Scent Sensing: Exploring a Low-Fidelity Scent Medium for Olfactory-Based Interactions

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Figure 1: Scent Sensing Study Snapshots

ABSTRACT

Olfactory-based interactions (OBI) are steadily increasing due to advanced olfactory displays developed by established researchers and commercial companies. However, there is a lack of literature that investigates both qualitative and quantitative understandings of users' conscious olfactory abilities, perceptions, and reactions. This preliminary work presents steps toward exploring a low-fidelity scent medium for OBIs that evaluates users' ability to identify and discriminate various synthetic scents via scratch-and-sniff stickers. Paper olfactory displays utilized during OBI investigations can deliver quality scented experiences while increasing users' confidence in their smelling capabilities and memory recall. We conducted individual usability studies with undergraduate and graduate students (N=40). Observations from this study suggest that synthetic scents that imitate natural odors created an affective impression on users. Insights from this experimental design reveal the exigency of encouraging researchers to implement the use of a simple scent mediums to explore participants' olfactory abilities and perceptions while also ensuring quality experiences.

CCS CONCEPTS

• **Human-centered computing** → **User studies**.

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KEYWORDS

Olfactory, Smell, Paper prototyping, Olfactory Experience, Scents, Emotions

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1 INTRODUCTION & BACKGROUND

Dream pioneer the Marquis d'Hervey de Saint-Denys discovered through self-experimentation that he had the ability to manipulate the setting of his dreams to reflect the external world by repeatedly exposing himself to a particular perfume that he intentionally inhaled while awake in 1867 [13]. Since then, researchers have explored olfactory influence on emotions and memory with technological advancements. Olfactory-based interactions (OBI) has explored areas such as assisting the visually impaired [12], sessile bubbles for art [14], scented vehicular experiences [4], wearbles [1], and virtual reality [8]. These user-centered OBIs are steadily increasing which will soon require a uniform approach to ensuring user safety and awareness during their olfactory experiences.

With OBIs entering fields that may require a variety of settings, interactions, and users with varying ages, education, and backgrounds. Modern advancements in sensorial experiences such as Virtual and Augmented Reality (VR/AR) have incorporated the paper prototyping technique to assist users in immersive scenarios [9]. Designers are exploring interactive approaches to odor stimulation and evaluations by venturing into more noncomplex olfactory displays that prioritize users' scent perceptions and capabilities. FoodChestra is a pulley-based mechanism that openly hangs perishable food items designed by Tai et al. [16]. One of the system's multimodal features is highlighting the diffusion of natural odors

from the various fruits/vegetables which can be considered a simple olfactory display. TranScent aims to provide users with a hybrid approach to meditating with the use of paper or cone incense olfactory displays that are burnt in the real world while immersing the users in the audiovisual virtual environment [10]. Brooks & Lopes [2] even evaluated a toolkit that utilizes scratch-and-sniff stickers within a 3D-printed or cardboard cassette.

Scent Sensing emphasizes the importance of making olfactory displays with common/affordable materials, styled for quick encounters, and reducing exposure to electrical components, expert coding experience, or chemicals/liquids. Utilizing paper olfactory displays as a scent delivery medium is cost-effective, reliable, and does not require advanced skills or equipment. Paper olfactory displays are a simple technique to also predict possible challenges to more complex OBIs. In earlier research, we utilized paper-prototypes as accessible and durable olfactory displays during remote OBI study sessions via Zoom [7]. We found that they were effective in providing mental/emotional stimulation in various active settings. Much like the aforementioned researchers, our work is also concerned with the development of a low-fidelity olfactory display that provides a quality user experience. However, we specifically investigate users' unique olfactory ability to (i) supply a name for the unidentified odor [15], and (ii) differentiate amongst the odors. To evaluate the ScentSensing system we propose the following research questions:

- **RQ1:** Can synthetic scents that are inspired by natural odors affectively stimulate users?
- **RQ2:** Do users' perceptions of naturally occurring odors and synthetically compromised odors differ?

We expect insights gained during this study to contribute to the design and evaluation of future OBIs.

2 EXPERIMENTAL DESIGN

2.1 Participant Demographics

40 students (F=21, M=19) were recruited from the University of Alabama to participate in the 45-minute Scent Sensing study session. The average age was 20.3 (SD=3.2), with a range from 18 to 34. Students signed a consent form approved by the University of Alabama's Institutional Review Board (IRB) prior to beginning the activity. A short pre-survey was then administered to disclose any medically diagnosed allergies, their frequency of cologne/perfume wear, their frequency of wearing corrective eyewear, their frequency of respiratory/sinus illnesses, current health status, any previous nose, throat, or ear injuries, and their frequency of experiencing stress/anxiety. All participants were novices in olfactory training experiences.

2.2 Methodology

The study environment was sanitized by wiping down the table, chairs, laptop, and pens before and after each participant with 70% isopropyl. Each participant arrived at the study room at their designated time to begin the pre-study procedure. The participants read and signed the consent form. They also were informed that they are allowed to cease the study whenever they feel uncomfortable. This study offered minimal risk to the participants. Lastly, participants completed a pre-survey on Qualtrics. Once the documents are completed, the study session began.

