Digital intervention for smell training: a real-world study on engagement, adherence, and behavioural dynamics

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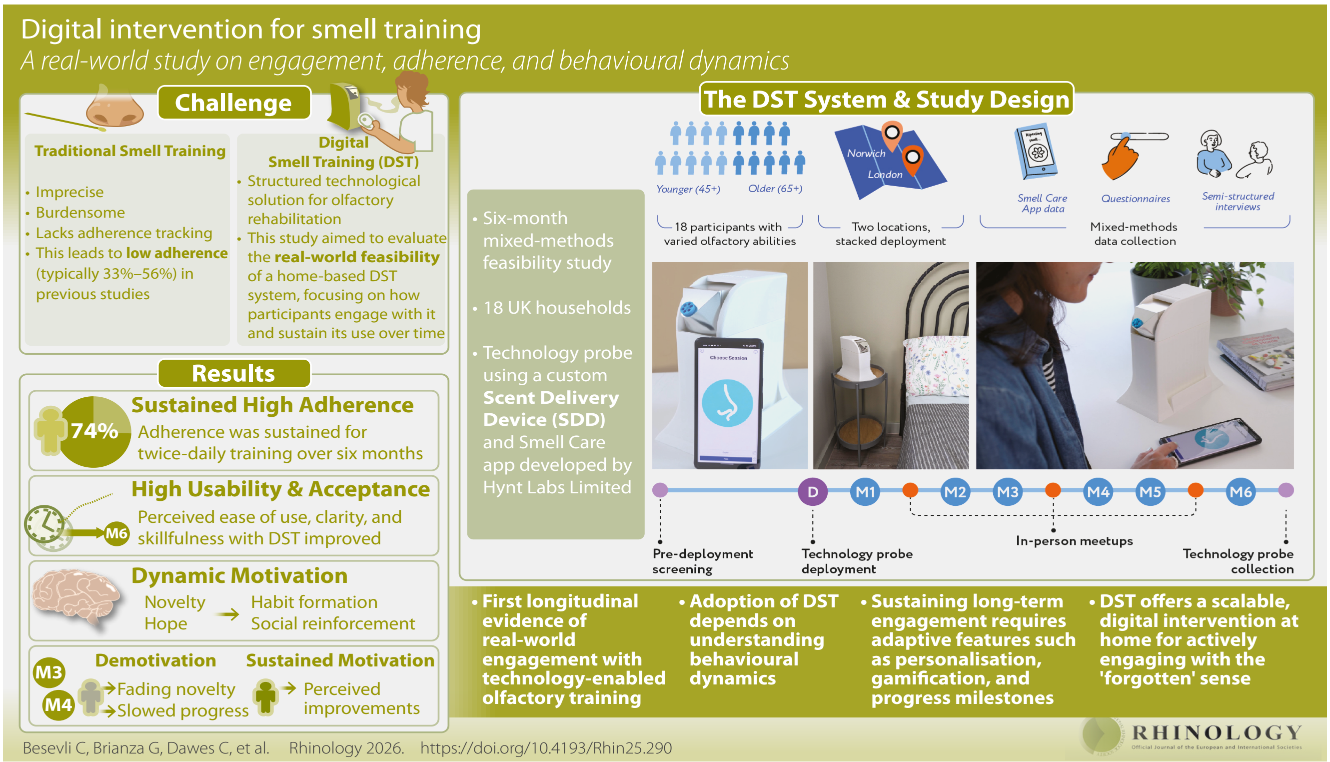
Rhinology 64: 3, 0 - 0, 2026
https://doi.org/10.4193/Rhin25.290



Abstract

Background: Despite advances in digital health, many interventions fail, not due to technical shortcomings, but because they are not meaningfully adopted or sustained in everyday life. Understanding real-world engagement remains a critical gap, especially in under-explored domains such as olfactory health. This study aimed to evaluate the real-world feasibility of a home-based Digital Smell Training (DST) system, focusing on how participants engage with it and sustain its use over time.

Methodology: A six-month real-world feasibility study of a DST system, combining a scent-delivery device and mobile app, was tested in 18 UK households with and without olfactory disorders. A mixed methods approach captured adherence and user experiences over time.

Results: Participants completed 74% of 5,600 potential sessions, showing high adherence to twice-daily training. Qualitative data revealed dynamic behavioural patterns: users' motivations fluctuated over time, shaped by perceived progress, novelty effects, and evolving relationships with the intervention.

Conclusions: This study offers rare insight into how people engage with unfamiliar digital health tools outside controlled settings. Beyond the specific use case of smell, our findings highlight design and engagement strategies essential for achieving real-world impact, showing that sustained adoption hinges not just on innovation, but on behavioural understanding.

Key words: olfaction, olfactory disorders, olfactory training

Introduction

Digital health technologies are transforming prevention, therapy, and rehabilitation [1], but many remain in pilot stages, with limited insight into real-world use or factors supporting sustained engagement [1–3]. Feasibility studies are early-stage investigations that assess whether an intervention is appropriate for further testing, focusing on acceptability, demand, implementation, and practicality [3]. This study explores long-term engagement with a digital smell training (DST) system, comprising a scent-delivery device and mobile application, over six months in participants' homes (Figure 1). Using a mixed-methods approach, we examined adherence patterns and lived experiences to generate insights ahead of formal clinical trials.

Smell disorders affect approximately 22% of the population [4], rising to over half of adults 65–80 and nearly 75% over 80 [5,6]. They are linked to neurodegenerative diseases such as Parkinson's [7] and Alzheimer's [8], and may signal broader health risks, including higher five-year mortality [9]. The COVID-19 pandemic underscored the lack of rehabilitation options, as widespread anosmia exposed significant care gaps [10–12]. Olfaction also supports in flavour perception [13], safety [14], emotional connections [15], social bonding [16] and well-being [17]. Yet it remains largely neglected by healthcare systems [12] and public discourse [18].

Given its importance, interventions are needed for rehabilitation and prevention. Smell training [19–21], regular exposure to specific scents, can aid recovery, especially when sustained over months, and is emerging as a preventive strategy in older adults [22,23]. Yet traditional methods (e.g., sniffing essential oils or scented pens) are imprecise, cumbersome, and lack adherence tracking [20,24,25]. Low adherence rates in previous studies [26–28] point to a broader gap: limited insight into user barriers, motivations, and integration of smell training into daily life [20,25,28].

