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Making Invisible Change Felt: VR and Olfaction Design for Translating Corrosion

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Figure 1: Participant experiencing a punctual smell (rusticles & iodine) during the smell VR experience, in public.

Abstract

Communicating slow, invisible environmental processes such as corrosion remains challenging in public contexts. We explore how smell can function as a creative design material in a multisensory VR experience for science communication. Using Research-through-Design (RtD), we developed and iteratively refined a 5-minute VR experience across co-design, prototyping, and public deployment. Olfaction was introduced as an embodied layer to translate imperceptible chemical processes into experiential form. Findings from a festival deployment with 73 participants show that smell enhanced immersion and memorability for some users but was perceived inconsistently and often amplified already salient visual moments.

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We characterise smell as an *unruly material* due to variability in perception, diffusion, and context, and contribute an RtD account of multisensory VR design for science communication, outlining implications for designing with olfaction in public settings.

CCS Concepts

• **Human-centered computing** → **User centered design**; **Virtual reality**; *Laboratory experiments*; *Field studies*.

Keywords

multisensory VR, olfaction, research through design, science communication, environmental awareness, embodied experience, materiality, public engagement, corrosion

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1 Introduction

Communicating slow, distributed, and largely invisible environmental processes such as corrosion, poses a persistent challenge for public engagement. Corrosion unfolds across temporal and spatial scales that are difficult to perceive, yet its consequences are profound, affecting infrastructure, ecosystems, and economies. Making such processes perceptible, relatable, and meaningful in informal public settings remains a concern for science communication.

Virtual Reality (VR) has been increasingly used to address this challenge by enabling the visualisation of otherwise inaccessible phenomena and guiding audiences through staged, immersive narratives [6, 11]. At the same time, multisensory approaches suggest that engagement with complex phenomena is not solely cognitive but also embodied and affective. Among these modalities, olfaction remains underexplored in Human-Computer Interaction (HCI), despite its strong links to memory, emotion, and perception [10, 15].

This paper explores how smell can be used not simply as an atmospheric enhancement, but as a *creative design material* for translating imperceptible scientific processes into embodied experiences. We present an overview of the Research-through-Design (RtD) inquiry used in the development of a multisensory VR experience that communicates the causes and consequences of steel corrosion. Across the RtD trajectory spanning co-design, iterative prototyping, and a public festival deployment, olfaction emerged as a critical but challenging design material.

Rather than treating smell as a controlled variable, we investigate how it participates in shaping experience in messy, public contexts. Our focus is not on demonstrating causal effects, but on understanding how multisensory elements interact with narrative, perception, and context in practice. We contribute:

- An overview of the RtD process of designing multisensory VR for public science communication;
- An articulation of smell as an *unruly material* in interactive systems;
- Design considerations for deploying olfactory experiences in public, heterogeneous settings.

By framing smell as a creative material for translating invisible environmental change into embodied experience, this work aligns with broader efforts to explore how creativity and interactive systems can foster new forms of engagement with societal challenges.

2 Background

Communicating complex scientific phenomena to public audiences requires translating abstract processes into perceptible forms. Prior work has explored VR as a science communication medium, demonstrating its potential to enhance engagement, presence, and learning across domains such as ocean science and climate change [9, 11].

Multisensory HCI research further suggests that combining modalities can deepen experiential engagement [10]. Smell, in particular, is closely linked to memory and affect [5], and has been shown to influence presence in immersive environments [4]. However, much of this work remains lab-based, focusing on controlled delivery and generic scents.

Designing with smell introduces unique challenges. Odour perception is highly variable and shaped by environmental factors

such as airflow, temperature, and spatial context, as well as individual differences in sensitivity and prior experience [8, 15]. These characteristics make smell *unruly*, difficult to standardise, but also position it as a rich, expressive material for design.

Research-through-Design (RtD) offers an approach for engaging with such complexity, allowing knowledge to emerge through iterative making and reflection [16]. In this work, we use RtD to explore how multisensory VR experiences are shaped across stages of design, testing, and public deployment.

