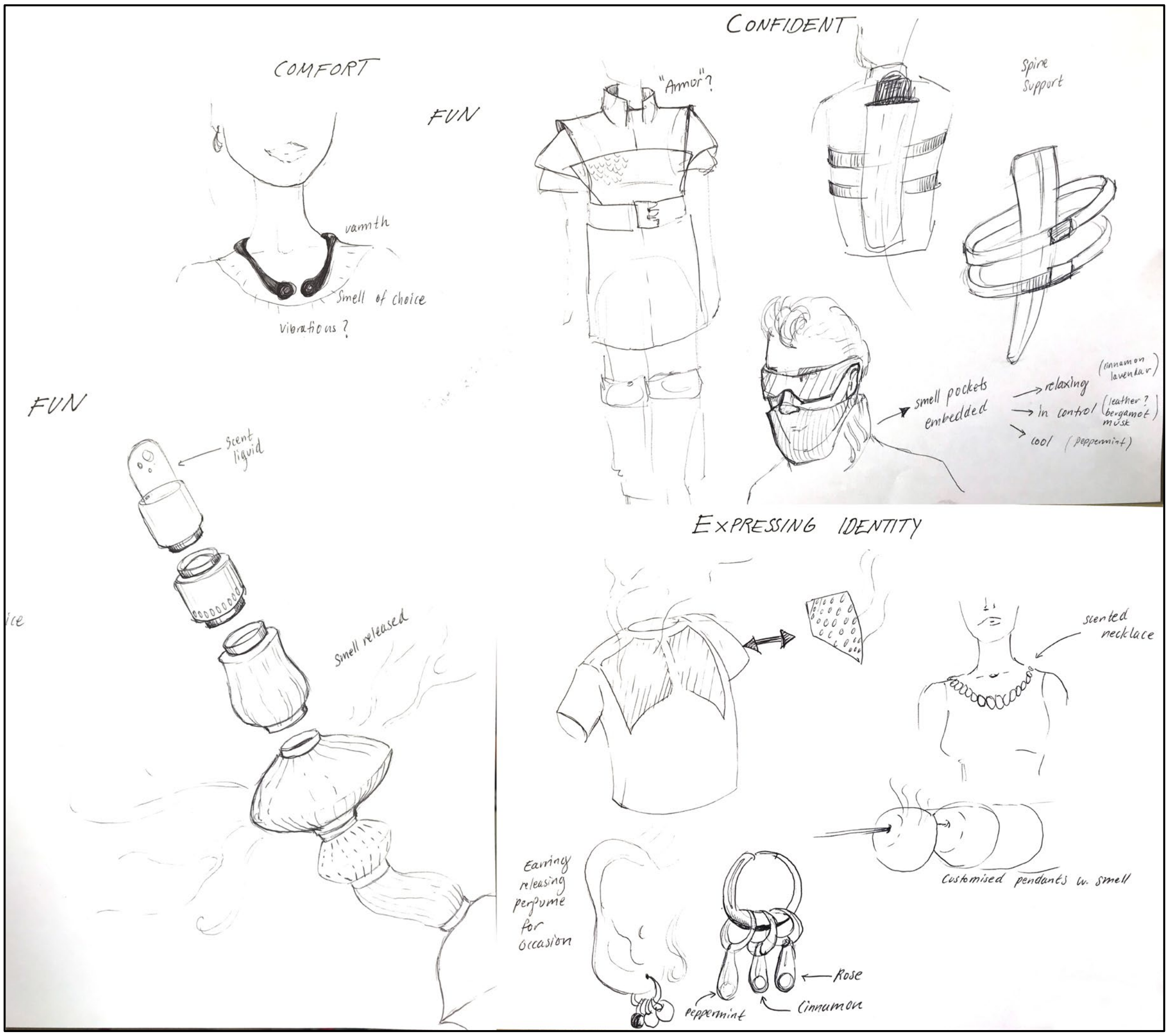



Figure S7. Sketches from Designer 1 created during design exploration 2 (*individual* session).