DST, which integrates digitally controlled scent delivery devices (SDDs) with mobile apps, offers a structured, personalised, and trackable approach to smell training. Advances in Human-Computer Interaction (HCI) have enabled these systems to be deployed at home [29,30], but until now, no longitudinal studies have explored their real-world use.

The aim of this study was to evaluate the feasibility of a six-month, home-based DST system, focusing on how participants engage with and sustain its use, providing the first longitudinal evidence of real-world engagement with a technology-enabled olfactory training.

Materials and methods

Study design & setting

This six-month feasibility study was conducted in participants' homes across London and Norwich, UK. Each household received a bespoke DST system, developed by OWidgets (now Hynt Labs), comprising a digitally controlled scent-delivery device (SDD) with six scent channels and the Smell Care mobile app (iOS/Android compatible).

DST was deployed as a technology probe to observe real-world use, identify needs, and inform future design [31]. Users were asked to complete two five-minute sessions daily.

Four core scents, lemon, peppermint, lavender, and cinnamon, were used consistently across participants, following established smell training protocols [19,20]. To support engagement, participants selected two additional scents monthly from a predefined list [32], coordinated during monthly home visits (Supplementary Text 1).

During monthly visits, researchers refilled cartridges, conducted semi-structured interviews, and administered questionnaires. Participants also voluntarily joined bi-monthly community meetups with the interdisciplinary research team, including clinicians, HCI researchers, built environment specialists, industry, and charity partners, which offered opportunities for shared reflection and design feedback.

Participant recruitment

Participants were recruited via partner organisations (SmellTaste, Future Care Capital), referrals from a regional Smell and Taste Clinic, and local outreach in London and Norwich. Two target groups were sought:

(i) Adults aged 45 and older with potentially reversible olfactory disorders (e.g., post-infectious olfactory dysfunction), reflective of the typical demographic and etiology that needs olfactory training [33],

(ii) Adults aged 65 and older with no or only minor olfactory impairments (Table 1) included to explore DST's preventive potential in healthy ageing and early mitigation of age-related smell decline.

This dual focus enabled the inclusion of individuals seeking support and those interested in preventive care.

Interested individuals completed an online form with informed consent, demographics, and screening questions. Eligible participants attended a remote onboarding session outlining procedures and expectations. Each received a £100 voucher in monthly instalments aligned with study visits and interviews. Travel costs for community meetups were reimbursed, with refreshments provided. Compensation and communications were co-developed with Public Patient Involvement (PPI) contributors, who offered ongoing feedback on study materials and participant experience.

Eligibility criteria

Inclusion criteria were as follows:

- Age ≥45 and an olfactory disorder with potential for reversibility assessed through the Olfactory Assessment Test (OAT) (34) or age ≥65 with no or minor olfactory impairment
- Ownership of a smartphone compatible with the Smell Care App (minimum Android 5.0 or iOS 11)