3 RtD Trajectory

Our inquiry unfolded across: 1. co-design, 2. iterative prototyping; and 3. public deployment. Rather than a linear process, these stages functioned as iterative probes, shaping and refining the design.

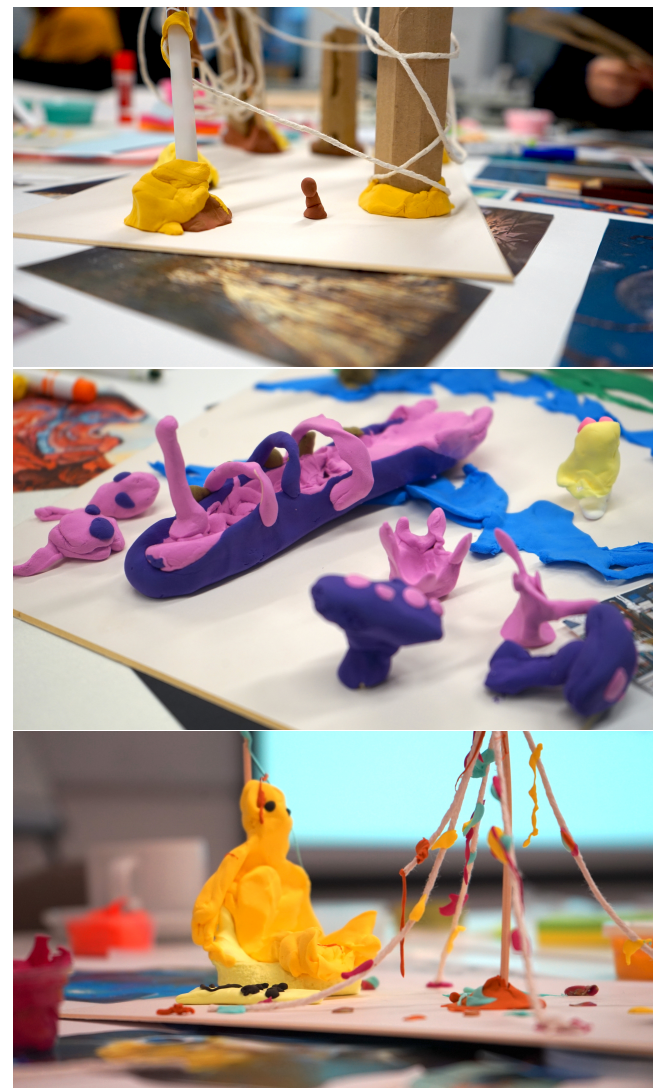


Figure 2: Top: human figure and large structures; titled '*Rustopia*' (1). Middle: colourful underwater world (2). Bottom: human figure and things caught in a structure (3).

3.1 Co-design: Exploring Narrative and Scale

We conducted a co-design workshop with 9 participants from design and research backgrounds to explore how corrosion could be represented experientially. Participants generated narrative concepts through diagrams, moodboards, and physical dioramas.

Three design directions emerged (see dioramas in Fig. 2): dystopian collapse, underwater exploration, and laboratory-style investigation. Across these, recurring themes were the importance of scale (micro vs macro), narrative progression, and affective engagement.

Importantly, participants proposed multisensory elements such as smell to enhance immersion and meaning-making. While not initially used, this suggestion informed later stages of the design.

4 VR development: from alpha to beta

We iteratively developed the VR experience in close consultation with corrosion scientists to ensure an engaging narrative that accurately conveyed key scientific facts: corrosion processes, contributing factors, and their environmental and economic impact. The alpha prototype was shared with collaborators to assess both scientific clarity and emotional resonance, even among experts. Feedback informed subsequent iterations prior to public deployment.

4.1 Alpha VR tested with corrosion scientists

4.1.1 Methods. Dioramas (1) and (2) from the co-design workshop informed scene 2, while observations of bio-chemical corrosion processes (diorama (3)) and scientific explanations shaped the microscopic perspective of scene 1. The storyboard and narration were developed with scientists, and the first VR iteration was tested with 13 corrosion researchers (engineering, biology, data science). Open-ended interviews captured experiential feedback and factual accuracy, and were analysed to identify recurring issues.