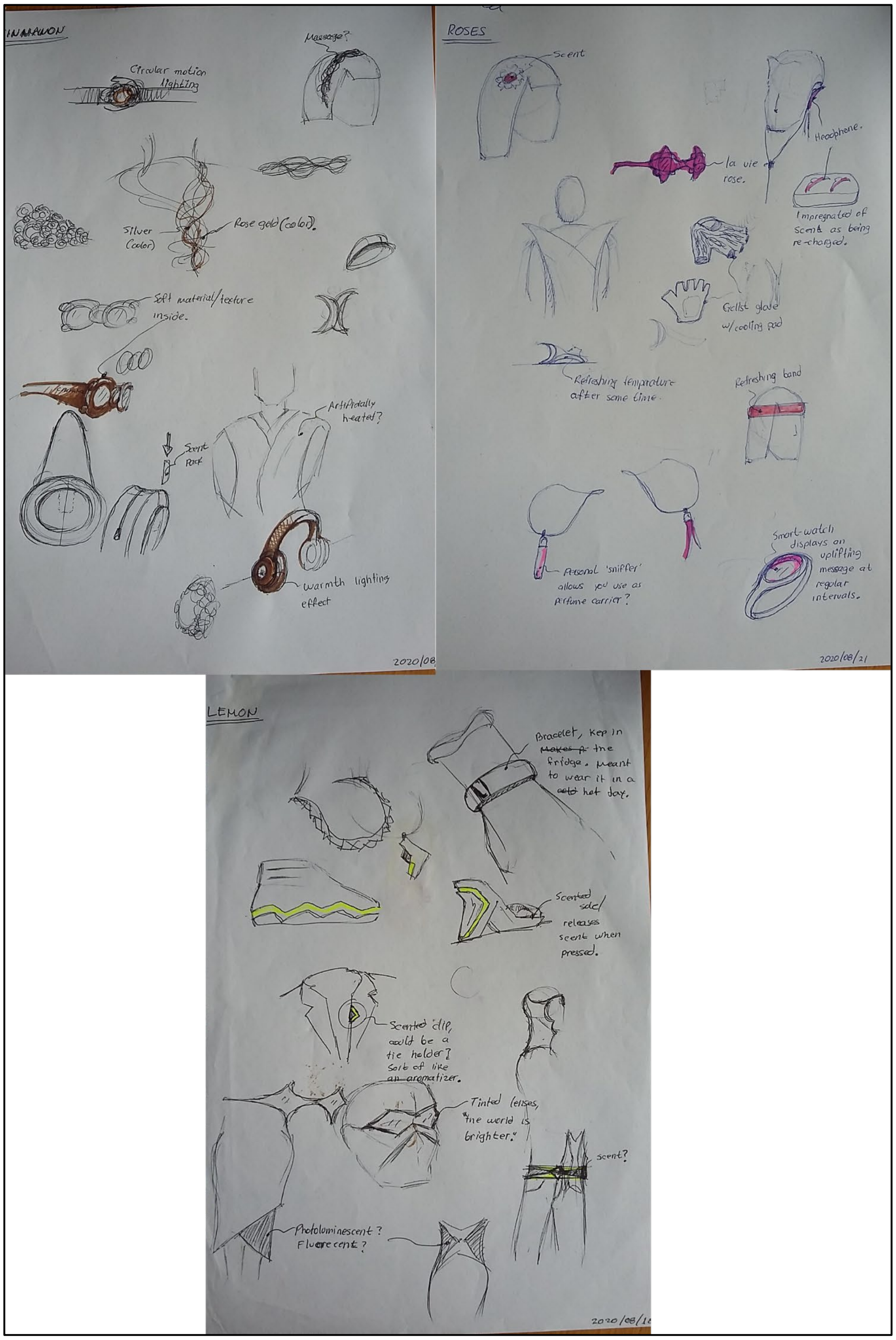



Figure S8. Sketches from Designer 3 created during design exploration 2 (*individual* session).