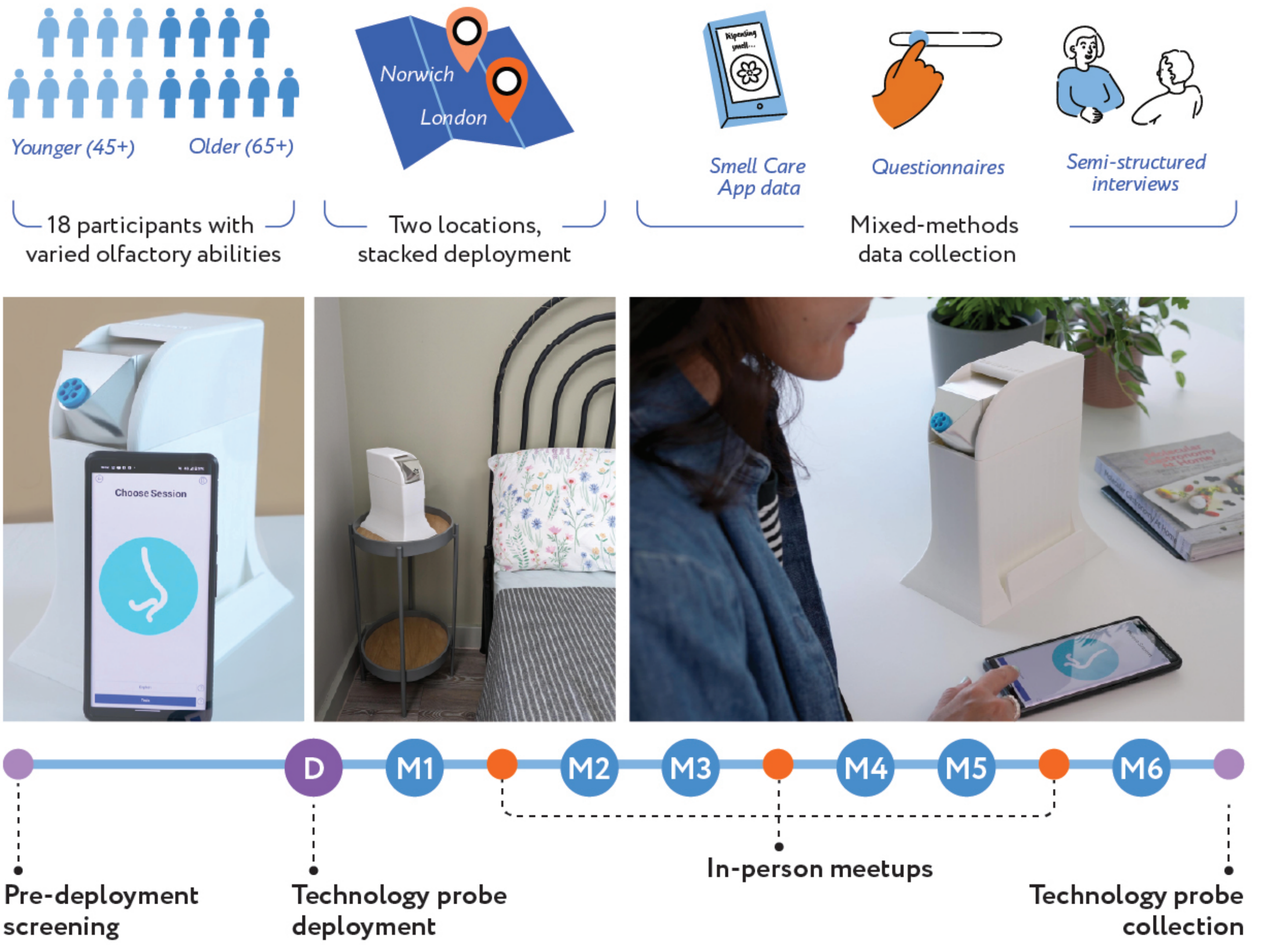


Figure 1. Overview of the six-month mixed-methods feasibility study using the custom-built, hand assembled, tested, and certified Scent Delivery Device (SDD) and Smell Care App (left). These were deployed in participants' homes (middle) to support daily digital smell training (DST) sessions (right). The study employed a technology probe approach conducted across two locations and two age groups (45+ and 65+), incorporating pre- and post-study assessments along with in-person meetups (Figure S1-1 for details).

- Live within a two-hour travel radius of the research team.

Exclusion criteria were as follows:

- Permanent olfactory loss (e.g., due to surgical trauma) and post-traumatic olfactory dysfunction assessed through the Olfactory Assessment Test (OAT) [34]
- Significant sensory impairments (e.g., severe hearing or vision loss)
- Pregnancy or cohabitation with someone pregnant
- Allergies or hypersensitivity to essential oils used in the device
- Planned prolonged absences during the study period (e.g., travel abroad for more than one month).

Measures

Quantitative measures:

We administered validated questionnaires at multiple time points to assess olfactory function, attitudes toward smell, and engagement with the DST. Some measures were collected pre- and post-deployment, while others were repeated at pre-, mid-, and post-study intervals (Figure S1):

- Olfactory function and its impact on quality of life, including enjoyment of food, using the English Olfactory Disorders Questionnaire (eODQ) [35]
- Perceived importance of smell, measured by the Importance of Olfaction Questionnaire (IOQ) [36]
- Perceived usability and acceptance of the DST technology, using a customised version of the Technology Acceptance Model (TAM) questionnaire [37]
- General affinity with technology, assessed via the Inclusion of Technology in Self-scale (ITAS) [38]
- Health-related quality of life, focusing on mobility, self-care, usual activities, pain/discomfort, and anxiety/depression, using the EQ-5D [39].

App-based measures:

The Smell Care App recorded detailed data for each smell

Table 1. Participant demographics and contextual characteristics, including age, gender, self- reported smell ability, household composition, and living space.

Participant ID	Age Group	Gender	Smell Ability [*]	Household Composition	Living Space
P01L2023	53 (younger)	Male	39 (high)	Partner & two kids	House
P02L2023	51 (younger)	Female	26 (low)	Alone	Flat
P03L2023	51 (younger)	Male	17 (low)	Has a tortoise	Flat
P04L2023	49 (younger)	Male	4 (low)	Partner & two kids	House
P12L2023	56 (younger)	Female	47.5 (high)	Partner & child	House
P13L2023 [1]	51 (younger)	Female	38 (low)	Partner & two cats	House
P06L2023	45 (younger)	Male	24 (low)	Two kids	House
P16L2023	49 (younger)	Female	38.5 (low)	Partner & two cats	House
P17L2023	59 (younger)	Female	44 (high)	Partner, one child & one dog	House
P05L2023	66 (older)	Female	39.5 (high)	Partner	House
P07L2023	72 (older)	Female	32 (low)	Has two cats	Flat
P08L2023	66 (older)	Female	29.5 (low)	Partner	House
P09L2023	67 (older)	Female	24 (low)	Alone	Flat
P10L2023	73 (older)	Female	35.5 (low)	Has a tenant & a dog	House
P11L2023	65 (older)	Male	42.5 (high)	Partner	House
P14L2023 [2]	73 (older)	Male	22.5 (low)	Partner	House
P15L2023 [3]	65 (older)	Male	51 (high)	Partner & one dog	House
P18L2023	70 (older)	Male	42 (high)	Partner & one dog	House

[*] Self-reported smell ability, calculated using the Negative Scale of the eODQ [35]. Scores above 38.5 were categorised as high ability; scores of 38.5 or below were categorised as low ability, based on the classification proposed by Mattos et al. [40]. [1] Dropped out after one month of DST due to health reasons. [2] Dropped out after three months of DST due to personal reasons. [3] Dropped out after three months of DST due to professional reasons.

training session. Each session included 12 scent deliveries (two per scent), and for each delivery, the app logged the timestamp, scent identity, and the participant's perceived intensity rating (0 = not intense at all, 10 = extremely intense). Incomplete sessions, where fewer than 12 scent deliveries were completed, were also captured.

Primary outcomes included i) perceived intensity ratings for each scent and ii) adherence to the training protocol, defined as completing two full sessions per day (i.e., 24 scent deliveries).

Qualitative and observational measures: Participants completed monthly semi-structured interviews consisting of:

- Month 0: Baseline routines and expectations
- Months 1-5: Engagement, benefits, and barriers
- Month 6: Final month reflection and full DST journey

At the first home visit, researchers conducted a contextual walkthrough. Participants selected a location for the DST device based on basic guidelines (e.g., avoiding humid areas or strong ambient smells). Researchers recorded device placement and environmental context (Table 1) to understand integration into daily routines.

Quantitative data analysis

Analyses drew on two data streams: i) session-level DST data automatically recorded by the Smell Care App and stored on Amazon Web Services (queried via SQL), and ii) validated questionnaires administered via Qualtrics at baseline (M0) and month 6 (M6).

Smell ability was calculated based on the eODQ [35], focusing on the 17 negative items rated on a 0-3 scale (0 = agree to 3 = disagree), yielding a total score between 0 and 51, with higher scores indicating better olfactory-related quality of life. To align with the original 17-item QOD-NS, i) the diet pair (items 6-7) was averaged, and ii) the weight pair (items 9-10) collapsed using the higher response. Following Mattos et al. [40], a ROC-optimised cut-off of 38.5 dichotomised participants into olfactory disorder–impaired (≤ 38.5) and unimpaired (> 38.5) groups.

