The Scent of Collaboration: Exploring the Effect of Smell on Social Interactions

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Figure 1: A) We designed a scent-emitting necklace to be worn by users during our study. B) Two users in the collaborative story writing task wearing the necklace. C) A standardized visual stimulus shown to users during the writing task.

ABSTRACT

Social interactions are multisensory experiences. However, it is not well understood how technology-mediated *smell* can support social interactions, especially in collaborative tasks. To explore its effect on collaboration, we asked eleven pairs of users to work together on a writing task while wearing an interactive jewelry designed to emit scent in a controlled fashion. In a within-subjects experiment, participants were asked to collaboratively write a story about a standardized visual stimulus while exposed to WITH SCENT and WITHOUT SCENT conditions. We analyzed video recordings and written stories using a combination of methods from HCI, psychology, sociology, and human communication research. We observed differences in both participants' communication and creation of insightful stories in the WITH SCENT condition. Furthermore, scent helped participants recover from communication breakdown even though they were unaware of it. We discuss the possible implications of our findings and the potential of technology-mediated scent for collaborative activities.

CCS CONCEPTS

• **Human-centered computing** → *User studies*; Empirical studies in HCI; **Interaction devices**.

KEYWORDS

Olfactory Interfaces; Collaboration; Social Interactions; Smell; Scent; Necklace; Communication

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1 INTRODUCTION

Social interactions are central to our everyday lives. Two common and important means of social interactions are face-to-face (F2F) conversations and social engagement ([31], ch. 4). F2F conversations have the distinction of seeing the other person in a conversation, while social engagement refers to participating in the activities of a social group. New technologies that support social interactions like F2F conversations and collaboration are being developed and integrated into people's lives [7]. These technologies are not only displays or desktop computers but are integrated into wearables as well. They often rely on controlling a stimulus, like a visual, tactile, or auditory signal in a natural way to help improve the quality of communication and increase social engagement [37].

Smell is a less commonly addressed sense that is integral to human-human interaction in the physical world [27]. People use scents such as perfumes and deodorants as a means of self-expression to convey a certain image or message, and keep bodily odors at bay. From psychology and sociology literature, we know that smell plays a vital role in influencing human interactions [3, 15]. Of our five senses, smell is the least understood in the HCI literature [36]. A few research projects such as Essence [1], inScent [10], and On-Face Interfaces [38] have investigated the design of olfactory interfaces with a focus on aesthetics and portability. However, these projects did not explore the impact of smell on social interactions. Investigating and understanding the effects of smell on social interactions in a collaborative setting can therefore generate insights into how olfactory interfaces could benefit such situations.

In this work, we investigate the effect of technology-mediated scent release[1] on the quality of communication and social engagement in a collaborative task. In a controlled within-subjects experiment, we asked eleven pairs of participants to collaboratively write a story based on a visual stimulus following the Thematic Apperception Test method [26]. Each pair randomly performed the task once without a scent stimulus and once with a controlled scent stimulus that was released from a wearable device prototype in the form of a jewelry piece. We adopted methods from HCI, psychology, sociology, and human communication research, and combined them for our data analysis.

In summary, our key contribution is an empirical study of how controlled smell release influences social interactions in a collaborative activity, analyzed using multiple methods from different HCI-related disciplines.

2 RELATED WORK

In HCI, smell has been explored mostly in the context of ambient notifications [25], designing VR experiences [29], and in-car interactions [41]. Most work on smell in HCI focuses on developing and evaluating smell-enhanced technologies. Looking at the effect of smell instead, Obrist et al. collected personally memorable smell experiences in an online questionnaire [27]. In their work, eleven users reported stories about how their social interactions had been affected by smell in the past. The key findings of this research were guidelines for designing experiences with smell, and its relevance for well-being and behavior change research in HCI. We adopted this approach to understand the role of scent in social interactions and explore the effect of smell on communication and social engagement.

