

Smell Above All: Envisioning Smell-Centred Future Worlds

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PHASE 1: FUTURING WORKSHOP

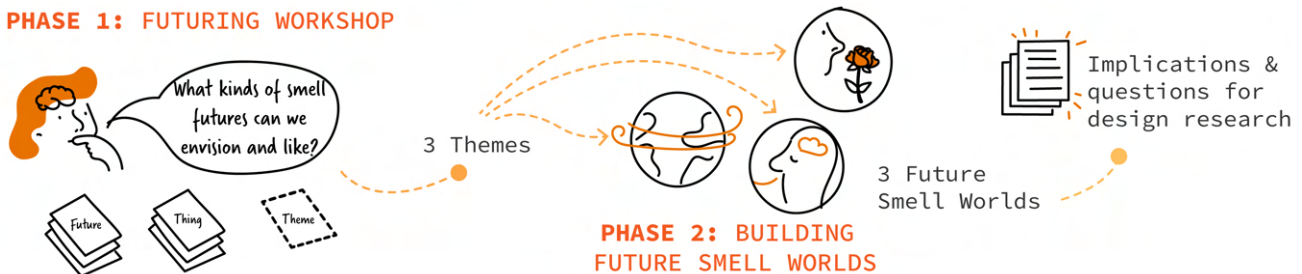


Figure 1: A diagram on our design futuring process; from Phase 1 Futuring Workshop to Phase 2 Building Future Smell Worlds.

ABSTRACT

Take a deep breath; what do you smell? While sight and hearing dominate our perceptions, the sense of smell is often overlooked, even undervalued. However, the importance of our sense of smell goes beyond detecting odours. It shapes our emotions, memories, behaviour, and quality of life. Recent advances in olfactory interfaces have sparked discussions about the future of smell in human-computer interaction. While efforts mainly focus on the realization of new olfactory interfaces, here we collectively explore alternative worlds centred around the sense of smell. First, we conducted a design futuring workshop involving individuals with varying smell capabilities and expertise to envision and discuss smell-centred futures. Then, through iterative reflection, we arrived at three smell worlds presented as narratives and visuals. From this conceptual work, we offer new perspectives and generative possibilities for design research that prioritizes our noses.

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DIS '24, July 1–5, 2024, IT University of Copenhagen, Denmark

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ACM ISBN 979-8-4007-0583-0/24/07

<https://doi.org/10.1145/3643834.3660699>

CCS CONCEPTS

• **Human-centered computing** → **HCI design and evaluation methods**; *User interface toolkits*; **Interaction design process and methods**.

KEYWORDS

Smell, Olfaction, Olfactory experiences, Odour space, Odours design, Design futuring, Speculative design, Design fiction, Narratives, Future Worlds

ACM Reference Format:

Ceylan Beşevli, Giada Brianza, Christopher Dawes, Nonna Shabanova, Sanjoli Mathur, Matt Lechner, Emanuela Maggioni, Duncan Boak, Carl Philpott, Ava Fatah gen. Schieck, and Marianna Obrist. 2024. Smell Above All: Envisioning Smell-Centred Future Worlds. In *Designing Interactive Systems Conference (DIS '24)*, July 1–5, 2024, IT University of Copenhagen, Denmark. ACM, New York, NY, USA, 15 pages. <https://doi.org/10.1145/3643834.3660699>

1 INTRODUCTION

Imagine having a tool that can detect just three drops of odour in two enormous Olympic-sized pools, and it does so in mere seconds. That extraordinary detector is none other than your very own nose [110]. The sense of smell has played a vital role in our survival throughout human evolution. Olfaction, the act of smelling, allowed early humans to navigate their environment, find food and

detect potential threats, including animals and diseases [56, 77]. However, the sense of smell often takes a backseat compared to sight or hearing, and it is undervalued among the five main senses by many individuals [77]. In a recent survey, a significant majority of respondents were much more willing to give up their sense of smell than their hearing or vision, and even in favour of keeping their hair or smartphone [51].

In the modern world, our reliance on the sense of smell for survival has decreased, often not considered vital for everyday tasks, with the exception of detecting gas leaks, fumes, and spoiled food [53, 97]. Despite this, the significance of olfaction extends beyond mere survival; it profoundly influences our emotions [40], memories [81], social interactions [12], enjoyment of food [97], well-being and quality of life [75]. Regardless, there has been a long-standing belief, mostly in the Western world, that the human sense of smell is not powerful or as important as other senses and is mainly important for reliving memories and eliciting emotions [50, 77]. Moreover, the lack of clear understanding about how we perceive odours (i.e., smells), along with the complexity of working with olfaction compared to other senses like vision, contributes to its neglect [77]. It's unsurprising that the majority of the human-computer interaction (HCI) work primarily focuses on vision and hearing, reflecting the historical and everyday neglect of the sense of smell [71].

Over the past two decades, we have seen a promising increase in the olfactory interfaces in HCI, as well as research around how to design smell-based interactions [71] and toolkits [66]. The body of research on olfactory interfaces has primarily focused on novel forms of odour delivery [20, 46, 52], their use in augmented and virtual experiences [37, 90], and brief explorations of these interfaces in daily life to explore use cases [68, 109]. However, there is ample room to explore how our relationship to our sense of smell could be changed through design. We advocate that there is a need to challenge the present neglect and broaden research horizons similar to the efforts happening for other senses [35, 49].

Design futuring encompasses diverse approaches that use design elements (e.g., visuals, narratives, prototypes) to explore potential futures [62], aiming not to offer solutions but to spark critical analysis, discussion, debate, and questions about alternative futures [39]. This paper presents our collective exploration of worlds centred around the sense of smell, employing a design futuring workshop, followed by reflective narrative building stages [99]. Our design futuring workshop posed the question of what kinds of smell futures we envisioned and desired. The participants (N=10) included individuals with varying smelling abilities (e.g., those with a very limited or mild sense of smell) and professionals working in smell research (i.e., medical experts, HCI, and built environment researchers) (Figure 1), providing richness to the visions and discussions. The workshop outcomes were synthesized into three themes:

- Theme 1: Exploring active engagement with our sense of smell amidst competing sensory inputs.
- Theme 2: Fostering a sense of belonging, placemaking, and communal experiences through smell.
- Theme 3: Exploring the potential of smells for communicating with other (non-human) beings towards co-existence and collaboration.

We transitioned from these themes to fabulations, a design futuring mode that uses storytelling to highlight overlooked relations when envisioning 'alternative lifeworlds' [99]. We introduce three interconnected smell-centric worlds as narratives and visuals; *Odoriferous*, *Sillage*, and *Signals*. World 1, "Odoriferous", illustrates the rediscovery of the sense of smell as an essential part of the multisensory self. World 2, "Sillages" envisions a future where olfaction heightens awareness of surroundings and fosters a sense of belonging and communal practices. World 3, "Signals," explores multi-species communication and odour identity through smell.

We generate knowledge through reflections on these worlds and draw implications from this conceptual work for future interaction design research on the sense of smell [62]. Our work builds upon the legacies of design to broaden the boundaries of design and invites the DIS community to an exploration of *how design can imagine new relations to ourselves, our societies, and the environment through smell*.

1.1 Related Work

We provide an overview of the significance of the sense of smell and a brief look at the olfactory interfaces in human-computer interaction research.

1.1.1 Importance of the Sense of Smell. It all starts with a sniff. When we inhale an odour, it hits the nose and travels through the olfactory nerve fibres (as electric impulses) to the olfactory bulb, where the information is analysed for the first time, before finally reaching the brain [59, 77, 94]. In the brain, two cognitive processes emerge: identifying and labelling, and assessing the odour's properties, as well as recalling emotions and memories connected with that specific odour [103]. The latter is why odours help us feel connected to people and places.

Recent research has linked our sense of smell to human behaviour, quality of life, and overall well-being [75]. For example, odours can make us want to move closer or further from specific objects (i.e., gas, chemicals) as a survival instinct [48, 57]. It is known that smell is closely tied to our enjoyment of food due to its ability to detect flavour profiles [95].

On the other hand, smell also plays a crucial role in social interactions, aiding in identifying family members and loved ones, and influencing empathetic responses [74, 79, 93]. Smells can even affect how we see our own body image, increase physical performance, and promote efficient cognitive functions [16, 17, 106]. Smell aids spatial navigation, allowing humans to orient themselves and track odours like dogs (despite the dominance of sight and hearing) [56, 89]. These examples demonstrate how advanced our sense of smell is. Our noses can also discriminate more than 1 trillion olfactory stimuli [22]. However, even if humans present similar physiological organisations, not everybody smells in the same way due to age, sex, genes and individual factors [82]. For example, the phenomenon called "asparagus pee" shows that only those with variations in the genes responsible for detecting this odour can smell it [85].

One of the most striking ways to demonstrate the importance of our sense of smell in daily life is by looking at the experiences of people affected by smell disorders/loss. Nearly half of individuals

suffering from smell loss experience depression (49%) and heightened anxiety (47%), while an overwhelming majority (95%) grapples with eating impairments. Additionally, feelings of isolation affect 64% of these individuals, and 59% report difficulties in maintaining relationships [86]. Globally, 5% of people are thought to have anosmia (i.e., inability to smell), with around 20% facing some form of smell disorder [32, 86] and our sense of smell declines naturally with age [82, 83]. Recently, it has been found that smell loss is also one of the early onset indicators of Parkinson's Disease, Alzheimer's and even subclinical psychotic-like traits [31, 91, 112]. Other reasons for smell loss can be infectious diseases (e.g., Covid-19), brain injury and head trauma, but there is much more to discover with new research studies that focus on the causes of and treatments for smell disorders [87, 88].

Despite its importance, the sense of smell remains one of the most under-researched and undervalued senses [51, 55, 77]. While there is only a small amount of research within the HCI community focusing on smell-related topics, we can observe a growing, multi-disciplinary effort to incorporate smell into interactive systems over the last decade [18, 19].

1.1.2 Growing Interest in Smell within Interaction Design. In this section, we provide a brief overview of the domains in which smells have been harnessed in designing human-computer interfaces and interactions (see [19, 28, 29] for a detailed overview).

It is no secret that HCI is an eyes-ears-hands dominated field, yet over the past twenty years, there has been a significant surge in research on smell-based interfaces [18, 29]. Advancements in smell delivery technology have greatly improved precision and control, enabling integration into compact and fashionable wearable devices [28, 29]. Novel electrical interfaces have been developed for stimulating the user's smell perception via electrical stimulation of the trigeminal nerve [20, 29]. Another exciting domain involves the development of smell-capturing prototypes, as well as olfactory interface DIY toolkits that enable fast prototyping and exploration of use cases [66, 68, 109]. This rapid evolution in olfactory interfaces has been further complemented with design guidance [71, 73].