Daily adherence was calculated as a percentage: 100% for two sessions, 50% for one, and 0% for none. Intensity ratings were reduced to weekly means (following a 0 – 10 rating scale), with only the first week of each month analysed to control for scent cartridge fade. Changes in intensity were tested with Linear Mixed-Effects models including fixed factors Month (1–6) and

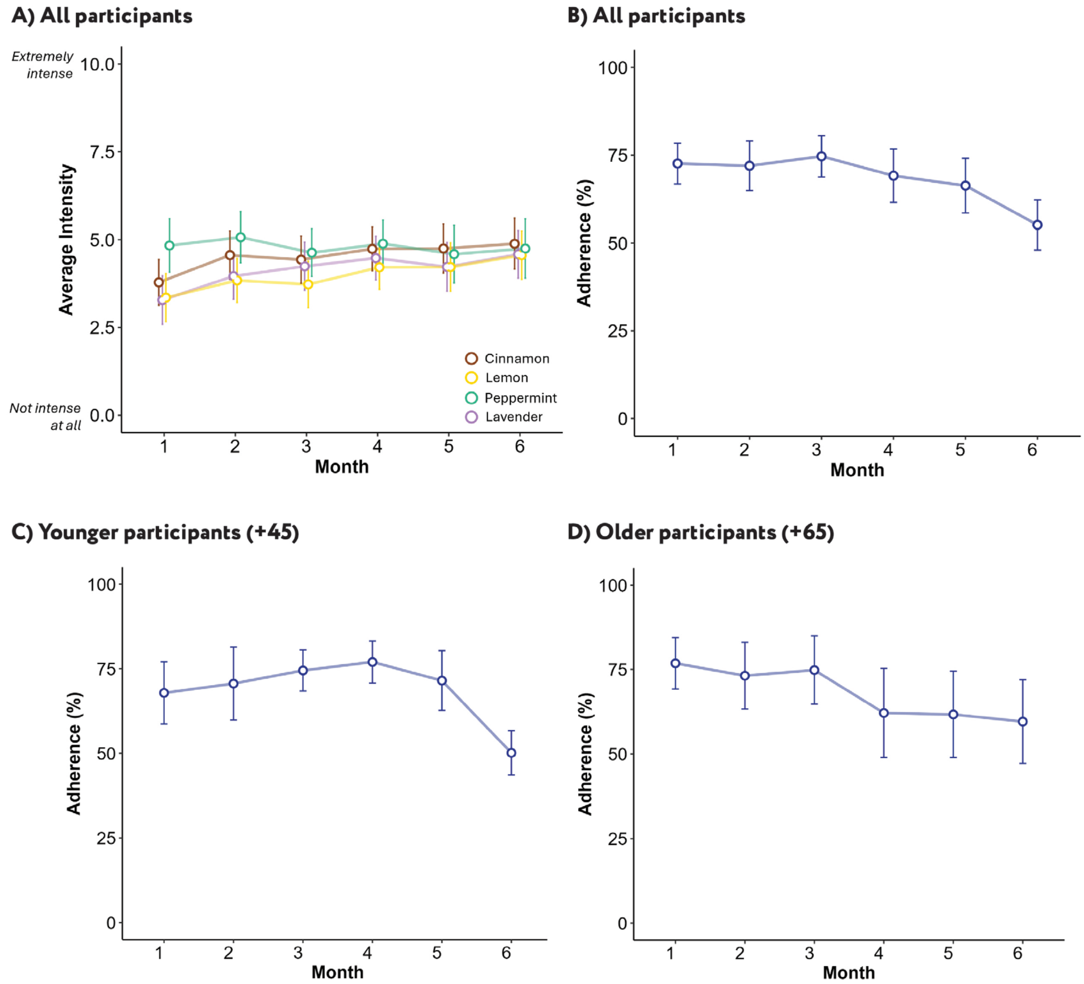


Figure 2. A) Line graph showing adherence of all participants over six months. Statistical analyses indicated a significant drop in adherence at M6. Descriptive data for the younger and older cohorts can also be found in C and D, respectively. B) Perceived intensity scores for all participants (0 = not intense at all, 10 = extremely intense) across six months, focusing on the first week of each period to control for scent fading and ensure consistency.

Scent (four levels) and a random intercept for participant; adherence was examined with a one-way repeated-measures ANOVA, and questionnaire change scores with paired t-tests. Holm-corrected post-hoc contrasts followed all omnibus tests, and Cohen's d effect sizes accompanied relevant statistics. LME analyses were run in R 4.3.2 (lme4 1.1-35, emmeans 1.10) and t-test comparisons using Jamovi (2.6.26), all $\alpha = 0.05$, two-tailed.

Qualitative data analysis

Semi-structured interviews were conducted at seven time points: once pre-deployment and monthly during the six-month DST period. Interviews were transcribed verbatim and analysed using NVivo (v14). A combined deductive–inductive thematic analysis [41] was used, supported by trajectory analysis [42] to examine changes over time. Coding was led by the first author with feedback from three additional researchers for consistency. Analyses proceeded month-by-month under high-level themes (e.g., motivation, daily challenges), with subthemes derived inductively and refined iteratively. A time-ordered matrix [42] enabled cross-time comparisons, highlighting evolving patterns in participant experiences (Figures S2–S4).

Results

Participants

Eighteen households were recruited, divided into two age cohorts: 45–59 and 65–73 years, with 11 female and 7 male participants. Self-reported olfactory function varied according to the eODQ [35]. Three participants withdrew: one after one month for health reasons and two after three months for personal or professional reasons. Fifteen participants (83%) completed the full six-month deployment and were included in the quantitative analyses.