Social interactions are shaped predominantly by our sight, touch, and hearing. Garrido et al. showed people with depression were more likely to engage in social interaction with music [17]. Similarly, to target the sense of taste, Boltong et al. showed that common social interactions centered around eating and drinking are an important part of helping patients heal during a chemotherapy treatment [6]. Creativity and creative activities can also be enhanced through sensory experiences [19]. Gonçalves et al. conducted a study with 100 high school students to investigate the effects of auditory and olfactory support during a creative writing task. They found that support in the form of scent is beneficial for creative work, and recommend integrating scent into creative writing environments [19]. However, they did not explore the effect of smell on social interactions during F2F conversations. Similarly, Zemke et al. explored the effect of smell in a physical environment, e.g., a room or lobby [43]. Their study results point to ambient scent having a positive effect on the number of social interactions between users.

Like Goncalves et al. [19], our study also includes a story writing task and investigates the impact of smell. However, we focus on the effect of smell on social interactions and engagement rather than merely the number of social interactions or creativity. We also analyzed the data with multiple lenses to reach further insights into the impact of smell on communication and social engagement. In this work, we aim to generate insights regarding the impact of smell on a collaborative task. Our research is looking for a deeper understanding of the quality of communication and social engagement in F2F settings — as elements of social interactions. This way, we would like to contribute ideas into which social interaction scenarios scent could be integrated to be beneficial for the user.

3 USER STUDY

We designed our study to measure the impact of *released scent* on users' social interactions during a collaborative writing task. Our task included writing a story inspired by a given image using a collaborative text editor (MS Word)[2].

3.1 Study Design

Our user study was within-subjects with two conditions: WITHOUT SCENT (baseline) and WITH SCENT, and was conducted in pairs. In the WITHOUT SCENT condition, participants did not wear a device, and no scent was released. In the WITH SCENT condition, both participants wore a device that released a timed scent. Similar to Essence [1] and inScent [10], we used peppermint scent because it enhances alertness, focus, and concentration [39]. Each device was filled with 5 drops of peppermint essential oil diluted in 15 ml of filtered water.

[1]For clarity, we distinguish between the human sense of *smell*, and *scent* as the effect created by certain molecules in the air.

[2]https://office.live.com/start/word.aspx; we chose Microsoft's Word Online editor since all our participants were familiar with it.

We recruited 22 participants, 10 female and 12 male (M = 25.6 years; SD = 0.94 years), through our university's mailing lists. Participants were arranged in eleven pairs. Ten participants chose to be paired with a friend; the other 12 participants were paired up randomly. They were instructed not to put on any scents (perfume, cologne, scented deodorant) before the experiment. All participants reported having normal olfactory acuity, and were compensated with a 20 Euro raffle. Each pair executed each condition once. Six pairs started with the WITHOUT SCENT condition, and five pairs started with the WITH SCENT condition. During each condition, a participant pair worked together to write a single story inspired by a visual stimulus (Fig. 1, C). We chose story writing in pairs to facilitate collaboration and understand the impact of scent on social interactions.

3.2 Prototype Description

To explore the effect of smell on social interactions during a collaborative task, we needed to create a prototype. We explored several ways of delivering the scent, e.g. as a desktop device or through a smartwatch, but decided to aim for a smell interface worn close to the body to assure that the scent released would reach the participant's nose directly without the need to carry it in their hands all the time. Hence, we decided on a jewelry piece. Jewelry has been used in the context of social interactions before [23]. Our focus, however, was not to invent another artifact. Instead, we utilized previous projects (Essence [1] and inScent [10]) as inspiration to create our prototype. Our artifact design was a means to an end for the study. For this research, we designed two devices as our study design required a pair of participants to collaborate for the task. For replication purposes, details on the design and building process can be found in the supplementary.

3.3 Task & Procedure

The user study was conducted in a silent room. The timeline in Fig. 2 visualizes all steps of the experiment. Before starting the experiment, participants signed consent and data protection forms. Then, each participant was asked to sit in front of a computer. The participants sat 1.5 feet away from each other (see Fig. 1), which is considered a 'close phase' personal distance for social interactions according to Hall's proxemics [20]. Lastly, we demonstrated to participants how our device works to avoid its novelty effect. We verified with participants that scent released from the device reached their nose directly. Then, each participant filled out a short personality test based on the mini-IPIP BIG Five scale [12] (Fig. 2, step 1). Next, the pair received an image that was displayed on a 60' screen in front of them. The pair was asked to write a story about that image within 15 minutes. They were prompted to talk aloud, communicate, discuss their thoughts, and use their imagination and creativity to prepare and write a script together. The images displayed on the screen were chosen from a standardized pool used in the Thematic Apperception Test (TAT) ([26], see Fig. 1). It is important to note that TAT images are designed such that the impact of every image on possible stories is balanced [9].