One growing application of smell integration can be observed in Virtual Reality (VR) applications aimed at enhancing immersion [8]. Researchers are investigating odours for their ability to encourage behaviour change, promote relaxation, and aid navigation in VR [1, 71, 111]. There's growing interest in olfactory interfaces for regulating mood and behaviour, like managing stress and anger while driving, improving sleep, and boosting a sense of agency [3, 4, 27, 33, 67]. Further, research has explored using smells for conveying and recalling information for messaging and driving notifications [34, 37, 71, 72], as well as for learning, memory recall, and targeted memory activation [5, 15]. There's a nascent exploration into employing smells in social interactions, with research into olfactory wearables for enhancing positive face-to-face communication [25]. Advancements in smell delivery hold promise for healthcare olfactory interfaces [31], particularly in rehabilitating smell loss [88]. The development of a portable digital solution now allows at-home smell care [10].

As our understanding of the intricacies of the sense of smell grows, along with insights into its significance and the recent surge of interest in HCI, we find ourselves at a pivotal juncture. The

question now emerges: *What future smell worlds lie ahead, and how can design research play a role in shaping these?*

2 DESIGN FUTURING FOR SMELL WORLDS

Complementing the growing efforts around olfactory interfaces, we aim to explore futures that care for the sense of smell using a *design futuring* approach. Under the umbrella of "design futuring", there are various practices, including speculative design [6, 39], design fiction [11], discursive design [101], and others [62]. Design futuring emphasizes shared characteristics across these approaches. Firstly, it employs design not only to solve immediate problems but also to generate knowledge through debate, contestation, and reflection. Secondly, design futuring focuses on envisioning alternative futures that significantly diverge from the present, actively engaging with and questioning the possibilities of what the future could be [62]. Considering the key characteristics of design futuring, we argue that applying it to smell is especially fitting. We need to (i) challenge the current neglect of the sense of smell with outlooks that place smell at the centre and (ii) begin exploring further how design could play a role in these.

Design futuring work can take various forms of manifestation. One of these forms involves the use of props, known as diegetic prototypes, at the heart of the inquiry [6]. Other forms are in written formats such as fictional narratives and fabulations [6, 102]. In presenting our overall smell futuring output, we adopt a fabulation approach. Borrowing from Søndergaard et al., "Fabulations invite researchers and designers to mobilize storytelling to foreground absent or neglected relations when imagining alternative lifeworlds" [99]. Different to design fiction, it does not foreground technology but imagines social relations, political tensions and absent imaginaries. Fabulations offer a compelling way to discover the possibilities of bringing smell into our lives through design.

Our design futuring had two phases, (i) a futuring workshop to understand people's ideas and desires about future worlds around smell, from which we generated themes, and (ii) creating future-smell worlds as fabulations that add to the trajectories around smell.

2.1 Phase 1 - Futuring Workshop

2.1.1 Participants. Design futuring work has previously faced criticism for being the exclusive domain of designer-artists. There is a recognized need to include individuals to actively and consciously engage in speculation alongside the researchers [54, 62]. We adopted a participatory approach to futuring that involved four participants with different smell abilities (i.e., severe and mild anosmia - smell loss) and six professionals working in smell research with various backgrounds (i.e., design and built environment, HCI, psychology, rhinology and olfactology) [62, 105].

The participatory workshop allowed us to suspend our biases, open ourselves to different perspectives, and involve people with smell disorders' voices in the outputs [41]. Most importantly, this approach ensured the inclusion of minority groups, such as people with smell disorders who had a unique relationship with their sense of smell, in shaping the envisioned futures. All participants are currently engaged in a long-term study focused on addressing smell loss and novel olfactory interfaces, either as study participants

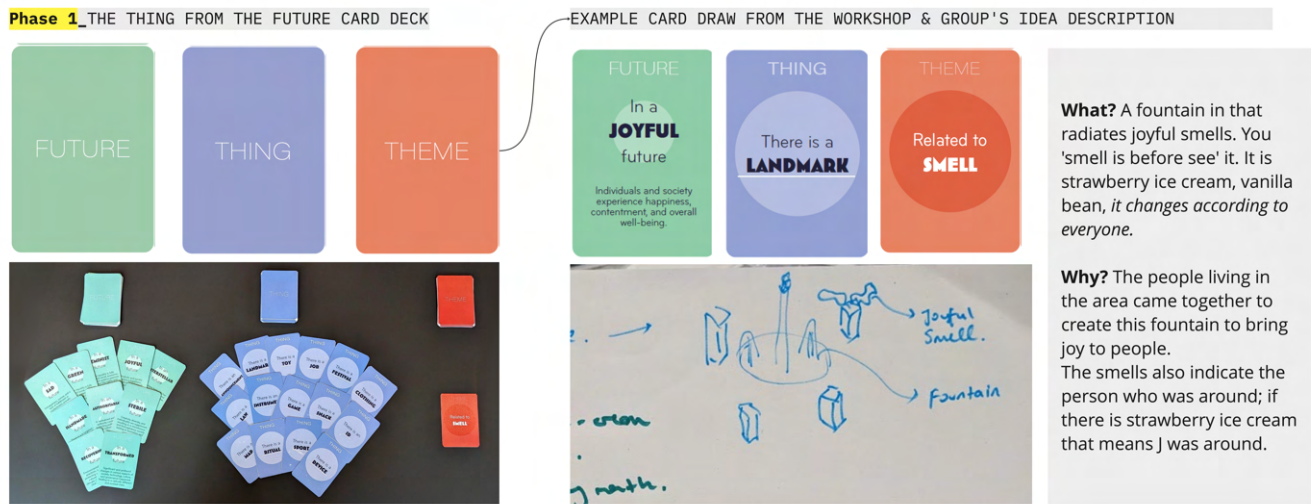


Figure 2: ‘The Thing from the Future’ Cards: Comprising three card types—Future, Object, and Theme. In our version, we provided descriptions for the Future cards, while the Theme cards were exclusively dedicated to ‘Smell.’ On the right is an example card draw done by a group along with their description of the world.

or as members of the research team. In that sense, all participants were acquainted before the workshop commenced.

2.1.2 Method. During the design futuring workshop, participants were divided into three groups, each led by a moderator, to actively explore future scenarios centred around the sense of smell. To facilitate the ideation process, each group received a deck of cards inspired by the “The Thing from the Future” card game [23]. The deck consisted of three distinct card types: Future, Thing, and Theme [24]. The Future cards depicted ten different types of futures, such as recovering, techno-futurist, or feminist. We added brief explanations on these worlds, which are not in the original deck, to help people make sense of these futures by also carefully leaving room for interpretation. There were fifteen Thing cards, which suggested tangible objects or entities like monuments, ceremonies, or devices. The Theme cards traditionally provide topics for constructing envisioned futures, like genetics, energy, and religion. To keep our focus on the central theme, the Theme category included a single card: “Smell” (Figure 2).

The participants engaged in an ideation session using the cards for approximately twenty minutes. Drawing card combinations from the decks, they explored two fundamental guiding questions: “What is that Thing and how is it used/practiced? Why does it exist?” Participants with smell disorders took the lead in drawing cards, while moderators asked the aforementioned questions as the groups began brainstorming ideas, being mindful of everyone’s participation [104]. In terms of levels of engagement of participation, the participants were collaborating with the researchers, as well as sharing the authorship of the futures generated [41]. Each group repeated this process for at least two card draws, resulting in seven distinct concepts created by the participants. Subsequently,

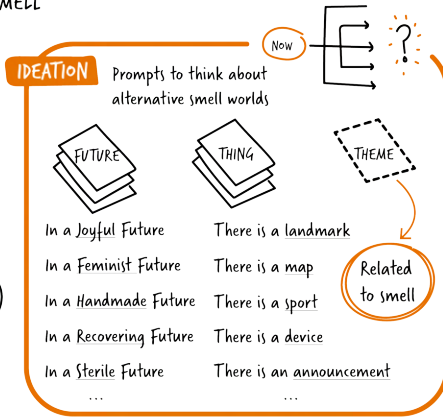
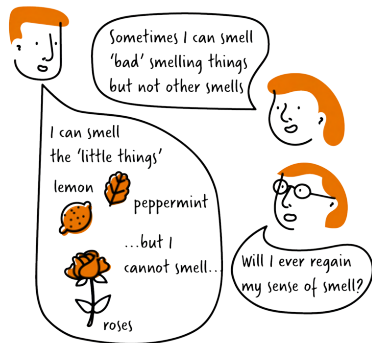
the groups presented their envisioned concepts in brief presentations, followed by a concluding discussion that asked what sort of smell-futures they desired. Throughout these discussions, participants engaged in critical analyses, drawing comparisons between the envisioned worlds and our present reality. The moderators took notes of the ideas and the plenary discussions.

2.1.3 Phase 1 - Futuring Workshop Insights. The first author compiled the workshop notes written by each group moderator. Later, we reconvened to further categorize the ideas and created the following summary. Participants with smell disorders highlighted the significant impact of the loss of smell on their daily lives, affecting their enjoyment of food and well-being. Participants further stated that the ability to smell wasn’t something they necessarily fully appreciated before it was lost. Reflecting on their olfactory experiences, some participants mentioned being able to detect certain scents, like lemon, but not others, such as roses or the scent of loved ones. Additionally, they described how their smell perception fluctuated daily and so they relied on familiar scents from products like deodorants and shower gels for personal hygiene or known ingredients and measurements while cooking. Overall, there was unanimous agreement regarding the insufficient dialogue concerning smell and smell disorders, accompanied by a consensus that research emphasizing their importance, as well as technologies involving the sense of smell, should expand and attract more attention for both direct and indirect contributions to helping people with smell disorders.

One of the most frequently debated topics in the workshop centred around the gendered nature of scents, particularly perfumes (Figure 3). Several participants shared their liking for fragrances typically associated with the opposite gender but expressed discomfort in freely wearing them due to societal gender norms. This

PHASE 1: FUTURING WORKSHOP

INFORMAL DISCUSSIONS ABOUT THE SENSE OF SMELL



CONCEPTS DISCUSSION

- Remove inequalities
 - Gender equality in smell
 - Freedom of smell expression
 - We (currently) use flowers to disguise our 'animal' smell
- 3 GROUPS + 7 CONCEPTS

- Phantom smells
- olfaction and memory
- Memory stimulation (stimulate brain to augment parts of it)
- Microchip in the brain
- perfume that reacts to one's own skin

HOW TO INFLUENCE RESEARCH - LAST THOUGHTS

What we imagine can come true

When film becomes reality

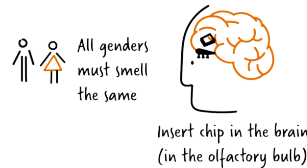
What is a more desirable smell world?