Adherence and engagement data over time

Data were collected between July 2023 and August 2024 across two locations (London and Norwich, UK). We report adherence

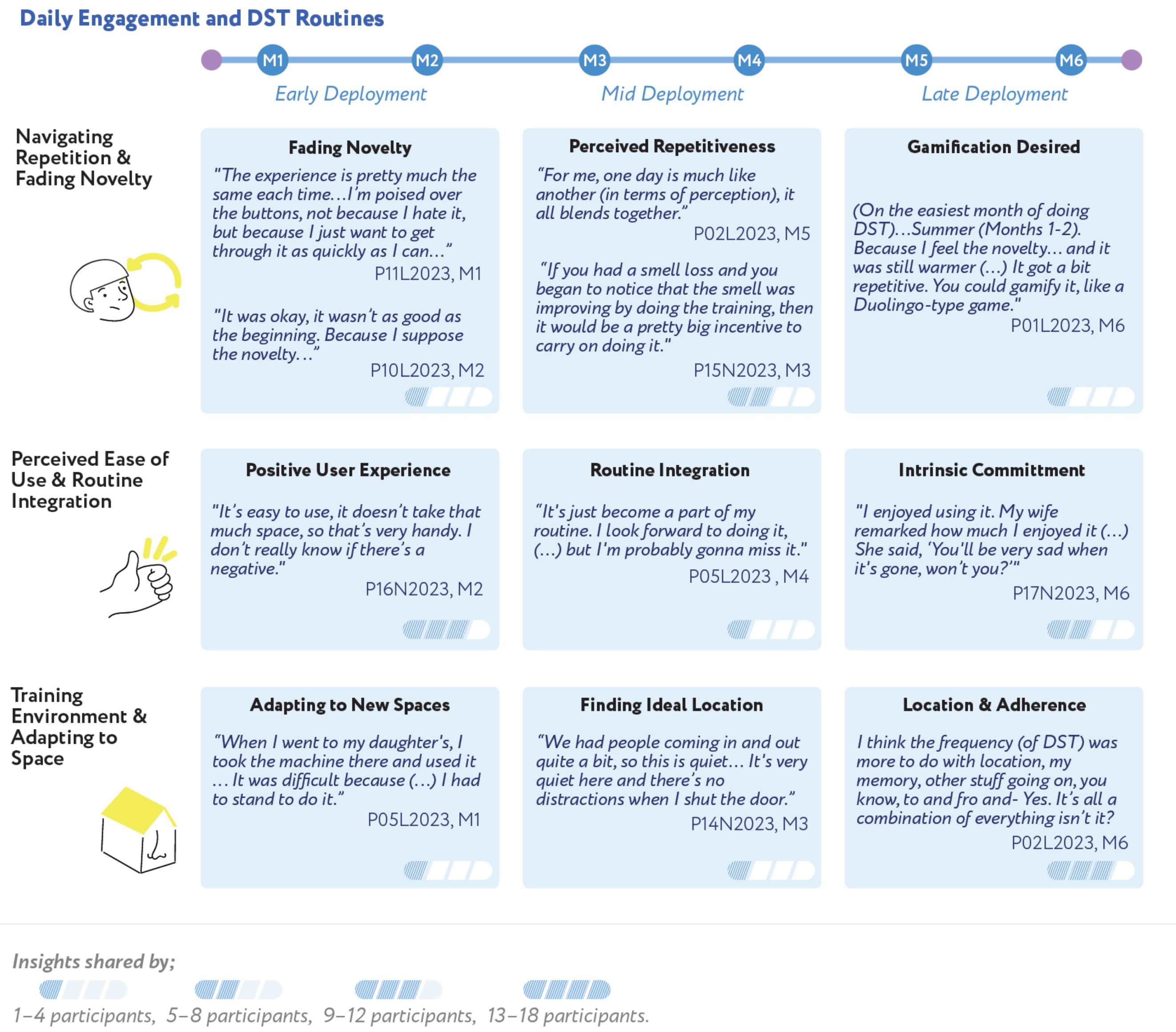


Figure 3. Example of qualitative findings on 'Daily Engagement and DST Routines', presented across three phases of deployment: early (M1–2), mid (M3–4), and late (M5–6). The sectioned bars below each box indicate the frequency of each insight: 1 bar = 1–4 participants, 2 bars = 5–8 participants, 3 bars = 9–12 participants, 4 bars = 13–18 participants.

over the six-month period and compare pre/post questionnaire responses (Table 1).

Adherence: Overall adherence to DST was 74%, with full completion of two daily sessions and partial completion (one session) counted as 50%. Across the six-month deployment, the 15 participants who completed the study completed 4,150 out of 5,620 possible sessions.
A Repeated Measures ANOVA suggested that there was a significant difference in adherence rates across months, with post-hoc t-tests (with Holm correction) highlighting a significant decrease in adherence rates from Month 1 (M = 72.6% ± 5.8%) to Month 6 (M = 55.1%, ± 7.1%) at a medium effect size ($p = 0.024$, Cohen's $d = 0.613$) (Figure 2A). It is worth noting that M6 coincided with Christmas break for the London cohort, and summer break for the Norwich cohort, suggesting some of this decline may be attributed to external events (such as travelling, as highlighted in the interview data section). Moreover, the remaining comparisons between M1 and M2 - M5 were all non-significant (all $p > 0.999$, $d < 0.221$); suggesting a continuous engagement.

Scent ratings: A linear mixed-effects model (random intercepts for participants) revealed significant fixed effects of Month ($\chi^2(5) = 17.74$, $p = 0.003$) and Scent ($\chi^2(3) = 21.91$, $p < 0.001$) on perceived intensity ratings. Post hoc comparisons (Holm-corrected) showed that ratings increased from Month 1 to Month 6 (p =

0.003), with trend-level differences emerging around Months 4–5 ($p > 0.057$, and that peppermint was rated significantly more intense than both lemon and lavender (both $p < 0.001$) (Figure 2, D).

Well-being: Paired samples t-tests comparing pre- and post-deployment eODQ [35] scores revealed significant improvements in Taste Distortions (Item 5: '*Food tastes different from what it used to*', M = 2.07 ±1.10 to 2.53 ±1.25, t(14) = -2.43, p = 0.029, d = 0.628) and Coping (Item 12: '*I wonder if I will ever be able to live with this problem*', M = 2.73 ±1.16 to 3.2 ±1.08, t(14) = -2.43, p = 0.029, d = 0.628). The remaining eODQ items showed no significant differences (all $p > 0.05$). Likewise, there were no changes in participants' valuation of their sense of smell (IOQ $p > 0.05$) [36], or in self-reported depression and anxiety (EQ-5D, both $p > 0.096$, $d < 0.187$)[39]. However, there was a significant improvement in subjective sense of smell performance by participants (M = 3.33 ±2.526 to 5.00 ±3.44, t(14) = -2.33, p = 0.035, d = 0.602).