TAT helps reveal participants' underlying motives and perceptions of the social world by asking them to write stories inspired by an ambiguous image. The choice of the TAT image[3] was based on the manual by Weiner et al. [40]. After the first 15 minutes, participants were asked to stop writing and fill out an Iowa Communication Record (ICR) [13], which is a questionnaire to measure the quality of communication. Afterwards, the second collaborative writing session began with a new TAT image, with the opposite condition (WITH SCENT or WITHOUT SCENT). In the WITH SCENT condition, the device released scent every 3 minutes, i.e., at the 0th, 3rd, 6th, 9th, and 12th minute, controlled by an Arduino microcontroller. The researcher just had to trigger the start of the Arduino program remotely, similarly to Essence [1] and On-Face Interfaces [38]. The scent was released for ten seconds, and intensity was kept uniform for all participants. Between conditions during the break, we ventilated the room to ensure no scent was left in the room, following the procedures by Gagarina and Pikturniene [16]. Finally, we interviewed each pair of participant together regarding their experiences.[4]

3.4 Measures

We drew established research methods from different disciplines to understand the impact of smell and its relevance for HCI in our user study. In particular, we wanted to study (i) the effect of scent release on the quality of communication that participants had during story writing; (ii) the impact of scent on participants' social engagement in a collaborative task; and (iii) the role of scent during communication breakdown(s).

3.4.1 Iowa Communication Record (ICR). To measure the first effect, we used the *Iowa Communication Record (ICR)* [13]. It is used widely to understand the quality of human communication and has been validated across multiple studies (e.g., [5, 14, 35]). The ICR consists of semantic differentials for the quality of communication, measured on a nine-point scale (e.g., "relaxed–tense," "personal–impersonal"). It also considers the length of time two people know each other, their relationship, conflicts during the conversation, and communication breakdowns.

3.4.2 SCORS-Global. To measure the second effect, we adopted the SCORS-Global method [4] used in psychology to understand the narrative accounts of written stories and social engagement. Psychology researchers advocate this method for its simplicity to understand underlying notions of a written text [2]. It uses TAT images for the narratives. SCORS-G includes eight dimensions, which are scored using a seven-point Likert scale. Our user study only used the three dimensions of SCORS-G that focus on social interactions.

The first, *Complexity of representations of People (COM),* is based on the ability to understand and distinguish between feelings and people's personalities seen in an image. Higher scores are suggestive of a more mature and complex understanding of the TAT images [32]. The second, *Affective quality of representations (AFF)*, captures the emotional lens with which people view our world and what they expect from relationships. Lower scores indicate that a person views her environment in a malevolent way, while higher scores

[3]Included TAT images: 01, 02, 3BM, 04, 06BM, 07BM, 08BM, 010, 12M, and 13MF.
[4]During the experiment, depending on their sitting posture participants sometimes held the device to keep it pointing straight up, as confirmed in exit interviews.

Figure 2: Timeline of the user study: first, the device was demonstrated to participants, followed by the mini IPIP BIG Five personality questionnaire. After a break of 5 minutes, in session one, a Thematic Apperception Test (TAT) image was shown on the screen, and participants started writing their story based on it. Session two was conducted similarly, with the only difference being whether scent was released or not. Both sessions ended with participants completing the Iowa Communication Record. Each session lasted 15 minutes followed by a 10-minute break. The complete duration of the user study was one hour, and the conditions were counterbalanced.

suggest a cooperative way [32]. The third, *Understanding of social causality (SC),* assesses the extent to which a person understands human behavior, for example, how a person gets from point A to B and C. Shorter narratives (word length) are generally rated lower on the variable, though not exclusively [32].