4.1.2 Findings from open-ended interviews. Participants confirmed that the 5-minute duration and two scenes (see Fig. 3) were appropriate and the content accessible for non-experts. Key improvements were identified and implemented in the beta prototype:

- include electro-chemical indicators (Fe^{++} and e^-) to visualise material loss;
- improve representation of bacterial colonies (exponential growth);
- enhance underwater immersion (colour, bubbles);
- smooth transitions between scales;
- further emphasise consequences of corrosion (e.g. collapsing structures, leaking pipes);
- add localised audio cues to direct attention;
- provide a clearer ending (e.g. logo).

Scientists reported confusion about spatial orientation and scale in scene 1. We retained this to create intrigue, gradually revealing the microscopic scale through electro-chemical signs and bacterial growth. Suggestions for user movement were not implemented due to physical space constraints and motion sickness concerns [14].

4.2 Beta VR tested with university members

4.2.1 Methods. After incorporating feedback from scientists, we tested the improved 5-minute beta prototype (as featured in Fig. 4)



Figure 3: Alpha VR. Top: microscopic bacterial corrosion (scene 1). Bottom: sunken ship and structures (scene 2).

with 16 non-specialist participants to ensure the experience was ready for public deployment. Participants completed:

- (1) Slater Usability Scale (SUS-P) [13];
- (2) System Usability Scale (SUS) [3, 7];
- (3) User Experience Questionnaire – Short (UEQ-S) [12].

4.2.2 Findings from the Questionnaires. Results indicate:

- (1) **SUS-P:** Moderate-to-high presence (being there: $M=5.56$, $SD=1.09$; remembering a place: $M=5$, $SD=1.03$), alongside awareness of the virtual setting ($M=4.56$, $SD=1.15$). Both scenes were perceived as non-realistic, as expected.
- (2) **SUS:** The system was rated as usable, consistent, and easy to learn.
- (3) **UEQ-S:** The experience was perceived as supportive, efficient, clear, and inventive. The lowest score (5.68/7) for “boring vs exciting” still indicates a positive experience.

4.3 Take-aways and next RtD steps

The VR experience emerged through iterative refinement informed by workshop participants and scientists, balancing scientific accuracy with affective engagement.

Early ideas such as gamification and complex interactivity were not pursued further, while multisensory extensions beyond audio-visual stimuli, as highlighted by co-design workshop participants, remained feasible without modifying the VR application and informed subsequent RtD directions.



Figure 4: Beta VR. Top: microscopic corrosion processes and bacterial colonies (scene 1). Bottom: collapsing underwater structures including the sinking ship (scene 2).

4.4 Smell as Design Material

Smell was introduced last, as a means of translating corrosion into an embodied, sensory experience. Two approaches were defined:

- **Punctual** - these were phenomenon-specific scents, related to corrosion processes;
- **Atmospheric** - these were ambient scents aimed to enhance the environmental context.

We experimented with both synthetic and natural materials. Commercial “sea” scents were rejected for their artificial character, leading to the development of bespoke scents using seaweed. Rust-related scents included both a synthetic “Iron Smelting” commercial scent and a bespoke scent made of a mixture of rusticles and iodine, that produced a sulphuric odour.

Through this process, smell emerged as an *unruly material*:

- **Instability**: natural materials such as seaweed evolved over time through fermentation;
- **Diffusion**: scents were difficult to contain, localise and control spatially and required different approaches;
- **Variability**: participants due to their idiosyncrasies perceived and interpreted smells differently;
- **Intensity**: strong odours such as “Iron Smelting” could provoke avoidance or discomfort.

These properties required ongoing adjustment and highlighted the limits of precise control in public deployments.

4.5 Public Deployment

The VR experience was deployed at a family-friendly festival with 73 participants. Two parallel setups were used: one with olfactory augmentation (SVR) and one without (no-SVR).