Usability and acceptance: TAM questionnaire [37] showed significant improvements, indicating growing familiarity and acceptance over time. Notable improvements were observed in perceived usability ('*Using the Smell Care device & App in my daily life enables me to complete the smell training more quickly*', (M = 1.53 ±0.834 to 1.13 ±0.352, t(14) = 2.45, p = 0.028, d = 0.632), ease of use ('*I would find it easy to get the Smell Care device & App to do what I want*', M = 2.13 ±0.834 to 1.27 ±0.70, t(14) = 4.026, p = 0.001, d = 1.039), clarity ('*My interaction with the Smell Care device & App would be clear and understandable*', M = 1.93 ±0.961 to 1.27 ±0.594, t(14) = 2.320, p = 0.036, d = 0.599), and skilfulness ('*It would be easy for me to become skilful at using the Smell Care device & App*', M = 1.87 ±1.246 to 1.13 ±0.352, t(14) = 2.219, p = 0.044, d = 0.573). However, ITAS [38] presented null findings ($p > 0.999$).

Qualitative real-world experiences and behaviours

Findings from interviews show how participants' motivations, engagement behaviours, and perceptions of smell evolved over time (Supplementary Text 2 - Extended Qualitative Findings with Supporting Quotations, Figures 3, S2–S4).

Daily use and routine integration: DST was generally perceived as simple and quick to use, often taking under five minutes. Most participants integrated it into daily routines, with visible device placement serving as a helpful cue. However, contextual factors, such as lack of private or scent-neutral spaces, household interruptions, or travel, sometimes disrupted engagement. Reminders and support from cohabitants helped maintain regular use. Participants also suggested increasing portability to better support adherence across varied contexts.

Motivations and drivers of engagement: Participants' initial motivations varied by olfactory ability (Table 1). Those with low smell ability were primarily driven by hope for recovery, while others joined out of interest in the research. Early signs of perception improvement, even minimal, were often motivating. Emotional and sensory associations with smell, such as food and family, played a key role in sustaining engagement. Social support from peers, family, and community meetups further reinforced commitment, whereas participants lacking support networks reported greater feelings of isolation.
Motivation tended to decline slightly around Months 3–4, particularly when perceived olfactory progress plateaued. Some participants described 'going through the motions', while others tried to make sessions more mindful and keep an 'open mind'. Individuals with high baseline smell ability sometimes struggled to stay engaged once the novelty wore off.

Perception of smell over time: Participants' experiences of smell perception were gradual, often subtle and ambiguous (Figures S3–S4). Fluctuations were common, and many expressed uncertainties about whether perceived changes were genuine. Over time, participants reported growing trust in their own perception, though reassurance (e.g., via the app or social validation) remained important. By Month 3, some reported more consistent improvement, often recognised retrospectively. A few remained disappointed by limited progress near the end, but many continued out of habit, hope, or a sense of commitment.

Reflections on the DST experience: At study end, 11 participants who had previously tried traditional smell training described DST as more structured, convenient, and engaging. Features such as scent randomisation, timed delivery, and digital logging encouraged focus and accountability. DST was also seen as less cumbersome and more scientifically framed than analogue methods. Participants recommended linking DST to daily routines, using visible placement, and remaining patient during plateaus. Several expressed a desire to continue using DST after the study. This interest was reiterated at a community follow-up event six months later (December 2024).

Discussion

This study evaluated the feasibility of a six-month, home-based DST system. Our findings provide the first longitudinal evidence of DST use in everyday settings, showing how olfactory rehabilitation can be sustained within daily routines while revealing key barriers and benefits to engagement. With a 74% adherence rate, DST outperformed traditional smell training studies over three months (e.g., 56% in Fornazieri et al. [27], 48% in Schriever et al. [26], 33% in Haas et al. [43]), highlighting the potential for digital platforms to support sustained, accessible olfactory care.
Participants cited DST's automated delivery, minimal setup,

and brief sessions as key to daily integration. Unlike manual methods, DST reduced friction and enhanced usability, aligning with TAM principles [37]. Most users tied sessions to consistent routines (e.g., mornings or evenings), supporting habit formation, a known engagement driver [44]. Nevertheless, engagement still varied by individual context. Younger participants with busier schedules, defined here as those aged 45–59 years, exhibited lower adherence (67%) compared to older participants (65–73 years, 82%). Qualitative findings showed that younger participants struggled with adherence due to work demands and external disruptions, expressing a need for more portable devices for travel or unstructured days, echoing prior research [45]. Advances in olfactory interfaces could therefore enable portable DST solutions that fit busy lifestyles and support sustained engagement.

Motivational dynamics also played a critical role. Drawing on Self-Determination Theory (SDT), which emphasizes competence, autonomy, and relatedness support sustained engagement [44], we interpret participants' experiences. Participants noticing gradual improvement reported renewed motivation, reflecting competence, consistent with work linking perceived recovery to greater participation [46]. While prior studies suggest perceived improvement can reduce adherence as users disengage once feeling improvements [47] this was only partially observed: participants with higher baseline smell ability (Table 1) and less perceived need for improvement sometimes lost interest after 1–2 months as novelty waned. This supports evidence that both perceived improvement and baseline ability shape engagement [26,28]. For this group, engagement may be better sustained through fewer but more stimulating or gamified sessions. DST's current format, two rounds of six scents at 10 seconds each, may be overly intensive. Prior work with normosmic participants similarly suggests that shorter, manageable sessions improve adherence [28].

For some participants, the challenge was slow or absent perceived recovery rather than loss of novelty. Some saw little or fluctuating progress, which led to doubt or frustration (Figures S2, S4). In line with this, previous research has shown that lack of perceived improvement contributes to attrition [46]. Because olfactory recovery can take up to 24 months [26], sustaining motivation may rely on design features that foster competence [44]. Adaptive elements such as milestones, incremental feedback, or tailored challenges can reinforce progress even when gains are limited, supporting engagement across both slow and rapid recovery trajectories.