3.4.3 Video Recordings. An independent psychology researcher used the video analysis pattern of Heath et al. [21] to investigate communication breakdowns. The researcher transcribed the videos as conversations and visible conduct (gestures and head nods) based on the timeline to develop preliminary observations and insights. For any action in the video, the researcher analyzed how the action might result from prior actions, how one person might treat the other person's action, or what the action may have led to afterwards.

3.5 Results

To investigate the impact of smell on participants' social interactions, we triangulated different data sources, such as behavioral data, participants' verbal accounts, video recordings, self-reports using psychometric scales, and exit interviews. Regarding counterbalancing, we had 11 pairs of participants, which resulted in five encountering the WITH SCENT condition first, and six the other one. (If we leave out one data pair in our analysis, for five pairs in each group, we get the same results. This holds for every combination of five pairs, no matter which pair we leave out.)

Two authors and an external psychologist rated the written stories. Each rated them over three to four rounds individually, following the SCORS-G manual [32]. Intercoder reliability analysis was performed using Cohen's kappa to determine agreement and consistency between all coders for the rated stories. There was a near-perfect agreement among all three coders for three dimensions [COM: κ = .900, (95% CI, .643 to .937), p < .0005; AFF: κ = .964, (95% CI, .717 to .943), p < .0005; SC: κ = .902 and (95% CI, .618 to .927), p < .0005]. A Shapiro-Wilk test showed our data was not normally distributed for the ICR, COM, AFF, and SC scores. This was confirmed by a Kolmogorov-Smirnov test. Therefore, non-parametric statistical tests were conducted for both ICR and SCORS-G (COM, AFF, and SC).

3.5.1 Effect of Scent on the Quality of Communication. Scent played a significant role in enhancing the overall quality of communication on certain Iowa parameters. After applying a Bonferroni Correction to reduce the alpha level because of the multiple comparisons being made using sub-scales, our α_{new} = .005. Our results showcase that participants were more *open* ($\chi^2_r(1) = 10.22$, $p < 0.005$), with a mean score of 7.81 in the WITH SCENT condition compared to 6.27 in the WITHOUT SCENT condition (where 1 = guarded, 9 = open). Their communication was more *in-depth* ($\chi^2_r(1) = 8.90$, $p < 0.005$), with a mean score of 3.68 in the WITH SCENT condition compared to 5.04 in the WITHOUT SCENT condition (where 1 = in-depth, 9 = superficial). Furthermore, we did not find any significant difference in any other communication parameters of IOWA.

The video recordings and exit interviews corroborate our results. Analyzing the video recordings found the WITH SCENT condition leading to more open and in-depth communication during the task. After the third scent release, while P5 was writing the story, she told her partner that she was more thoughtful towards the task. P6 agreed and cited P5's flow of the story construction depicting the same. Similarly, in the exit interview, P14 reported that "*I felt relaxed when the scent was released, and it gave me a sense of belonging [to] the experiment*".

3.5.2 Effect of Scent on Complexity of Representations (COM). The *COM scores* in the WITH SCENT condition (mean = 4.34, 95% CI 2 to 6.5) were rated higher compared to the WITHOUT SCENT condition (mean = 3.84, 95% CI 1.5 to 6.5). A Friedmann test showed that the difference in COM scores between the two conditions is statistically significant ($\chi^2_r(1) = 8.75$, $p < 0.05$) [42]. The video recordings revealed that after the release of scent, participants were more attentive towards the shown TAT image. P16 explained that "*scent was helpful as a brain booster, as it redirected me to look into some complex and hidden parts of the image.*". We observed that after every scent release, participants took turns in their story focusing upon different objects in the image. P9 reported that "*the scent release worked as a short break for me to close my eyes, and rethink the story [with] feelings associated with characters".*

3.5.3 Effect of Scent on Affective Quality of Representations (AFF). The *AFF scores* in WITH SCENT condition (mean = 4.12, 95% CI 1 to 6) was similar compared to the WITHOUT SCENT condition (mean = 4.09, 95% CI 1 to 6). A Friedmann test showed there is no significant difference between the two conditions ($\chi^2_r(1) = 1.09$, $p > 0.05$). Analyzing the video recordings, it was found that participants did not focus on understanding evoked interpersonal relationship among the characters in either condition. During exit interviews, we asked for emotions elicited during the task. P20 reported that "*I could not find myself in a position where the image evoked any emotions in me that would influence my story.*" P15 reported that "*for both sessions, the emotions elicited in stories were nearly similar. I couldn't see any effect of the scent.*"