SOME FUTURING CONCEPTS

1. STERILE - NO SMELL



2. GENDER EQUALITY OF SMELLS



3. JOYFUL SMELL NEIGHBOURHOOD

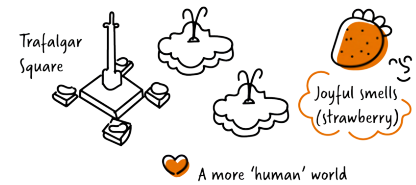


Figure 3: Scribing from the Phase 1 Futuring workshop, encapsulating some of the generated concepts and subsequent discussions.

discussion stemmed from the ideas generated by groups; one idea envisioned a world where a surgical procedure eliminated the olfactory bulb, erasing gender-specific scent perceptions. Another idea aimed at deconstructing the gendered concept of scents, allowing individuals to embrace the fragrances they resonate with, irrespective of gender associations. It was also noted that recent brands are emerging, exemplified by those producing gender-neutral fragrances or scents that adapt based on the wearer's skin chemistry, marking a shift towards inclusivity and personal choice in the fragrance industry.

Another thought-provoking idea involved a world where bodily odours were strictly prohibited. In this scenario, people wore smell-neutralizing headgear and were only allowed to smell in certain places like a hotel room. This concept parallels our current world, where smell aversion is prevalent, characterized by using fragrances to mask natural body odours or deodorants that eliminate sweat odours.

Other ideas involved a greater integration of the sense of smell into everyday practices. One of them painted a society in which the sense of smell is so advanced that it can drive the creation of drawings, sculptures, and other art forms. Another idea drew inspiration from the bowerbird's behaviour, where humans utilized scents to attract potential partners. Lastly, there was an idea that leveraged the potential of smells to infuse urban environments with joy. This

idea involved placing smells commonly associated with pleasantness (while recognizing their subjective nature) around a future neighbourhood, akin to a community ritual where people came together to experience the smells. Further discussions involved the intricate link between smell and memories, and the possibility of using smells to store the past.

During the plenary discussions, participants with smell disorders emphasized the need to care for the sense of smell, underscoring its value, often realized only upon its loss. There was a consensus on the desire for a future where routine smell testing parallels sight and hearing assessments for everyone. Further, participants expressed a desire for a community that actively appreciates smells and integrates scent into daily life, considering it a desirable future. However, ideas related to the oppression of smell and the uniformity of smell environments were also noted as uncanny and parallel to today, especially in Western countries.

2.2 Smell-Themes for Design Research

By annotating the ideas generated and discussed in the workshop, we initially found links to theory that create avenues for future design research to explore. Inspired by the ideas generated in the workshop, each author took pictures that evoked a desirable future for the sense of smell for them. This reflective practice deepened the discussions about where and how design could contribute to the futures that prioritised the sense of smell (Figure 4). Overall, following

an iterative analysis of workshop findings [14] and our discussions, we identified three themes, each presenting a conceptual shift from present to future research.

2.2.1 Theme 1: Exploring active engagement with the sense of smell. This theme underscores the lack of awareness regarding our sense of smell and the importance of designing strategies to reignite our connection with it. Workshop attendees emphasized how losing their sense of smell significantly impacted their daily lives, affecting pleasure in eating and overall well-being, as previous research also demonstrates [75]. On the other hand, with age [83], olfactory abilities decline, and there are studies linking smell loss to neurodegenerative diseases [31, 112]. Hence, proactive care for our sense of smell is crucial.

One promising avenue where design could play a pivotal role is in the realm of smell training. This practice involves consciously exposing oneself to different scents for short durations each day, demonstrating potential improvements in olfactory abilities [88]. Additionally, the development of olfactory interfaces has facilitated controlled odour delivery and perception tracking [10], predominantly for individuals with smell disorders. However, there's a need to reconceptualize design's role in encouraging broader participation in regular smell exercises among the general population.

When we talk about "exercise" or "training" in the context of smell, it doesn't necessarily mean adding another task to our to-do list; rather, it's about embracing the smells present in our daily lives. However, paying attention to smells isn't always easy. Our evolutionary development has equipped us to navigate a complex, ever-changing world. While our brains are skilled at processing our surroundings, they often filter out extraneous details [71, 94]. Among the various sensory inputs we receive, such as visuals, sounds, and temperature, our brains tend to habituate to smells quickly or perceive them without paying attention [59]. In this respect, there might be a need to reduce the sensory overload often present in urban settings.

As McGee points out [78], "*The purpose of olfaction was not to dissect the smell of coffee into its volatile ingredients or ponder the nuances of an orange or a grouse. But neither was the original purpose of hearing to develop spoken language or music! People who love coffee and many other aromatic materials do, in fact, dissect and ponder. It doesn't come naturally, but it's doable and rewarding.*" We are yet to understand what being attentive to smells might imply, but we can design ways of bringing it into focus.

This theme prompts us to design ways to engage our sense of smell daily, despite the competing sensory inputs that command our attention.

2.2.2 Theme 2: Smell for placemaking and communal experiences. In the workshop, the concept of "joyful-smell future neighbourhoods" was discussed as being the most desirable future. This inspired us to centre a theme around enabling belonging and social interaction through scent.

Studies suggest that smells are integral to shaping the character of places, forging emotional bonds between individuals and their environment, and enhancing well-being [96, 108]. In today's dynamic world marked by frequent relocations and immigration, the role of scent in placemaking becomes even more significant. HCI

design explores how technology can contribute to creating meaningful spaces, focusing on personal, collective, and performative aspects [2, 36]. Thus, there's an opportunity for design research to explore ways to foster belonging and placemaking through smell.

In the pre-modern West, odour-rich "healing gardens" existed, where the strength of the smell of a plant was associated with its presumed medical power [26]. On the other hand, recent regulations address overpowering odours in cities by treating all smells equally, whether they come from sewage or flowers [21]. This approach emphasizes the need to shift from merely masking or reducing smells to acknowledging their potential contribution to a place's unique identity. Landscape design is emphasizing this shift by incorporating smell as a component in creating sensory gardens that engage all five senses [107].

In addition to fostering a sense of belonging, smell can play an active role in communal and cultural practices, particularly when exploring perspectives beyond the Western context [26]. For example, the Jahai people living in the Malay Peninsula integrate smell into various aspects of life, including language, religion, and medicine [76]. Similarly, in Japan, there is a shared practice known as *monkō*, which involves appreciating the scent of fragrant trees [80]. During the workshop, we discussed the idea of curating smell gatherings that everyone could enjoy and participate in. Utilizing smell to bring forth the history and awareness of various co-located communities could serve as a starting point for designing communal experiences. Recreating scents from the past is gaining traction in the emerging field of olfactory heritage [9], and recent advancements in smell-capturing technology in olfactory interfaces research could facilitate such endeavours [68]. The profound influence of smells on memory has long been studied in olfactory interface research, exemplified by prototypes integrating smell into photographic archiving [15]. However, this theme encourages us to contemplate how design can transcend nostalgia, focusing on cultivating shared scent experiences that foster community connection and awareness of cultural heritage.

2.2.3 Theme 3: Communicating and collaborating with the other (non-human). The workshop discussion reflected on the concept of body odours and masking these *animalistic* smells. The latter keyword pushed us to think more about smell from a non-human species point of view in the post-workshop discussions. On the other hand, we acknowledge that the connections between humans and animals are often framed within a Euro-American mode of comparison [64]. This mode of comparison tends to rank one category over the other, potentially leading to the devaluation or erasure of the "lesser" category [98]. Therefore, we note that our goal here is to highlight the parallels that smell brings to human and non-human species. This theme includes the consideration for other companion species, whether they exist within or outside our bodies and how smell could be a bridge to and from them [45, 54].

Many animal and insect species rely heavily on smell to survive. As mobile beings, they require the ability to locate and connect with members of their species. They achieve this, as well as deter or fend off predators, by intentionally releasing volatile substances as signals, similar to how flowers emit scents [84]. Olfactory interfaces research also explored the potential of using smell to communicate information, such as creating scent associations between certain

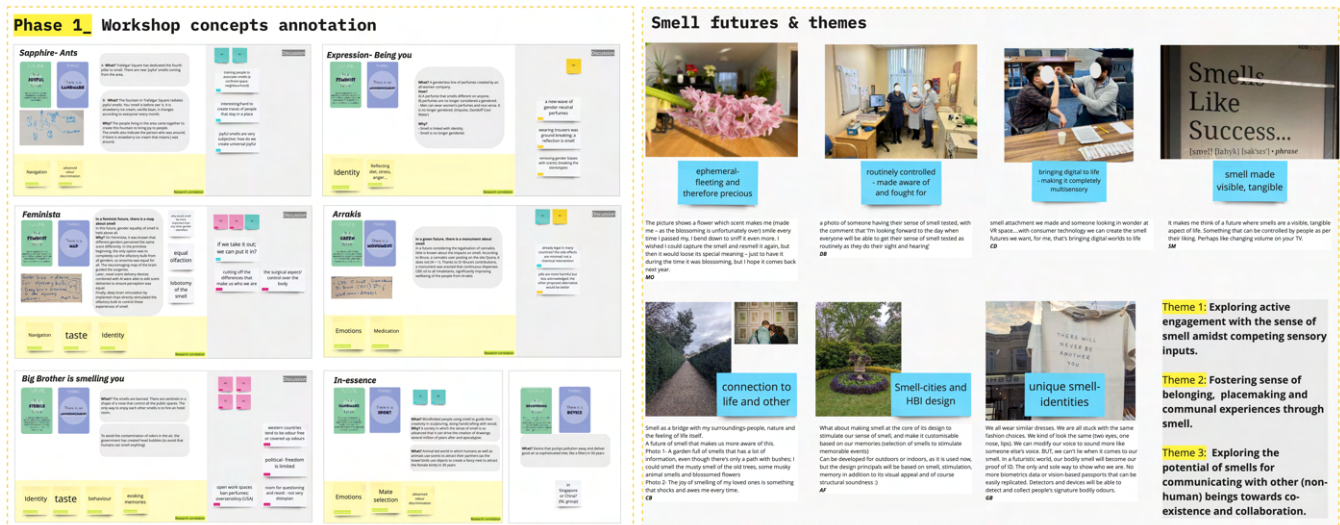


Figure 4: A screenshot of Phase 1 Workshop’s collaborative sense-making process. It began with summarizing and annotating ideas, followed by discussions prioritizing smell care in future scenarios, which were then synthesized into overarching themes.

smells (i.e., lemon) and notifications (i.e., a message from a person) [34, 72]. On the other hand, the potential of smells emerges as a communication medium with the other as well. Beyond to established use of smells to repel “unwanted” species, we see potential in using smells with a design lens for co-existence and communication with the *beyond-human*.

In contrast to animals and plants, which proudly emit their scents, humans often strive to avoid, eliminate, or disguise them [70], a sentiment also echoed in our workshop discussions. Similar to the non-human smell signals we noted earlier, human smells also carry vital information about people’s diet, mood, and even age [70, 97]. Smells even change how we perceive our body image [16]. Workshop participants noted their ongoing use of personal hygiene products based on their memory of their scents, demonstrating sensitivity to how they might be perceived by others, even though they themselves cannot detect their own scent. Research on olfactory interfaces has also explored wearables that emit perfumes during face-to-face interactions for creating favourable first impressions [25]. On the other hand, the reasons why we may “stink” are actually due to the beyond-human within our bodies as well; the microbiomes [30, 38]. Our regular smells directly indicate the well-being of our superorganism, showing whether our habits support its health or pose potential problems [97]. Previous research on designing with the body and microbiomes has sought ways to bring awareness to the microbiome through visual tracking [13]. This theme explores the potential of smell, which already provides insights into the states of the microbiome in our body, to advance these strands of research.