Social connection also played a role. Community meetups boosted motivation for some, while others felt isolated. This maps onto SDT's relatedness dimension and points to the value of peer features (e.g., forums, shared milestones) to enhance retention, mirroring trends in other digital health tools [1,44].

Environmental factors influenced adherence. Participants emphasised the need to place the SDD in visible, scent-neutral areas, but many faced barriers created by household layouts, cohabitation, or ambient smells (Table 1). These constraints highlight how olfactory care is intertwined with domestic architecture and sensory flows, areas rarely considered in home design [48]. Notably, participants expressed a desire to continue DST post-study, viewing it as valuable beyond research. This underlines the importance of feasibility studies not only for technical assessment, but for informing scalable, sustainable models of care [1–3]. Our collaboration with industry and non-profits also demonstrated how real-world deployment can be supported through cross-sector pathways.

For clinical and public health settings, particularly in rhinology and social care, DST in the home offers an important step forward. Embedding DST and monitoring into domestic or supported environments (e.g., care homes) could potentially help maintain olfactory abilities in ageing populations, while also enabling early identification of changes that may signal broader health concerns, such as neurodegenerative disease [7,8]. DST's structured format and digital tracking also complement emerging digital smell tests [30,49], helping to build a comprehensive olfactory care pathway, from proactive maintenance to long-term monitoring. While this study provides insights into adoption and engagement, future work can assess DST's clinical or financial feasibility for providers or decision-makers.

More broadly, this study responds to calls for real-world evidence on digital health tools beyond the lab [1,3]. As such tools transition from pilot to practice, feasibility studies offer vital insight into the drivers of sustained, meaningful engagement. In this context, DST represents not only a training tool but a step toward reintegrating the "forgotten" sense into wellbeing and ageing care [12,26].

Conclusion

As a feasibility study, which often relies on small convenience samples to generate in-depth behavioural insights that inform future trials, our focus was on real-world use and acceptability [3]. With 18 households across two UK cities, we captured in-depth behavioural and spatial dynamics. While context-specific, these findings offer valuable guidance for future trials. Study procedures, including interviews and meetups, may have enhanced adherence, which could differ in less structured settings. Future work should assess long-term engagement across more diverse populations. Scaling to more diverse populations and longer timelines will be key to realising DST's therapeutic potential and designing inclusive, behaviourally attuned smell care interventions.

Acknowledgements

The Smell Care (I-smell: Engaging Users in Smell Self Care at Home) research project was 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, i.e. the digital scent technology developed with support by the European Research Council Proof-of-Concept (ERC PoC) SmellHealth award (966774).

We are deeply grateful to all the participants who generously shared their time and experiences throughout the six-month study. Special thanks to Ana Marques for her thoughtful support in capturing participant reflections during our community meetups. We are also thankful to Nonna Shabanova for her creative input on the 3D design aspects of the device sleeve during the early stages of the field study. We thank Richard Hopper and Viktor Pesek at Hynt for their technical guidance and collaboration. We also gratefully acknowledge the contributions of Future Care Capital (FCC), as well as Peter Bloomfield. Finally, we extend our appreciation to all the "friends of Smell Care" who have supported our study and its activities.

Author contributions

MO conceived and conceptualised the DST study with CP, EM, with input from AF, DB. CB, GB, SM were responsible for the methodology development, deployment coordination, participant recruitment, and data collection in the respective locations supported by CD. Data analysis and paper write-up process was led by CB, with close input from all partners. CB was leading the qualitative data analysis and integration with the quantitative data, provided by GB and CD. SM, SB were part of the iterative data analysis process and discussion. All co-authors carefully reviewed, discussed, and approved this final submission.

Conflict of interest

Emanuela Maggioni (EM) and Marianna Obrist (MO) are co-founders of Hynt Labs Limited (formerly OWidgets Ltd), developing digitally controlled multi-channel scent-delivery devices used within the feasibility study. All other authors report no conflict of interest.

Funding

The Smell Care (I-smell: Engaging Users in Smell Self Care at Home) research project is 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.

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Rhinology 64: 3, 0 - 0, 2026
https://doi.org/10.4193/Rhin25.290