Rather than a fully uncontrolled environment, the setting can be characterised as a *public, minimally-controlled deployment*, where we had little control over airflow, group behaviour, and spatial layout, all of which influenced the experience. Data collection involved observations and short exit questionnaires, providing some insights into what participants found memorable and meaningful.

In both conditions, participants responded positively to the science communication VR experience, describing it as engaging and educational. For example, participants noted it was “a great idea and really neat way to communicate scientific ideas” (P01, SVR) and a “fun way of educating people in this topic” (P32, no-SVR). Several highlighted its memorability, with one participant stating it offered “knowledge about corrosion that [they] will never forget” (P66, SVR).

At the same time, a few participants noted that immersion could compete with comprehension, reporting that “the experience was so immersive [that] some of the science facts were not easily taken in” (P40, no-SVR). Suggestions for improvement included adding an avatar and increasing interactivity.

In the olfactory augmentation setup, participants confirmed that multisensory elements contributed to their experience, commenting that “extra smells really added to the immersion, but they were rather unexpected!” (P11, SVR). For some participants, smell itself became a memorable moment, indicating its affective impact, although its role in supporting understanding was less clearly articulated.

However, responses to sensory activation were inconsistent. Some participants explicitly reported noticing smells: “when the ship was sinking, I had a change in smell” (P58, SVR); while others did not report any sensory stimulation despite being exposed to scents. This variability highlights the difficulty of reliably capturing olfactory experiences in short, in-situ evaluations in public.

Participants often linked smell to audiovisual events, reinforcing immersion and cross-modal perception: “when I saw the starfish I could smell seaweed” (P05, SVR). During the public deployment, recall was more frequently associated with large-scale impactful events such as collapsing structures and the sinking ship, but microscopic processes were also mentioned: “I was aware of corrosion [...] but I was not aware of the influence of bacteria in this.” (P03, SVR).

Overall, the findings suggest that while smell contributed to immersion and memorability, its effects were variable and often aligned with amplifying already salient moments of the VR narrative rather than directing attention toward specific scientific explanations. Key themes included surprise at the role of bacteria, strong reactions to large-scale consequences, and the role of multisensory stimulation in shaping the overall experience.

5 Discussion

Through our RtD process, we developed a multisensory VR experience that communicates corrosion in an emotionally engaging way. Public deployment showed that participants engaged with slow, hidden electrochemical processes, with smell emerging as a memorable component for some. Balancing affect and information remained central, shaping both design decisions and outcomes.



Figure 5: Top: Participant being offered a jar of rusting metal (*'rusticles'*) combined with iodine (scene 1). Bottom: Being offered a cotton ball infused with *'Iron Smelting'* (scene 2).

5.1 RtD Science Communication for Multisensory VR

The design space was initially open, indeterminate. While the goal was clear, appropriate narrative and sensory strategies were not. RtD enabled progressive clarification, transforming uncertainty into structured experiential approaches through iterative experimentation, making and testing.

The co-design workshop surfaced key ideas such as multi-scale representation and affective engagement, informing early prototypes. Further design iteration then acted as attunement: each version revealed gaps in clarity or impact, enabling refinement. Design decisions emerged cumulatively across design stages rather than from singular insights, with input from scientists playing a role throughout.

Importantly, multisensory design proved relational rather than additive. Each sensory modality reshaped perception of others, requiring careful and ongoing alignment of narrative, scale, and pacing. Public deployment further highlighted contextual constraints,

supporting Bødker's view that in-the-wild research produces partial but valuable knowledge [2].

5.2 Designing with smell

Smell was introduced as a design probe, a material to help translate abstract processes into embodied experience. Rather than literal representation, we sought **olfactory equivalents**, evocative cues aligned with narrative moments that carried affect into the science.

Working with natural and synthetic scents revealed instability. Natural smells varied with environmental conditions, while synthetic ones diffused quickly and could become overwhelming. Some bespoke scents were discarded due to intensity, highlighting the difficulty of calibration.