2.3 Phase 2 - Building the Smell Worlds

After generating the themes, our initial approach involved crafting narratives resembling design fiction scenarios [11]. These narratives included references to specific technologies, guiding our discussions on realizing these technological concepts. However, as we

progressed, we recognized the need for a more imaginative leap. The fabulation approach offered “ways of designing, ways of knowing, and ways of living with or without technology” with our sense of smell [99]. This fabulation approach allowed us to present a compelling world that addressed challenges such as neglect [51], misinformation [77] from a wider public point of view, and the ongoing olfactory interface agendas in odour delivery methods [29], and their potential uses in everyday life [68, 109]. Our objective was to create a space for free exploration, joyful allyship, and optimism, akin to previous research [99].

To facilitate this creative process, the authors utilized a Miro board containing the workshop summaries and themes. We incorporated new inspirations to construct future worlds, incorporating visuals and quotes from literary works that linked with the themes. In the process of conceiving these smell worlds, we initially drafted them individually and then collaboratively refined and expanded upon each world, moving beyond their initial outlines.

2.3.1 Researcher positionality in world creations. We now highlight the aspects of our positionality that have consciously or subconsciously shaped the composition of these final worlds. Kozubaev and colleagues’ framework [62] encourages researchers engaged in design futuring to openly reflect on their positionality, potential biases, privileges, and politics that influence the envisioned worlds. Existence within this world is not a neutral, shared experience, neither the smell worlds we have designed claim to speak to a universal future.

As mentioned, Phase 1 involved participants with varying backgrounds and smell abilities, which shaped the themes and Phase 2 smell worlds in various degrees [41]. Our team, which created the final worlds, brings together diverse backgrounds in design, psychology, heritage, architecture, and HCI. Our diverse cultural makeup includes Turkish, Italian, Russian, Indian, British, and German influences. All the authors involved in creating the final smell



Figure 5: A visual depicting World 1 - Odoriferous.

worlds possess a fully functional sense of smell and have experience in multisensory experiences, and developing olfactory interfaces. Our current location has undoubtedly influenced the worlds; therefore, we wonder how the smell worlds could be envisioned in other geographical locations.

3 THREE SMELL WORLDS

We introduce three intricately linked future smell worlds derived from themes synthesized in the design futuring workshop. Each world is visually represented through mixed media collages, aiming to reflect their essence, similar to prior work [99, 102]. World 1, "Odoriferous," depicts the rediscovery of smell as integral to a multisensory self. World 2, "Sillages," imagines a future where smell heightens awareness and fosters community. World 3, "Signals," presents multi-species communication through scent. All of the smell worlds demonstrate the power of smell to affect our everyday experiences, elicit emotions, and undergo a transformation over time, depending on what world we live in.

3.1 World 1: Odoriferous

We are born with a nose that knows kin from others, recognizes toxic food and fires and avoids them. However, these abilities became less vital as we developed expiration dates, fire alarms, and the ability to recognize our parents by sight or sound. Our eyes and hearing became our primary modes of experiencing life. Beyond the input nature had granted us, we created more and more sources for visuals and audio with technology, catering to those senses. We became bi-sensorial beings, not multi-sensorial. While we decided which smells were acceptable, we also started abolishing unpleasant smells. We started to have homogeneous, muted odours around us; places and people started to smell the same. So, our brains stopped paying attention to it, gradually losing this sense.

Along with smell, we lost the pleasures of eating and our connection to others, our emotions became less vivid, and our bodies started to lose their balance. We began to forget, and joy started slipping away. It became clear that we needed to nurture the senses as a whole and not as isolated parts.

To rekindle our awareness of smell, we needed to dial down the reliance on audio-visual stimuli. We created designs that highlighted the smells surrounding us and simplified the other sensorial input. It visually showed us effervescent smell molecules, volatiles, swirling all around us (Figure 5), each bringing a representative of the body that emitted them, providing a second-hand perception of the odoriferous world. This visible volatile world came with descriptions so we could approach or avoid them. This stirred a sense of curiosity within us. We found ourselves drawn to the pleasant, the "sweet", the "resinous", and the "spicy", only to be met with surprises as the descriptors often diverged from our actual perceptions. We wondered if these mismatches were intentional or if our responses to smells were different from each other. Gradually, our exploration extended to the "pungent" and the unpleasant, seeking first-hand experiences. Then the perception of smell became truly ours.

Our brains began to pay more conscious attention to odours and woke up from slumber. We started discriminating more subtle differences in odours. However, it wasn't just the momentary satisfaction of identifying notes in our surroundings or inferring their meaning. Smelling itself became the actual reward. Our senses thrived with the stimulation the world provided; we found joy in consciously diving into and fully experiencing our multisensory selves.

3.2 World 2: Sillage

The odoriferous world not only granted us a new dimension to experience life, but also provided an awareness of our surroundings and the people we shared it with. We were so taken with this world that we



Figure 6: A visual depicting World 2 - Sillage.

created new tools to allow us to tune in to the smells around us even more. Through this, we perceived the sillage, the odour trail (Figure 6), left by beings. There were sillages of people, animals, plants, and others that had passed by. It brought an unexpected awareness of the daily rhythms within our area – the early riser that had the faintest sillage, and the unhurried stroller’s sillage lingered longer. We couldn’t see them, but we felt their presence within our vicinity.

Driven by this newfound communal awareness, we started gathering to smell the sillages around our area. Led by our noses, this practice became a cornerstone for placemaking and fostering a sense of belonging. Our connection to the neighbourhood’s history emerged organically, bypassing the need for external information; we could smell the elder wood in the fences of the garden. The future, too, teased us through the sillage – the early fragrance of blossoms carried by the wind told us the winter was close to an end.

Beyond delving into the past and anticipating the future, we also embarked on a quest to fully embrace the present smells. Rejecting the ubiquitous scents of year-round plants and artificial sources that homogenized our area’s sillage, we created new smell pillars. Everyone created their own version filled with plants their nose enjoyed. These tall pillars of smell allowed a symphony of smells across the vicinity. We found ourselves attuned to the subtle changes in each neighbour’s garden – the dormant soil, the budding leaf, the blooming flower. This heightened appreciation kept us connected to the odoriferous world, drawing us back to the act of smelling each day.

As our olfactory journey continued, we developed more ways to capture, create and share these intricate sillages, transforming them into our communal stories told through smells. These scent-stories stirred emotions, often without a clear understanding of why or which memory they were linked to. It was an intimate and shared experience, open to interpretation. As the volatiles from bodies, and the sillages evaporated, the tangles of emotion, perception, and thought lingered.

3.3 World 3: Signals

The sillages made us more aware of the world we shared with others. While their visual tracks were not always visible to the eye, they were perceptible to our augmented nose. This awareness of the other initially created a sense of unease. However, it also started to provide comfort, revealing in our previously curated sensory worlds that kept some senses out, an opening in the sensory world that showed living things surrounded us. Unlike us, they intentionally left their smells as signals (Figure 7): to mark their territory, attract possible mates, and deter competition. We became aware of their presence without seeing or hearing them, adjusting our paths and sillages to give them peace of mind.

Mixed feelings arose when we started encountering the sillages of insects that visited our house. They had managed to evade us, but now we were awakened to their presence. We were sharing our space with them. Some emitted fruity and green scents, while others were musty and unpleasant. These were signs that living things were working hard to survive, we felt it in our noses and respected that. So, we began designing tools to create smell-signals distributed across our space to attract butterflies and repel bedbugs. This later led us to wonder if we could non-verbally communicate with them through smell, beyond simple approach or avoid signals. We experimented with new forms of coexistence.

Coexistence with others did not just mean the beings sharing our space, but of the microbiome within our own bodies. This internal ecosystem became a barometer for our well-being; shifts in the scent of breath and bodily fluids signalled when our microbiome needed attention. It was an ancient practice that we had forgotten, but it became accessible again.

We furthered our collaboration with the microbiome to design ways to alter our body odours. But we didn’t want to unleash our body odours so quickly though, for generations had accustomed us to masking our natural scents. We started to work with the microbiome to shift the strong odours of our bodies into subtle, distinctive signals.



Figure 7: A visual depicting World 3 - Signals.

As this journey unfolded, we discovered our authentic essence, our unique olfactory identities.

4 DISCUSSION AND REFLECTION ON THE FUTURE SMELL WORLDS

Having showcased three future smell worlds, we provide an overview of the three future smell worlds showcased (Table 1). Kozubaev et al. [62] introduced five "Modes of Reflection" in design futuring, which we applied in our work. These modes include *formgiving*, *temporal representations*, *researcher positionality* (Section 2.3.1), *real-world engagement*, and *knowledge production*. *Formgiving* infers the reasons why we choose to represent some futures over others. In the world creation, the themes derived from the design futuring workshop served as the foundation. *Temporal representations* urge authors to reflect on which notions of time they equip. The imagined smell worlds, though we call them future worlds, could be located in a past, present, or future at all these times simultaneously or moving in between them, as is the trademark of fabulations [99]. We did this through ambiguity in the technologies described or the lack of them in the smell worlds. To elaborate, in our worlds, there is a reduced focus on envisioning or creating technology and a greater emphasis on exploring social dynamics, cultural interactions, and power structures within the coexistence of humans, non-human entities, the environment, and technology [102].

It's worth noting that the concepts explored in the worlds stem from themes derived from futuring workshops. While not entirely new or feasible, they are grounded in the imagination and desires expressed by participants, representing a wide range of stakeholders (see Section 2.1.1. for background details). We specifically highlight that, except for World 1, the topic of smell loss or disorders is intentionally omitted. Instead, these worlds consistently portray

a society where the sense of smell is valued and celebrated as the desired future among the participants.

Below, we unpack each world, extracting implications in the form of questions for design research [92], aimed at *producing knowledge* [62] through our design futuring work.

4.1 Unpacking the Odoriferous World

This world portrays a journey of rediscovering the sense of smell as an integral part of the multisensory self, emphasizing its significance and the joy of conscious olfactory experiences. Latour [65] suggests that purposeful smelling helps us notice more details and discover new aspects of the world and ourselves, which influences our storytelling of the Odoriferous World. We are yet to uncover the potential outcomes of this conscious attention to smells.

We introduce this world with a sombre outlook, embodying the consequences of smell loss from the insights gleaned from the workshop participants. Participants with smell disorders had noted how it impacted their enjoyment of food and wellbeing [75]. While smell loss can result from various causes, including infectious diseases or medical issues, research indicates that everyone is susceptible to olfactory decline with age, emphasizing the importance of active engagement with our sense of smell [83]. However, active engagement with smell poses a challenge, as highlighted in "Theme 1" despite being surrounded by various scents.