This experiment required users to (i) give a name/description for an odor; and (ii) distinguish between administered odors as similar, familiar, or different to previous personal odor experiences. Grape, popcorn, bubble gum, apple, and lavender-scented scratch-and-sniff stickers were administered to participants in 5 individual rounds. Stickers were kept in separate Ziploc bags to ensure their scent quality. Between each round, users inhaled coffee grounds for 15 seconds. A digital timer was used to alert researchers to remove the coffee from the study table and administer the stickers. It is recognized that coffee beans assist in distinguishing scents due to their ability to possess a strong binding affinity to the olfactory receptors which can result in the detachment of other odorants from the receptors [5]. This will help with reducing olfactory fatigue and sensitivity to the study odor. A large box fan set to HIGH was present while also having both study room doors open. This allowed for controlled ventilation. Participants' audio was recorded for later analysis. The instructions consisted of, "Inhale deeply and try different visualizations that help you recall the scent in your mind. There is no right or wrong answer." We encouraged them to use colors, sounds, time periods in their lives, and other various descriptions to assist in their memory recall. We did not give participants a time limit to offer their descriptions. Participants were also not disqualified from the study if they did not complete the study tasks. Time was allotted for brief interviews where their memories and perceptions of the study were also recalled. All participants were compensated with $40 digital Amazon gift cards. Figure 1 depicts snapshots that were captured during the study. **A.** These are some of the scratch-and-sniff stickers used during the study. They were cut and stored individually to ensure freshness. **B.** A participant sniffing the sticker. **C.** A participant sniffing the coffee grounds that were used to clear the olfactory pallet.

3 RESULTS

The observed study data is presented in Table 1. We evaluated the data using Tukey's multiple comparisons of means [11] for the analysis of the relationship between the odor pairs and their accompanying sore. The user score scale was "1: Uninterested", "2: Curious", and "3: Correct". Each scent category (grape, popcorn, bubble gum, apple, and lavender) was assigned 1 through 5. This analysis was conducted at a 95% family-wise confidence level so that the confidence intervals and p-values would be adjusted to control for the overall type I error rate. The pairwise comparison reported p-values that indicate the statistical significance of the differences between the scent categories. The comparison between "Popcorn - Grape" (**p adj = 0.003**) and "Bubble Gum - Popcorn" (**p adj = 0.020**) shows a significant difference. Other comparisons did not show significant differences (**p adj > 0.05**). Pearson's Chi-squared test [6] was also utilized to determine if there was a significant association or difference between these specific scent categories. "Grape vs Popcorn" reported **p-value = 6.058e-05**. "Popcorn vs BubbleGum" reported **p-value = 0.00069**. "Popcorn vs Apple" reported **p-value = 0.00060**. Based on the given results, we suggest that there is

Table 1: Tukey Multiple Comparisons of Means 95% Family-Wise Confidence Level

Odor Pairs	Mean Difference	Lower Bound	Upper Bound	P Adj.
Popcorn-Grape	-0.47	-0.83	-0.11	**0.003**
Bubble Gum-Grape	-0.07	-0.43	0.28	0.978
Apple-Grape	-0.22	-0.58	0.13	0.419
Lavender-Grape	-0.12	-0.48	0.23	0.872
Bubble Gum-Popcorn	0.40	0.04	0.75	**0.020**
Apple-Popcorn	0.25	-0.10	0.60	0.310
Lavender-Popcorn	0.35	-0.01	0.70	0.059
Apple-Bubble Gum	-0.15	-0.50	0.20	0.778
Lavender-Bubble Gum	-0.05	-0.40	0.30	0.995
Lavender-Apple	0.10	-0.25	0.45	0.939

evidence of a significant association or difference between the odor "Popcorn" when compared to the other odors.

4 DISCUSSION

RQ1: Can synthetic scents that are inspired by natural odors affectively stimulate users? The findings from our Scent Sensing study revealed that the synthetically compromised odor, "Popcorn", does indeed affectively stimulate users as seen from the statistically significant differences. We later discovered that these suggestions align with Castro et.al [3] findings. These researchers identified a list of rank-ordered descriptors for 10 basis vectors obtained from non-negative matrix factorization. Amongst the list of odor labels is "Popcorn" with its own column of associated scents and descriptors. During this study, users attempted to provide a name or description for the odor they inhaled via scratch-and-sniff stickers. Common descriptions reported from our users during the "Popcorn" assessment emphasized *"Stale"*, *"Buttery"*, *"Croissant"*, *"Bean"*, *"Nutty"*, *"Brief"*, *"Wood"*, *"Dull"*, and *"Earthy"*.

RQ2: Do users' perceptions of naturally occurring odors and synthetically compromised odors differ? Naturally occurring odors such as flowers, fruit, or sweat can vary in intensity/duration and may be difficult to maintain freshness. Synthetic scents created from altering odor notes through chemical manipulation can also vary in intensity/duration while also including the risks of spillage or bodily harm. This study suggests simple odor mediums such as paper can deliver quality OBIs that influence users' perceptions. Other mediums such as cheesecloths, carbon filters, cotton, and wood should also be explored for ambient displays or with more accelerated odor delivery techniques. Utilizing more comprehensible mediums can translate well into the future of olfactory education, training, and awareness. Scent Sensing's insights raise the importance of designing OBIs for simple scent deliveries to low the barrier for future olfactory research.

5 CONCLUSION

This paper discusses the design and evaluation of Scent Sensing, a systematic approach to understanding users' unique olfactory abilities to (i) supply a name for the unidentified odor and (ii) differentiate amongst the odors. Evaluation results from this user study suggest that the interaction with synthetic scents that are inspired by natural odors via scratch-and-sniff stickers can affectively stimulate the inhalers. Exploring accessible olfactory displays can increase the interest of users with varying demographics to explore or incorporate more modular interactions into their daily lives. Furthermore, insights from this study could be used to enhance future olfactory-based interactive systems.

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