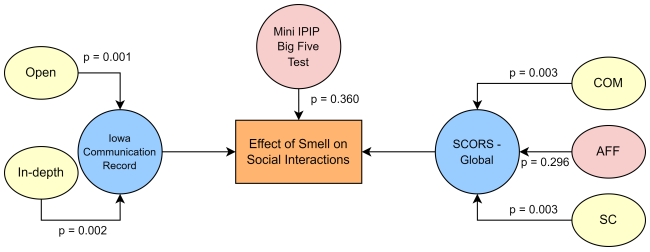

Figure 3: Summary of our results: For SCORS - Global, COM and SC were found to be significantly different in the scent condition compared to the no scent condition. Similarly, for ICR, we found Open and In-depth attributes significantly different. Mini IPIP Big Five test and AFF values were not found to be significantly different in the two conditions.

3.5.4 Effect of Scent on Understanding of Social Causality (SC). The *SC scores* were rated higher in the WITH SCENT condition (mean = 4.53, 95% CI, 2 to 7) compared to the WITHOUT SCENT condition (mean = 3.54, 95% CI, 1 to 7). A Friedmann test revealed a significant difference between the two conditions ($\chi^2_r(1) = 8.75$, $p < 0.05$). This implies that the experience and interpretation of the image shown in the stories were more comprehensive and detailed in the WITH SCENT condition. In a session when the scent was released P12 stopped writing and shifted her focus to the image. This shift in focus helped her re-frame the story considering all the characters and elements presented as observed from the video recording. A similar trend was observed for P3, P9, and P17. When we asked about flow and details of the story during the exit interview, P3 told us: "*It was very sudden and magical after the scent release that I could look for non-vital elements in the image that somehow related to the characters*". Similarly, P17 reported that "*scent made me meditate for a while and focus on connecting the story using different points that we wrote together.*"

3.5.5 Effect of Scent on Communication Breakdowns. Interestingly, in the exit interviews, 17 of 22 participants did not report smell being helpful in overcoming communication breakdowns, matching their ICR scores. However, we observed for seven participants in the WITH SCENT condition that when they struggled to continue with the story, the scent release helped overcome this breakdown. This recovery was not dependent upon the condition they started with. Surprisingly, six of them were also among the 17 participants who did not report any perceived role of smell.

3.5.6 Effect of Participant's Relationships on Communication. In the ICR, participants were asked to report if they already knew their partner. They needed to classify the partner as a stranger, acquaintance, (best) friend, and report the length of time they had known their partner. A χ^2 test of independence showed that participants who classified themselves as (best) friends were more informal compared to acquaintances and strangers (χ^2 (21) = 17.992, $p = 0.003$). There were no other significant correlations between relationship status and other ICR parameters.

4 DISCUSSION

Based on these results, we see the potential for scent to be used as a medium for communication, turn-taking, and social engagement. Below, we highlight the effect of scent on two factors of collaborative social interactions: quality of communication and social engagement. We also reflect on how scent can help overcome communication breakdowns, and provide insights on how integrating scent technology can mediate social interactions and collaborations.

4.1 Influence on Quality of Communication

Overall, scent seemed to have a positive impact on the quality of communication in our task. The data points to qualities such as in-depth discussion and openness in a conversation when scent was used. Additionally, in a conversation between two people, e.g. while solving a problem, scent had the potential to help them find a solution. This study also confirms the effect of the peppermint smell. The choice of scent is influenced by the type of task associated with the study [24]. Studies focusing on sleep can use lavender [34]; those focusing on high alertness may use coffee smell [22], etc. However, a detailed discussion of this choice of task-specific smells is beyond the scope of this paper.