In the Odoriferous World, we explore the concept of *dimming* distractions based on audio and vision to draw attention to surrounding scents. The specifics of this design are intentionally left ambiguous for varied future solutions, depicting a real-time visual overlay showing volatile molecules akin to augmented reality. This overlay aligns with Gibson's notion of "perception at second-hand," allowing individuals to become aware of smells through visual cues. Similar to the flavour wheels breaking down complex flavours, the

Future World	Smell	What future of smell is envisioned?	When and where is this future?	Who is imagined in this future?
World 1: Odoriferous		Smell awareness and appreciation	An undefined future, location not disclosed.	A group of people or a person, unspecified.
World 2: Sillage		Smell for a sense of belonging and communal practices	An undefined future, location not disclosed.	A community living in a specific area.
World 3: Signals		Smell for understanding and communicating with beyond-human	An undefined future, location not disclosed.	Human & non-human species.

Table 1: Overview of the three smell worlds.

technology deconstructs smells into categories like fruity, mushroomy, and green, facilitating a multisensory experience.

This world illustrates the shift from *second-hand* to *first-hand perception* [43] through actively experiencing smells. The use of mislabelled categories introduces small *surprises*. When reality aligns with our expectations, such as seeing coffee and smelling it, our brains process this information efficiently without much conscious attention. However, when there's a deviation from our expectations, our brains shift focus to assess and respond to the anomaly. [7]. Also, it's important to note that labels like "pleasant" may not be universally perceived as such due to various factors such as age, sex, genes, cultural, and individual differences [82]. Design research further holds the potential to cultivate playful interactions with our olfactory sense. While not everyone may readily embrace opportunities to explore the smells around us, our goal is to ignite new perspectives on the potential of engaging with the sense of smell.

4.1.1 Implications of the Odoriferous World for design research. When considering design implications, we pose the question: In the context of the Odoriferous world where residents are experiencing smell loss akin to our workshop participants, how can this environment serve as a catalyst for inclusion? Can we repurpose technologies primarily oriented toward audio and visual experiences to instead diminish these senses, shifting focus to the olfactory experiences in our everyday lives and subsequent interactions? How can we render the intangible and ever-present sense of smell more tangible to capture people's attention? Design research may delve into cross-modal associations between smell and shapes [44], as well as colours [69], to develop visual representations of smell. Beyond visuals, we encourage design researchers to explore methods of prompting individuals to "stop and smell the flowers," thereby drawing conscious attention to smell. Introducing surprises in smell experiences could turn smelling into an exploration akin to geocaching, fostering playful engagements with smell. We extend design researchers the invitation to explore whimsical approaches to engage with our sense of smell. How can the DIS community contribute to enhancing this experience and ensure it becomes a positive shared experience for all individuals, including those with varying smell and sensory abilities?

4.2 Unpacking the Sillage World

Sillages pick up where the previous world has left; with the newfound appreciation of the sense of smell, there is the addition of new tools for augmenting it even further. cent. While smell augmentation technologies are still in development [20, 29, 58], which

could be helpful for people with smell loss, the narrative imagines their feasibility. In this world, people recognize each other through their lingering scents, fostering a deeper sense of co-presence.

Placemaking is a growing topic for HCI [36] and has been explored through digital technologies and soundscapes tailored for auditory experiences [2]; we bring in smell into the mix. We imagine scent pillars are introduced throughout the neighbourhood to add to its unique identity, similar to green walls. These scent-pillars create dynamic sillages, heightening awareness of environmental differences in smells, coinciding with World 1.

In the fabulation, we described sillage trails that people could follow together, tapping into our innate ability to track scents [89]. Building upon existing practices such as smell walks [50, 108], where participants identify unique city or regional scents, we wonder how design can further enhance this sensory journey. Emerging technologies like acoustic trapping [46, 52] offer promising methods for capturing airborne scents, paving the way for the creation of distinctive scent paths; yet there remains to explore how this would unravel in situ and what interaction opportunities would arise.

This fabulation concludes by leveraging these spatial-smell tools for dynamic storytelling, expanding the narrative landscape beyond traditional audio-visual channels. This opens the design space for intangible cultural heritage that is filled with abstract, complex, and non-fit for the 'refined and retained' oral narrative [61]. Stories, besides enabling reflection on shared histories, foster understanding and empathy among members [100]. This can be envisioned on two levels: fostering connections among those who can smell and those who cannot, or can only partially smell, to cultivate a sense of commonality. Given the role of smells in placemaking and its link to emotion and memories, smell-based storytelling appears as a rich playing field for design research to explore.

4.2.1 Implications of the Sillage World for design research. We assert that design should not force social relations but allow for the accumulation of relations to others [63]. How can design leverage smells for placemaking to shape individuals' perceptions of their surrounding environments and foster stronger connections to them from a 'comfortable distance'? For those who want to join communal practices, how can design augment spatial practices guided by smells? On the other hand, as a way of building histories together, how can design research explore the potential of smell-based storytelling? How can this smell-based storytelling serve as a bridge between individuals with normal olfactory function and those with smell disorders, utilizing emotions as conduits to imagined futures

or recollected memories from the past? Exploring smell as a fabric for storytelling could benefit from the research dedicated to understanding the key design features of smell spanning from chemical, emotional, spatial, and temporal considerations [71].

4.3 Unpacking the Signals World

Signals World uses the concept of olfactory trails to bring the beyond-human entities surrounding us into the spotlight. Through heightened awareness, it depicts our awakening to the scent trails of animals, insects, and, ultimately, the microbiome. Smell serves as a bridge, enabling us to understand their presence and interpret their signals.

On the contrary, newfound awareness of insects' smells in our homes may evoke tension for many due to common fears or disgust associated with these beings, which was a topic also explored in another fabulation by Tsaknaki and colleagues [102]. While the awareness of insects' smells in our homes may evoke tension due to common fears or disgust, some insects emit pleasant scents resembling lemon [60], suggesting a potential shift in perceptions.

While the *Sillage* constantly changes with people moving and seasonal shifts, scents in our private spaces may remain more stagnant. This temporal aspect of smell [71] means habituation occurs, where the perception of scent decreases over time [42]. Additionally, scents can habituate differently based on their perceived pleasantness; we habituate to pleasant smells more than unpleasant ones. In our narrative, through augmentation of our noses, we highlight the consistent appreciation for pleasant smells from organisms sharing our private space, counteracting some of the habituation. However, balancing increased smell awareness without overwhelming our brain remains a question, especially with potential technological interventions [71]. Beyond this, the narrative proposes methods to attract or deter insects harmlessly, envisioning the initiation of smell-based communication with non-human entities.

The narrative also explores the symbiotic relationship between our bodies and the microbiome, where distinct bodily odours reflect their well-being. Acknowledging that body odours are a controversial topic, we also consider the functional aspects that our odours have, whether emotional or pheromonal [30, 47], as illustrated in Theme 3. Some workshop participants highlighted their continued reliance on personal hygiene products, recalling their scents from memory and demonstrating awareness of how they might be perceived by others, even though they cannot perceive their own scent. Considering these, through the fabulation, we imagined amplifying the positive signals (smells) emanating from our bodies through collaboration with the microbiome. This, in turn, could empower individuals to embrace and enhance their unique olfactory identities [70] without masking them. There could potentially be a shift in the collective perception of bodily smells over time, influenced by changing cultural norms and environmental factors depicted in the worlds.

4.3.1 Implications of the Signals World for design research. The *Sillage* and *Signals* worlds imagine an augmented sense of smell to enhance our awareness of our surroundings. However, how can we design a middle ground that allows us to consistently perceive pleasant smells without overwhelming our brains? Further, how can we design for non-verbal communication with beyond-human species

through smell? This prompts further exploration of *what* will be communicated and how to experiment with this responsibly and ethically. Moreover, can we harness smell's inherent signals to enhance reflection on bodily well-being? While visual representations of the gut microbiome [13] have been explored for understanding their state, this points to new ways of engagement with this topic. Lastly, we ask, how can design explore ways of working with the microbiome towards allowing people to curate their unique *subtle* smells, fostering a cultural shift towards embracing the diverse range of olfactory identities and abilities in society?

5 CONCLUSION AND FUTURE WORK

Imagine a future world where smell is at the centre of everyone's mind, practices and even cities. It's not a city filled with screens like in New York or sounds like in Delhi, but designed purely to address our sense of smell. We presented three future smell worlds as a means to explore, reflect upon, and discuss how design can imagine new relations to ourselves, our societies, and the environment through smell. We discussed the underlying motives of the worlds and offered implications and questions for further exploration. These questions range from addressing the design paradigms for empowering the olfactory sense to exploring the future of olfactory interfaces for communal practices.

Considering the limited attention given to the sense of smell in day-to-day life and the early stages of olfactory technology, we don't fully understand how heightened awareness of smells or a world around smell might impact our lives. Parallel to this, in creating the worlds that stemmed from the workshop, we first struggled with referring to specific technologies, shaping our discussions on how to bring them to life, not necessarily envisioning worlds that care and prioritise the sense of smell. Thereafter, we realized the need for a more imaginative approach offered by fabulation, inspiring new ways of designing and experiencing life with or without technology [99] in relation to our sense of smell.

Overall, our worlds raise more questions than they provide answers to, which is precisely why design futuring exists; it is a way of envisioning possibilities, not predictions; generating discussions, not solving immediate problems [54, 62]. The themes we drew from the design futuring workshop, and the smell worlds offer new lenses to think with; futures that care for the sense of smell.

As we look toward the future of smell, we recognize opportunities to increase the diversity of our participant pool and expand to new locations. This inclusivity could extend to individuals with diverse sensory abilities and needs, encompassing not only those with smell disorders, as we did, but also individuals who rely on their sense of smell for their profession (e.g., sommeliers, perfumers), as well as those experiencing loss in other senses. Further, beyond involving participants in *inspiring* [41] the creation of the smell worlds, we aim in the future to elevate their level of engagement to *collaboration*. For example, through generative reflection, where we bring the worlds back to the participants for feedback and consideration of which elements they want to bring forward, we seek to engage in a deeper level of "dreaming together" [41] to influence the future. We invite the design community to join us in broadening the futures of smell, to go beyond what is available now, to open their noses, and to unleash their imagination.

ACKNOWLEDGMENTS

We extend our sincere gratitude to our workshop participants for their invaluable contributions and unwavering dedication to pushing the boundaries of smell. Additionally, we would like to express our appreciation to Ana Marques for her outstanding scribing efforts and assistance during the workshop. Furthermore, we are grateful to Dr. Peter Bloomfield for his insightful discussions on smell care. Lastly, we thank the members of Fifth Sense for their continuous support of the Smell Care Project.

This research is part of "I-smell: Engaging Users in Smell Self Care at Home" project, funded by the Engineering and Physical Sciences Research Council (EPSRC) as part of UKRI and the National Institute of Health and Care Research (NIHR), EP/W031574/1 and based on the outcome from the European Research Council Proof-of-Concept (ERC PoC) SmellHealth award (966774).