These challenges position smell as an *unruly material*. Its behaviour depends on context, space, and individual sensitivity, making precise control difficult, particularly in public settings. Instead, olfactory design must accommodate variability.

Unpleasant smells proved particularly impactful, supporting findings that they enhance presence [1], but they also triggered avoidance. In our public deployment, combined audiovisual and olfactory cues occasionally produced strong physical reactions in participants, indicating heightened affective engagement.

Spatial factors further complicated design. Atmospheric smells dispersed unevenly in the large room, and the orchestration of manual delivery introduced variability. These constraints emphasise the importance of aligning spatial setup with olfactory design.

Flexible strategies, including calibration and opt-out options, are therefore essential. Despite its challenges, smell offers unique affective affordances that are worth pursuing, and that can extend engagement beyond the immediate experience.

5.3 Smell VR as a Tool for Science Communication

Participants reported learning about corrosion and being surprised by microscopic bacterial processes, indicating our VR experience successfully communicated core scientific concepts. This occurred across both setups, with olfactory augmentation and without, suggesting the audiovisual narrative was an effective communicator.

Smell contributed additional experiential depth. Participants described enhanced immersion and memorable moments, with one stating: "*knowledge about corrosion that I will never forget*" (P66, SVR). However, olfactory perception was inconsistent, with some participants not reporting smell at all even when there were scents.

Importantly, participants most often recalled dramatic events rather than microscopic processes. This suggests that smells, and their positioning within the narrative structure, intensified salient moments rather than focus attention on details, *functioning as an experiential amplifier* rather than as a cognitive guide.

Participants did not question the incongruity of smelling underwater, indicating that olfaction did not disrupt immersion but contributed to a broader sense of "chemical reality". This highlights its role in supporting imaginative and embodied engagement.

Overall, smell expanded science communication beyond visual and textual modes, introducing affective and sensory dimensions. However, its use for science communication requires careful consideration of variability, intensity, and audience diversity.

5.4 Limitations

The short exit questionnaires limited the depth of insights that could be gathered, and the manual smell delivery introduced variability. Visible scent sources such as seaweed may have influenced perception, and content analysis of the collected data involved interpretive subjectivity.

These constraints reflect broader challenges of studying multisensory systems in public contexts, highlighting the need for methods that balance ecological validity with richer data collection.

6 Design Implications

Across the study, four themes emerged: increased awareness of bacterial processes, strong affective responses to large-scale impact, smell as a variable sensory layer, and immersion linked to presence. Overall, multisensory VR supported engagement and broad understanding, while the role of smell remained context-dependent.

From these findings, we derive three key design implications for multisensory VR in public settings for science communication:

1. Design for affective amplification rather than information transfer. Smell is more effective at intensifying experience and reinforcing salient moments than conveying precise scientific content. Designers should therefore position olfaction as an affective layer that complements, rather than replaces, visual and narrative communication.

2. Design with, not against, material variability. Olfactory experiences are inherently unstable, shaped by environmental conditions and individual perception. Rather than attempting full control, designers should anticipate variability and incorporate it as part of the experience.

3. Balance experiential impact with interpretive clarity. While dramatic and immersive elements engage audiences, they can dominate what is remembered. Multisensory designs should therefore carefully balance affective engagement with the communication of underlying processes, particularly when translating invisible phenomena like bacterial corrosion.

7 Conclusion

This paper has presented an RtD exploration of multisensory VR for science communication, focusing on the use of smell as a design material. Through iterative design and public deployment, we have shown that olfaction introduces both opportunities and challenges in communicating complex, invisible phenomena.

Rather than functioning as a precise informational channel, smell operates as an affective and interpretive medium, amplifying experience and shaping what becomes memorable. By embracing its instability and ambiguity, designers can use smell to create more embodied and engaging encounters with scientific processes.

In the context of growing environmental challenges, such approaches offer ways of making invisible processes perceptible and felt. This work contributes to ongoing discussions on how creativity and interactive systems can support new forms of public engagement around complex societal and ecological issues.

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