4.2 Influence on Social Engagement

Prior research has shown that social engagement is a concept of utmost importance, not only for informing the design of interfaces but also for making them capable of adapting to participants [11, 43]. We explored how to make use of smell in a social engagement task. Our results show that participants performing a collaborative task understood complex representations of people's personalities (feelings and emotions) better in the WITH SCENT condition. This can be explained by the sense of smell targeting our brain's olfactory bulb that has direct connections to the two brain areas that control emotions and memories, the amygdala and the hippocampus [33].

The video recordings were essential to capture our participants' non-verbal behavior which was closely linked to social engagement. Here, social engagement is defined two-fold: relating to the task of coming up with a single story, and comprehending the TAT image. In the WITH SCENT condition, our SCORS data points to enriched characters' personality descriptions, evident psychological mindedness, and more differentiated characters. Participants described characters in a more nuanced way (higher COM ratings). On the SC scale, stories were more detailed, comprehensive, coherent, organized, and more fluid (with less jumping from one topic to the next). Furthermore, our data points to richer stories with more details on social causality in the WITH SCENT condition. This shows the

potential of smell to foster attentional and emotional involvement [30].

4.3 Overcoming Communication Breakdowns

People perceive events within terms of their ability to act, as described by Gibson's perception-action theory in psychology [18]. We observed different impacts of the scent. Our user study indicated that scent has the potential to help participants re-organize their thoughts and look more openly into the TAT image, resulting in resolving communication breakdowns. We found that participants did not trust their sense of smell; however, when we look at the objective data, we can observe how well they performed with the smell present. It is known that humans trust their eyes and ears more than their noses, possibly leading to the bias that causes the difference in rating and actual behavior [28].

4.4 Potential Applications

We often collaborate while brainstorming, problem-solving, prototyping, writing code or text, etc. The generation of ideas in these team processes is crucial; however, it is a difficult task. Based on our results, scent can provide a cue that can help in being more open and connecting ideas into a conclusive solution. Just as memory recall can be improved by presenting contextual smell that was present at the time memories were recorded, scent can also help retrieve learned facts during recalling activities like brainstorming [8]. Triggering scent in a collaborative process may change the way collaborators think about a problem, help problem-solving, and support openness. Apart from a necklace as the form factor, other options to integrate smell into collaborative sessions are conceivable via mobile phones, smartwatches, or even pieces of furniture such as whiteboards or chairs. With the recent surge of home-office setups and online meetings, collaboration over distance has been enabled and encouraged everywhere, making it particularly beneficial to integrate smell into devices that people have at home or on their bodies. Overall, the effect of smell on communication, collaboration, and deep thinking holds great potential in a variety of scenarios.

4.5 Limitations & Future Work

Several limitations of our study suggest the need for further experiments and future research. We did not explore the effect of the form factor, which could have influenced the overall experience and have contributed to a better quality of communication and social interactions. Also, future work can explore the effect of scent through an experiment in which the necklace is worn in both conditions to assure that the results are not effected by the form factor. However, our results are in line with previous studies [1, 10] that focused on smell as a central entity. Nevertheless, we intend to study the effect of the artefact further, e.g., by comparing the necklace to other form factors. Also, while we programmed the necklace controller to use identical release times each time, the number, time, and length of releases could be varied to understand whether this has an impact on users. Such a study might be able to derive more detailed guidelines for designing olfactory interfaces.

5 CONCLUSION

This paper aimed to understand the effect of smell on social interactions in a collaborative setting, specifically on the quality of communication, social engagement, and overcoming communication breakdowns in a story-writing task executed in pairs. We evaluated data measured with methods from different HCI-related fields in a user study. Data triangulation from psychometric methods, participants' verbal accounts, and video recordings provided insightful findings of how humans perceive smell during a collaborative task, often unknowingly. The released scent helped improve participants' communication quality during the writing task. Additionally, our results showed that in the WITH SCENT condition, participants were able to transfer complex representations in the images better into their written stories. Scent helped participants overcome communication breakdowns during their task. These results help us understand the potential smell holds for interfaces in the context of humans interacting with each other, such as supporting idea generation while brainstorming, connecting people in long-distance relationships, or triggering a particular memory or feeling. We hope that our findings help other HCI researchers and interaction designers to better understand the potential of smell in collaborative tasks.

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