REFERENCES

- [1] Renee (Woodruff) Abbott and Ana Diaz-Artiles. 2022. The impact of digital scents on behavioral health in a restorative virtual reality environment. *Acta Astronautica* 197 (Aug. 2022), 145–153. <https://doi.org/10.1016/j.actaastro.2022.05.025>
- [2] Andreas Almqvist, Anders Hedman, Adrian K Clear, and Rob Comber. 2023. Different Together: Design for Radical Placemaking. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, Hamburg Germany, 1–16. <https://doi.org/10.1145/3544548.3581080>
- [3] Judith Amores, Mae Dotan, and Pattie Maes. 2022. Development and Study of Ezzence: A Modular Scent Wearable to Improve Wellbeing in Home Sleep Environments. *Frontiers in Psychology* 13 (March 2022), 791768. <https://doi.org/10.3389/fpsyg.2022.791768>
- [4] Judith Amores and Pattie Maes. 2017. Essence: Olfactory Interfaces for Unconscious Influence of Mood and Cognitive Performance. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) (*CHI '17*). Association for Computing Machinery, New York, NY, USA, 28–34. <https://doi.org/10.1145/3025453.3026004>
- [5] Judith Amores Fernandez, Nirmita Mehra, Bjoern Rasch, and Pattie Maes. 2023. Olfactory Wearables for Mobile Targeted Memory Reactivation. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, Hamburg Germany, 1–20. <https://doi.org/10.1145/3544548.3580892>
- [6] James Auger. 2013. Speculative design: crafting the speculation. *Digital Creativity* 24, 1 (2013), 11–35. <https://doi.org/10.1080/14626268.2013.767276> arXiv:<https://doi.org/10.1080/14626268.2013.767276>
- [7] Ann-Sophie Barwich. 2019. A Critique of Olfactory Objects. *Frontiers in Psychology* 10 (2019), 1–11. <https://doi.org/10.3389/fpsyg.2019.01337>
- [8] Oliver Baus and Stéphane Bouchard. 2017. Exposure to an unpleasant odour increases the sense of Presence in virtual reality. *Virtual Reality* 21, 2 (June 2017), 59–74. <https://doi.org/10.1007/s10055-016-0299-3>
- [9] Cecilia Bembibre and Matija Strlič. 2022. From Smelly Buildings to the Scented Past: An Overview of Olfactory Heritage. *Frontiers in Psychology* 12 (Jan. 2022), 718287. <https://doi.org/10.3389/fpsyg.2021.718287>
- [10] Ceylan Beşevli, Christopher Dawes, Giada Brianza, Ava Fatah Gen. Schieck, Duncan Boak, Carl Philpott, Emanuela Maggioni, and Marianna Obrist. 2023. Nose Gym: An Interactive Smell Training Solution. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, Hamburg Germany, 1–4. <https://doi.org/10.1145/3544549.3583906>
- [11] Julian Bleeker. 2009. *Design Fiction: A Short Essay on Design, Science, Fact, and Fiction* (1 ed.). Wiley, California, USA, 561–578. <https://doi.org/10.1002/9781119815075.ch47>
- [12] Anna Blomkvist and Marlise Hofer. 2021. Olfactory Impairment and Close Social Relationships. A Narrative Review. *Chemical Senses* 46 (Jan. 2021), bjab037. <https://doi.org/10.1093/chemse/bjab037>
- [13] Laurens Boer, Harvey Bewley, Tom Jenkins, Sarah Homewood, Teresa Almeida, and Anna Vallgård. 2020. Gut-Tracking as Cultivation. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference*. ACM, Eindhoven Netherlands, 561–574. <https://doi.org/10.1145/3357236.3395588>
- [14] Virginia Braun and Victoria Clarke. 2012. *Thematic analysis*. American Psychological Association, Washington, 57–71. <https://doi.org/10.1037/13620-004>
- [15] Stephen Brewster, David McGookin, and Christopher Miller. 2006. Olfoto: designing a smell-based interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Montréal Québec Canada, 653–662. <https://doi.org/10.1145/1124772.1124869>
- [16] Giada Brianza, Jesse Benjamin, Patricia Cornelio, Emanuela Maggioni, and Marianna Obrist. 2022. QuintEssence: A Probe Study to Explore the Power of Smell on Emotions, Memories, and Body Image in Daily Life. *ACM Trans. Comput.-Hum. Interact.* 29, 6, Article 58 (nov 2022), 33 pages. <https://doi.org/10.1145/3526950>
- [17] Giada Brianza, Ana Tajadura-Jiménez, Emanuela Maggioni, Dario Pittera, Nadia Bianchi-Berthouze, and Marianna Obrist. 2019. As Light as Your Scent: Effects of Smell and Sound on Body Image Perception. In *Human-Computer Interaction – INTERACT 2019*, David Lamas, Fernando Loizides, Lennart Nacke, Helen Petrie, Marco Winckler, and Panayiotis Zaphiris (Eds.). Springer International Publishing, Cham, 179–202.
- [18] Jas Brooks, Pedro Lopes, Judith Amores, Emanuela Maggioni, Haruka Matsukura, Marianna Obrist, Roshan Lalintha Peiris, and Nimesha Ranasinghe. 2021. Smell, Taste, and Temperature Interfaces. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–6. <https://doi.org/10.1145/3411763.3441317>
- [19] Jas Brooks, Pedro Lopes, Marianna Obrist, Judith Amores Fernandez, and Jofish Kaye. 2023. Third Wave or Winter? The Past and Future of Smell in HCI. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, Hamburg Germany, 1–4. <https://doi.org/10.1145/3544549.3583749>
- [20] Jas Brooks, Shan-Yuan Teng, Jingxuan Wen, Romain Nith, Jun Nishida, and Pedro Lopes. 2021. Stereo-Smell via Electrical Trigeminal Stimulation. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–13. <https://doi.org/10.1145/3411764.3445300>
- [21] Michael Bull. 2017. *Designing with Smell, Environmental Scientists Perspective*. Routledge, New York, 111–118.
- [22] C. Bushdid, M. O. Magnasco, L. B. Vosshall, and A. Keller. 2014. Humans Can Discriminate More than 1 Trillion Olfactory Stimuli. *Science* 343, 6177 (March 2014), 1370–1372. <https://doi.org/10.1126/science.1249168>
- [23] Stuart Candy. 2018. *Gaming Futures Literacy: The Thing from the Future*. Routledge, Abingdon, Oxon, Chapter 6, 233–246.
- [24] Stuart Candy and J. Watson. 2018. *The Thing from the Future: Second Edition (Card game)*.
- [25] Yongsoo Choi, Rahul Parsani, Xavier Roman, Anshul Vikram Pandey, and Adrian David Cheok. 2012. Sound perfume: building positive impression during face-to-face communication. In *SIGGRAPH Asia 2012 Emerging Technologies*. ACM, Singapore Singapore, 1–3. <https://doi.org/10.1145/2407707.2407729>
- [26] Constance Classen. 1993. *Worlds of sense: exploring the senses in history and across cultures*. Routledge, Abingdon, Oxon.
- [27] Patricia Cornelio, Emanuela Maggioni, Giada Brianza, Sriram Subramanian, and Marianna Obrist. 2020. SmellControl: The Study of Sense of Agency in Smell. In *Proceedings of the 2020 International Conference on Multimodal Interaction*. ACM, Virtual Event Netherlands, 470–480. <https://doi.org/10.1145/3382507.3418810>
- [28] Patricia Cornelio, Carlos Velasco, and Marianna Obrist. 2021. Multisensory Integration as per Technological Advances: A Review. *Frontiers in Neuroscience* 15 (June 2021), 652611. <https://doi.org/10.3389/fnins.2021.652611>
- [29] Patricia Cornelio, Chi Thanh Vi, Giada Brianza, Emanuela Maggioni, and Marianna Obrist. 2023. *Smell and Taste-Based Interactions Enabled Through Advances in Digital Technology*. Springer International Publishing, Cham, 1–31. https://doi.org/10.1007/978-3-319-27648-9_16-1
- [30] B DeLacy Costello, A Amann, H Al-Kateb, C Flynn, W Filipaki, T Khalid, D Osborne, and N M Ratcliffe. 2014. A review of the volatiles from the healthy human body. *Journal of Breath Research* 8, 1 (Jan. 2014), 014001. <https://doi.org/10.1088/1752-7155/8/1/014001>
- [31] Neel Desai, Emanuela Maggioni, Marianna Obrist, and Mine Orlu. 2022. Scent-delivery devices as a digital healthcare tool for olfactory training: A pilot focus group study in Parkinson's disease patients. *DIGITAL HEALTH* 8 (Jan. 2022), 205520762211290. <https://doi.org/10.1177/20552076221129061>
- [32] Vincent M. Desiato, Dylan A. Levy, Young Jae Byun, Shaun A. Nguyen, Zachary M. Soler, and Rodney J. Schlosser. 2021. The Prevalence of Olfactory Dysfunction in the General Population: A Systematic Review and Meta-analysis. *American Journal of Rhinology & Allergy* 35, 2 (March 2021), 195–205. <https://doi.org/10.1177/1945892420946254>
- [33] Dmitrijs Dmitrenko, Emanuela Maggioni, Giada Brianza, Brittany E. Holthausen, Bruce N. Walker, and Marianna Obrist. 2020. CARoma Therapy: Pleasant Scents Promote Safer Driving, Better Mood, and Improved Well-Being in Angry Drivers. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. ACM, Honolulu HI USA, 1–13. <https://doi.org/10.1145/3313831.3376176>
- [34] Dmitrijs Dmitrenko, Emanuela Maggioni, and Marianna Obrist. 2019. Towards a Framework for Validating the Matching Between Notifications and Scents in Olfactory In-Car Interaction. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, Glasgow Scotland UK, 1–6. <https://doi.org/10.1145/3290607.3313001>
- [35] Marketa Dolejsova. 2018. Edible Speculations in the Parlour of Food Futures. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, Montreal QC Canada, 1–10. <https://doi.org/10.1145/3170427.3188406>

- [36] Paul Dourish. 2006. Re-space-ing place: “place” and “space” ten years on. In *Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work*. ACM, Banff Alberta Canada, 299–308. <https://doi.org/10.1145/1180875.1180921>
- [37] Nicolò Dozio, Emanuela Maggioni, Dario Pittera, Alberto Gallace, and Marianna Obrist. 2021. May I Smell Your Attention: Exploration of Smell and Sound for Visuospatial Attention in Virtual Reality. *Frontiers in Psychology* 12 (July 2021), 671470. <https://doi.org/10.3389/fpsyg.2021.671470>
- [38] Natalia Drabińska, Cheryl Flynn, Norman Ratcliffe, Ilaria Belluomo, Antonis Myridakis, Oliver Gould, Matteo Fois, Amy Smart, Terry Devine, and Ben De Lacy Costello. 2021. A literature survey of all volatiles from healthy human breath and bodily fluids: the human volatilome. *Journal of Breath Research* 15, 3 (July 2021), 034001. <https://doi.org/10.1088/1752-7163/abf1d0>
- [39] Anthony Dunne and Fiona Raby. 2013. *Speculative everything: design, fiction, and social dreaming*. The MIT Press, Cambridge, Massachusetts; London.
- [40] H. Ehrlichman and L. Bastone. 1992. *Olfaction and Emotion*. Springer, New York, 410–438.
- [41] Pedro Gil Farias, Roy Bendor, and Bregje F. Van Eekelen. 2022. Social dreaming together: A critical exploration of participatory speculative design. In *Proceedings of the Participatory Design Conference 2022 - Volume 2*. ACM, Newcastle upon Tyne United Kingdom, 147–154. <https://doi.org/10.1145/3537797.3537826>
- [42] Camille Ferdenzi, Johan Poncelet, Catherine Roubay, and Moustafa Bensafi. 2014. Repeated exposure to odors induces affective habituation of perception and sniffing. *Frontiers in Behavioral Neuroscience* 8 (April 2014), 119. <https://doi.org/10.3389/fnbeh.2014.00119>
- [43] J.J. Gibson. 1966. *The senses considered as perceptual systems*. Houghton Mifflin, USA.
- [44] G. Hanson-Vaux, A.-S. Crisinel, and C. Spence. 2013. Smelling Shapes: Cross-modal Correspondences Between Odors and Shapes. *Chemical Senses* 38, 2 (Feb. 2013), 161–166. <https://doi.org/10.1093/chemse/bjs087>
- [45] Donna Jeanne Haraway. 1994. A Game of Cat’s Cradle: Science Studies, Feminist Theory, Cultural Studies. *Configurations* 2, 1 (1994), 59–71. <https://doi.org/10.1353/con.1994.0009>
- [46] Keisuke Hasegawa, Liwei Qiu, and Hiroyuki Shinoda. 2018. Midair Ultrasound Fragrance Rendering. *IEEE Transactions on Visualization and Computer Graphics* 24, 4 (April 2018), 1477–1485. <https://doi.org/10.1109/TVCG.2018.2794118>
- [47] Yoshihiro Hasegawa, Masayuki Yabuki, and Masamoto Matsukane. 2004. Identification of New Odoriferous Compounds in Human Axillary Sweat. *Chemistry & Biodiversity* 1, 12 (2004), 2042–2050. <https://doi.org/10.1002/cbdv.200490157> <https://onlinelibrary.wiley.com/doi/pdf/10.1002/cbdv.200490157>
- [48] Wei He, Sanne Boesveldt, Cees de Graaf, and René A. de Wijk. 2014. Dynamics of autonomic nervous system responses and facial expressions to odors. *Frontiers in Psychology* 5 (2014), 1–8. <https://doi.org/10.3389/fpsyg.2014.00110>
- [49] Marie Hebrok and Henry Mainsah. 2022. Skinny as a Bird: Design fiction as a vehicle for reflecting on food futures. *Futures* 141 (Aug. 2022), 102983. <https://doi.org/10.1016/j.futures.2022.102983>
- [50] Victoria Henshaw, Kate McLean, Dominic Medway, Chris Perkins, and Gary Warnaby (Eds.). 2017. *Designing with Smell: Practices, Techniques and Challenges* (1 ed.). Routledge, New York. <https://doi.org/10.4324/9781315666273>
- [51] Rachel S. Herz and Martha R. Bajec. 2022. Your Money or Your Sense of Smell? A Comparative Analysis of the Sensory and Psychological Value of Olfaction. *Brain Sciences* 12, 3 (Feb. 2022), 299. <https://doi.org/10.3390/brainsci12030299>
- [52] Ryuji Hirayama, Diego Martinez Plasencia, Nobuyuki Masuda, and Sriram Subramanian. 2019. A volumetric display for visual, tactile and audio presentation using acoustic trapping. *Nature* 575, 7782 (Nov. 2019), 320–323. <https://doi.org/10.1038/s41586-019-1739-5>
- [53] Kara C. Hoover. 2010. Smell with inspiration: The evolutionary significance of olfaction. *American Journal of Physical Anthropology* 143, S51 (2010), 63–74. <https://doi.org/10.1002/ajpa.21441>
- [54] Noura Howell, Britta F. Schulte, Amy Twigger Holroyd, Rocio Fatás Arana, Sumita Sharma, and Grace Eden. 2021. Calling for a Plurality of Perspectives on Design Futuring: An Un-Manifesto. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–10. <https://doi.org/10.1145/3411763.3450364>
- [55] Fabian Huttmacher. 2019. Why Is There So Much More Research on Vision Than on Any Other Sensory Modality? *Frontiers in Psychology* 10 (Oct. 2019), 2246. <https://doi.org/10.3389/fpsyg.2019.02246>
- [56] Lucia F. Jacobs, Jennifer Arter, Amy Cook, and Frank J. Sulloway. 2015. Olfactory Orientation and Navigation in Humans. *PLoS ONE* 10, 6 (June 2015), e0129387. <https://doi.org/10.1371/journal.pone.0129387>
- [57] Pauline Jossain, Catherine Roubay, and Moustafa Bensafi. 2014. A pleasant familiar odor influences perceived stress and peripheral nervous system activity during normal aging. *Frontiers in Psychology* 5 (2014), 113. <https://doi.org/10.3389/fpsyg.2014.00113>
- [58] Kasun Karunanayaka, Adrian David Cheok, and Somaiyeh Vedadi. 2023. *Digital Smell: Toward Electrically Reproducing Artificial Smell Sensations*. Vol. 11. IEEE, USA. 50659–50670 pages. <https://doi.org/10.1109/ACCESS.2023.3278093>
- [59] Andreas Keller. 2011. Attention and Olfactory Consciousness. *Frontiers in Psychology* 2 (2011), 380. <https://doi.org/10.3389/fpsyg.2011.00380>
- [60] Patthamawadi Kiatbenjakul, Kanok-Orn Intarapichet, and Keith R. Cadwallader. 2015. Characterization of potent odorants in male giant water bug (*Lethocerus indicus* Lep. and Serv.), an important edible insect of Southeast Asia. *Food Chemistry* 168 (Feb. 2015), 639–647. <https://doi.org/10.1016/j.foodchem.2014.07.108>
- [61] Linda Kotut, Neelma Bhatti, Morva Saaty, Derek Haqq, Timothy L. Stelter, and D. Scott McCrickard. 2020. Clash of Times: Respectful Technology Space for Integrating Community Stories in Intangible Exhibits. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. ACM, Honolulu HI USA, 1–13. <https://doi.org/10.1145/3313831.3376354>
- [62] Sandjar Kozubaev, Chris Elsdon, Noura Howell, Marie Louise Juul Søndergaard, Nick Merrill, Britta Schulte, and Richmond Y. Wong. 2020. Expanding Modes of Reflection in Design Futuring. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. ACM, Honolulu HI USA, 1–15. <https://doi.org/10.1145/3313831.3376526>
- [63] Airi Lampinen, Donald McMillan, Barry Brown, Zarah Faraj, Deha Nemutlu Cambazoglu, and Christian Virtala. 2017. Friendly but not Friends: Designing for Spaces Between Friendship and Unfamiliarity. In *Proceedings of the 8th International Conference on Communities and Technologies*. ACM, Troyes France, 169–172. <https://doi.org/10.1145/3083671.3083677>
- [64] Joanna Latimer. 2013. Being Alongside: Rethinking Relations amongst Different Kinds. *Theory, Culture & Society* 30, 7–8 (Dec. 2013), 77–104. <https://doi.org/10.1177/0263276413500078>
- [65] Bruno Latour. 2004. How to Talk About the Body? the Normative Dimension of Science Studies. *Body & Society* 10, 2–3 (June 2004), 205–229. <https://doi.org/10.1177/1357034X04042943>
- [66] Yuxuan Lei, Qi Lu, and Yingqing Xu. 2022. O&O: A DIY toolkit for designing and rapid prototyping olfactory interfaces. In *CHI Conference on Human Factors in Computing Systems*. ACM, New Orleans LA USA, 1–21. <https://doi.org/10.1145/3491102.3502033>
- [67] Zilan Lin, Kai Kunze, Atsuro Ueki, and Masa Inakage. 2020. AromaCue - A Scent Toolkit To Cope with Stress using the 4-7-8 Breathing Method. In *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction*. ACM, Sydney NSW Australia, 265–272. <https://doi.org/10.1145/3374920.3374940>
- [68] Qi Lu, Wan Liang, Hao Wu, Hoian Wong, Haipeng Mi, and Yingqing Xu. 2020. Exploring Potential Scenarios and Design Implications Through a Camera-like Physical Odor Capture Prototype. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference*. ACM, Eindhoven Netherlands, 2021–2033. <https://doi.org/10.1145/3357236.3395434>
- [69] M Luisa Dematte. 2006. Cross-Modal Associations Between Odors and Colors. *Chemical Senses* 31, 6 (April 2006), 531–538. <https://doi.org/10.1093/chemse/bj057>
- [70] Johan N. Lundström and Mats J. Olsson. 2010. *Functional Neuronal Processing of Human Body Odors*. Vol. 83. Elsevier, USA, 1–23. [https://doi.org/10.1016/S0083-6729\(10\)83001-8](https://doi.org/10.1016/S0083-6729(10)83001-8)
- [71] Emanuela Maggioni, Robert Cobden, Dmitrijs Dmitrenko, Kasper Hornbæk, and Marianna Obrist. 2020. SMELL SPACE: Mapping out the Olfactory Design Space for Novel Interactions. *ACM Transactions on Computer-Human Interaction* 27, 5 (Oct. 2020), 1–26. <https://doi.org/10.1145/3402449>
- [72] Emanuela Maggioni, Robert Cobden, Dmitrijs Dmitrenko, and Marianna Obrist. 2018. Smell-O-Message: Integration of Olfactory Notifications into a Messaging Application to Improve Users’ Performance. In *Proceedings of the 20th ACM International Conference on Multimodal Interaction*. ACM, Boulder CO USA, 45–54. <https://doi.org/10.1145/3242969.3242975>
- [73] Emanuela Maggioni, Robert Cobden, and Marianna Obrist. 2019. OWidgets: A toolkit to enable smell-based experience design. *International Journal of Human-Computer Studies* 130 (Oct. 2019), 248–260. <https://doi.org/10.1016/j.ijhcs.2019.06.014>
- [74] Mehmet K. Mahmut, Richard J. Stevenson, and Ian Stephen. 2019. Do women love their partner’s smell? Exploring women’s preferences for and identification of male partner and non-partner body odor. *Physiology & Behavior* 210 (Oct. 2019), 112517. <https://doi.org/10.1016/j.physbeh.2019.04.006>
- [75] Yiling Mai, Susanne Menzel, Mandy Cuevas, Antje Haehner, and Thomas Hummel. 2022. Well-being in patients with olfactory dysfunction. *Physiology & Behavior* 254 (Oct. 2022), 113899. <https://doi.org/10.1016/j.physbeh.2022.113899>
- [76] Asifa Majid and Niclas Burenhult. 2014. Odors are expressible in language, as long as you speak the right language. *Cognition* 130, 2 (Feb. 2014), 266–270. <https://doi.org/10.1016/j.cognition.2013.11.004>
- [77] John P. McGann. 2017. Poor human olfaction is a 19th-century myth. *Science* 356, 6338 (May 2017), eaam7263. <https://doi.org/10.1126/science.aam7263>
- [78] Harold McGee. 2020. *A Sense for the Essential*. Penguin, Canada, xxiv.
- [79] Manfred Milinski, Ilona Croy, Thomas Hummel, and Thomas Boehm. 2013. Major histocompatibility complex peptide ligands as olfactory cues in human body odour assessment. *Proceedings of the Royal Society B: Biological Sciences* 280, 1755 (March 2013), 20122889. <https://doi.org/10.1098/rspb.2012.2889>

- [80] Kiyoko Morita. 1999. *The book of incense: enjoying the traditional art of Japanese scents* (first paperback ed.). Kodansha International, Tokyo.
- [81] Marianna Obrist, Alexandre N. Tuch, and Kasper Hornbaek. 2014. Opportunities for odor: experiences with smell and implications for technology. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Toronto Ontario Canada, 2843–2852. <https://doi.org/10.1145/2556288.2557008>
- [82] A. Oleszkiewicz, V. A. Schriever, I. Croy, A. Hähner, and Thomas Hummel. 2019. Updated Sniffin' Sticks normative data based on an extended sample of 9139 subjects. *European Archives of Oto-Rhino-Laryngology* 276, 3 (March 2019), 719–728. <https://doi.org/10.1007/s00405-018-5248-1>
- [83] Jonas K. Olofsson, Ingrid Ekström, Maria Larsson, and Steven Nordin. 2021. Olfaction and Aging: A Review of the Current State of Research and Future Directions. *i-Perception* 12, 3 (May 2021), 204166952110203. <https://doi.org/10.1177/20416695211020331>
- [84] Michael H. Parsons, Raimund Apfelbach, Peter B. Banks, Elissa Z. Cameron, Chris R. Dickman, Anke S. K. Frank, Menna E. Jones, Ian S. McGregor, Stuart McLean, Dietland Müller-Schwarze, Elisa E. Sparrow, and Daniel T. Blumstein. 2018. Biologically meaningful scents: a framework for understanding predator-prey research across disciplines. *Biological Reviews* 93, 1 (Feb. 2018), 98–114. <https://doi.org/10.1111/brv.12334>
- [85] M. L. Pelchat, C. Bykowski, F. F. Duke, and D. R. Reed. 2011. Excretion and Perception of a Characteristic Odor in Urine after Asparagus Ingestion: a Psychophysical and Genetic Study. *Chemical Senses* 36, 1 (Jan. 2011), 9–17. <https://doi.org/10.1093/chemse/bjq081>
- [86] C. M. Philpott and D. Boak. 2014. The Impact of Olfactory Disorders in the United Kingdom. *Chemical Senses* 39, 8 (Oct. 2014), 711–718. <https://doi.org/10.1093/chemse/bju043>
- [87] Carl M. Philpott, Andreas Espehana, Mairenn Garden, Ngan Ta, Nishita Gadi, Kala Kumaresan, Devina Maru, Lorenzo D. Stafford, Nina Bleasdale, and Duncan Boak. 2023. Establishing UK research priorities in smell and taste disorders: A James Lind alliance priority setting partnership. *Clinical Otolaryngology* 48, 1 (Jan. 2023), 17–24. <https://doi.org/10.1111/coa.13985>
- [88] Michal Pieniak, Anna Oleszkiewicz, Vittoria Avaro, Federico Calegari, and Thomas Hummel. 2022. Olfactory training – Thirteen years of research reviewed. *Neuroscience & Biobehavioral Reviews* 141 (Oct. 2022), 104853. <https://doi.org/10.1016/j.neubiorev.2022.104853>
- [89] Jess Porter, Brent Craven, Rehan M Khan, Shao-Ju Chang, Irene Kang, Benjamin Judkewitz, Jason Volpe, Gary Settles, and Noam Sobel. 2007. Mechanisms of scent-tracking in humans. *Nature Neuroscience* 10, 1 (Jan. 2007), 27–29. <https://doi.org/10.1038/nn1819>
- [90] Nimesha Ranasinghe, Pravar Jain, Nguyen Thi Ngoc Tram, Koon Chuan Raymond Koh, David Tolley, Shaianny Karwita, Lin Lien-Ya, Yan Liangkun, Kala Shamaiah, Chow Eason Wai Tung, Ching Chiuan Yen, and Ellen Yi-Luen Do. 2018. Season Traveller: Multisensory Narration for Enhancing the Virtual Reality Experience. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, Montreal QC Canada, 1–13. <https://doi.org/10.1145/3173574.3174151>
- [91] G. Webster Ross, Helen Petrovitch, Robert D. Abbott, Caroline M. Tanner, Jordan Popper, Kamal Masaki, Lenore Launer, and Lon R. White. 2008. Association of olfactory dysfunction with risk for future Parkinson's disease. *Annals of Neurology* 63, 2 (Feb. 2008), 167–173. <https://doi.org/10.1002/ana.21291>
- [92] Corina Sas, Steve Whittaker, Steven Dow, Jodi Forlizzi, and John Zimmerman. 2014. Generating implications for design through design research. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Toronto Ontario Canada, 1971–1980. <https://doi.org/10.1145/2556288.2557357>
- [93] Lavi Secundo, Kobi Snitz, Kineret Weissler, Liron Pinchover, Yehuda Shoenfeld, Ron Loewenthal, Nancy Agmon-Levin, Idan Frumin, Dana Bar-Zvi, Sagit Shushan, and Noam Sobel. 2015. Individual olfactory perception reveals meaningful nonolfactory genetic information. *Proceedings of the National Academy of Sciences* 112, 28 (July 2015), 8750–8755. <https://doi.org/10.1073/pnas.1424826112>
- [94] Gordon M Shepherd. 2004. The Human Sense of Smell: Are We Better Than We Think? *PLoS Biology* 2, 5 (May 2004), e146. <https://doi.org/10.1371/journal.pbio.0020146>
- [95] Charles Spence. 2015. Just how much of what we taste derives from the sense of smell? *Flavour* 4, 1 (Dec. 2015), 30. <https://doi.org/10.1186/s13411-015-0040-2>
- [96] Charles Spence. 2020. Using Ambient Scent to Enhance Well-Being in the Multisensory Built Environment. *Frontiers in Psychology* 11 (Nov. 2020), 598859. <https://doi.org/10.3389/fpsyg.2020.598859>
- [97] R. J. Stevenson. 2010. An Initial Evaluation of the Functions of Human Olfaction. *Chemical Senses* 35, 1 (Jan. 2010), 3–20. <https://doi.org/10.1093/chemse/bjp083>
- [98] Marilyn Strathern. 1998. Gender: Division or Comparison? *The Sociological Review* 45 (May 1998), 42–63. <https://doi.org/10.1111/j.1467-954X.1997.tb03453.x>
- [99] Marie Louise Juul Søndergaard, Nadia Campo Woytuk, Noura Howell, Vasiliki Tsaknaki, Karey Helms, Tom Jenkins, and Pedro Sanches. 2023. Fabulation as an Approach for Design Futuring. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference*. ACM, Pittsburgh PA USA, 1693–1709. <https://doi.org/10.1145/3563657.3596097>
- [100] Theresa Jean Tanenbaum. 2014. Design fictional interactions: why HCI should care about stories. *Interactions* 21, 5 (Sept. 2014), 22–23. <https://doi.org/10.1145/2648414>
- [101] Bruce M. Tharp and Stephanie M. Tharp. 2018. *Discursive design: critical, speculative, and alternative things*. The MIT Press, Cambridge, MA.
- [102] Vasiliki Tsaknaki, Pedro Sanches, Tom Jenkins, Noura Howell, Laurens Boer, and Afroditi Bitzouni. 2022. Fabulating Biodata Futures for Living and Knowing Together. In *Designing Interactive Systems Conference*. ACM, Virtual Event Australia, 1878–1892. <https://doi.org/10.1145/3532106.3533477>
- [103] Tim J. Van Hartevelt and Morten L. Kringelbach. 2012. *The Olfactory System*. Elsevier, USA, 1219–1238. <https://doi.org/10.1016/B978-0-12-374236-0.10034-3>
- [104] Torben Volkman, Markus Dresel, and Nicole Jochems. 2023. Balancing Power Relations in Participatory Design: The Importance of Initiative and External Factors. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, Hamburg Germany, 1–6. <https://doi.org/10.1145/3544549.3585864>
- [105] Ron Wakkary, Doenja Oogjes, Henry W. J. Lin, and Sabrina Hauser. 2018. Philosophers Living with the Tilting Bowl. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, Montreal QC Canada, 1–12. <https://doi.org/10.1145/3173574.3173668>
- [106] John-James Wooller, Jo Barton, Valerie F Gladwell, and Dominic Micklewright. 2016. Occlusion of sight, sound and smell during Green Exercise influences mood, perceived exertion and heart rate. *International Journal of Environmental Health Research* 26, 3 (May 2016), 267–280. <https://doi.org/10.1080/09603123.2015.1109068>
- [107] Jieling Xiao, Malcolm Tait, and Jian Kang. 2017. *The Design of Urban Smellscapes with Fragrant Plants and Water Features*. Routledge, New York, 83–95.
- [108] Jieling Xiao, Malcolm Tait, and Jian Kang. 2020. Understanding smellscapes: Sense-making of smell-triggered emotions in place. *Emotion, Space and Society* 37 (Nov. 2020), 100710. <https://doi.org/10.1016/j.emospa.2020.100710>
- [109] Hebo Gong, Yanan Wang, Zhitong Cui and Ting Chen. 2023. OlfacKit: A Toolkit for Integrating Atomization-Based Olfactory Interfaces into Daily Scenarios. *International Journal of Human-Computer Interaction* 0, 0 (2023), 1–20. <https://doi.org/10.1080/10447318.2023.2212512> arXiv:<https://doi.org/10.1080/10447318.2023.2212512>
- [110] Yaara Yeshurun and Noam Sobel. 2010. An Odor is Not Worth a Thousand Words: From Multidimensional Odors to Unidimensional Odor Objects. *Annual Review of Psychology* 61, 1 (Jan. 2010), 219–241. <https://doi.org/10.1146/annurev.psych.60.110707.163639>
- [111] Milia Zec and Winslow Porter. 2017. Tree VR. <https://www.treeofficial.com>
- [112] Yong-ming Zou, Da Lu, Li-Ping Liu, Hui-hong Zhang, and Yu-ying Zhou. 2016. Olfactory dysfunction in Alzheimer's disease. *Neuropsychiatric Disease and Treatment* 12 (April 2016), 869. <https://doi.org/10.2147/NDT.S104886>