Received for publication:
June 27, 2025
Accepted: January 3, 2026

Associate Editor:
Basile Landis

This manuscript contains online supplementary material

SUPPLEMENTARY MATERIAL

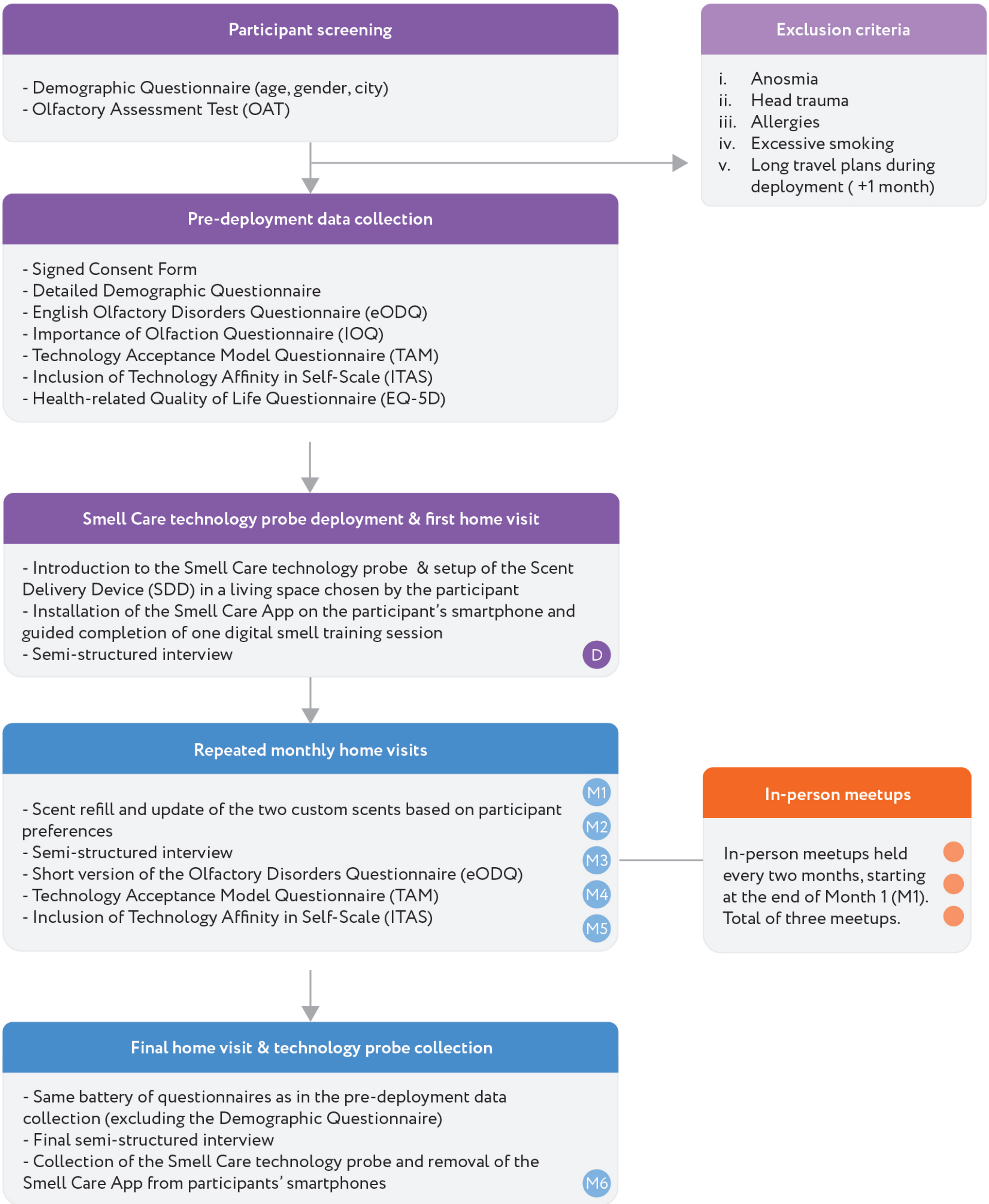

Figure S1. Study design diagram outlining the screening, pre-deployment, deployment, and postdeployment phases, along with the measures/methods used at each stage.

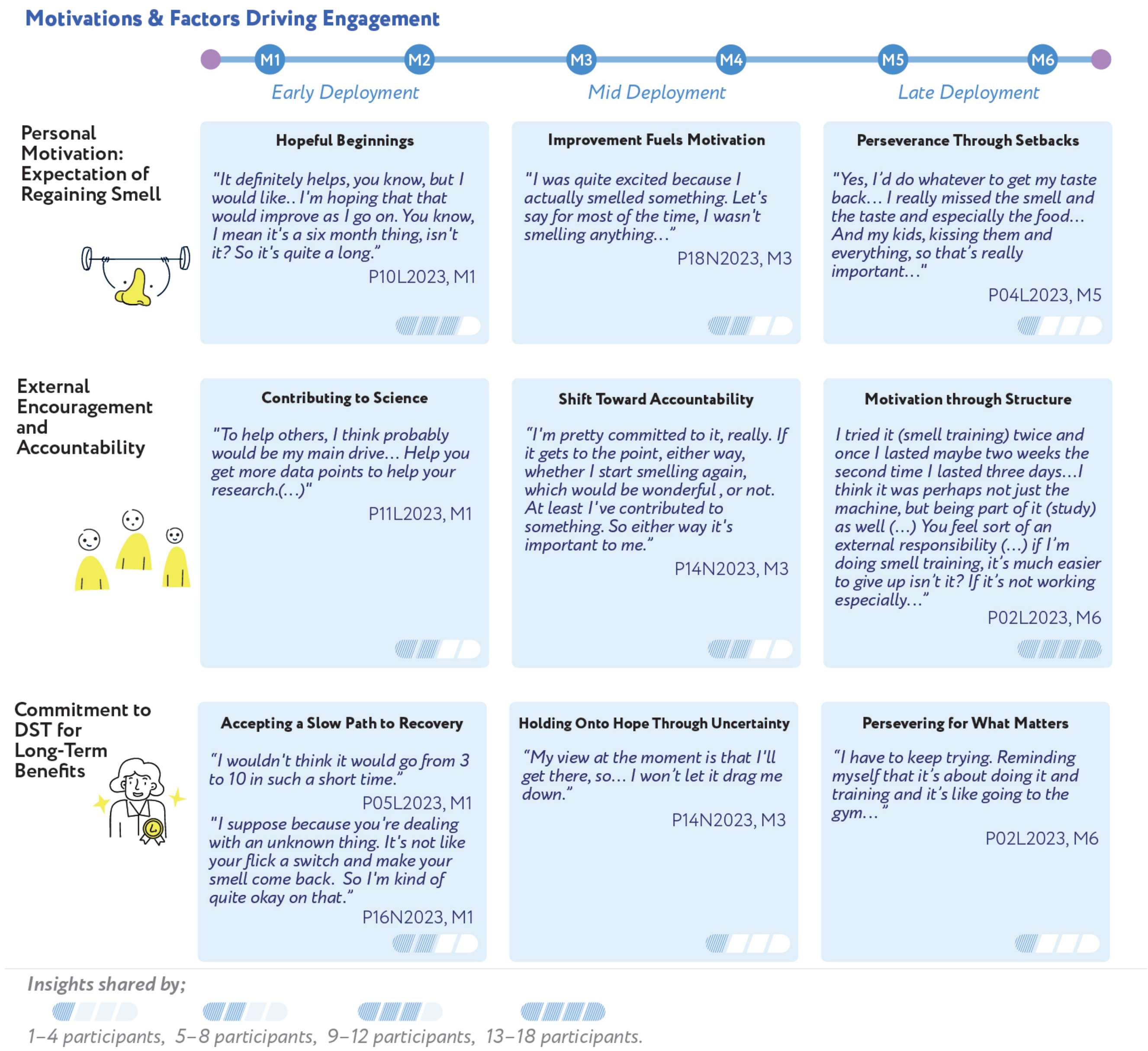

Figure S2. Example of qualitative findings on 'Motivations and Factors Driving Engagement', presented across three phases of deployment: early (M1–2), mid (M3–4), and late (M5–6). The sectioned bars below each box indicate how many participants mentioned each insight: 1 bar = 1–4 participants, 2 bars = 5–8 participants, 3 bars = 9–12 participants, 4 bars = 13–18 participants.

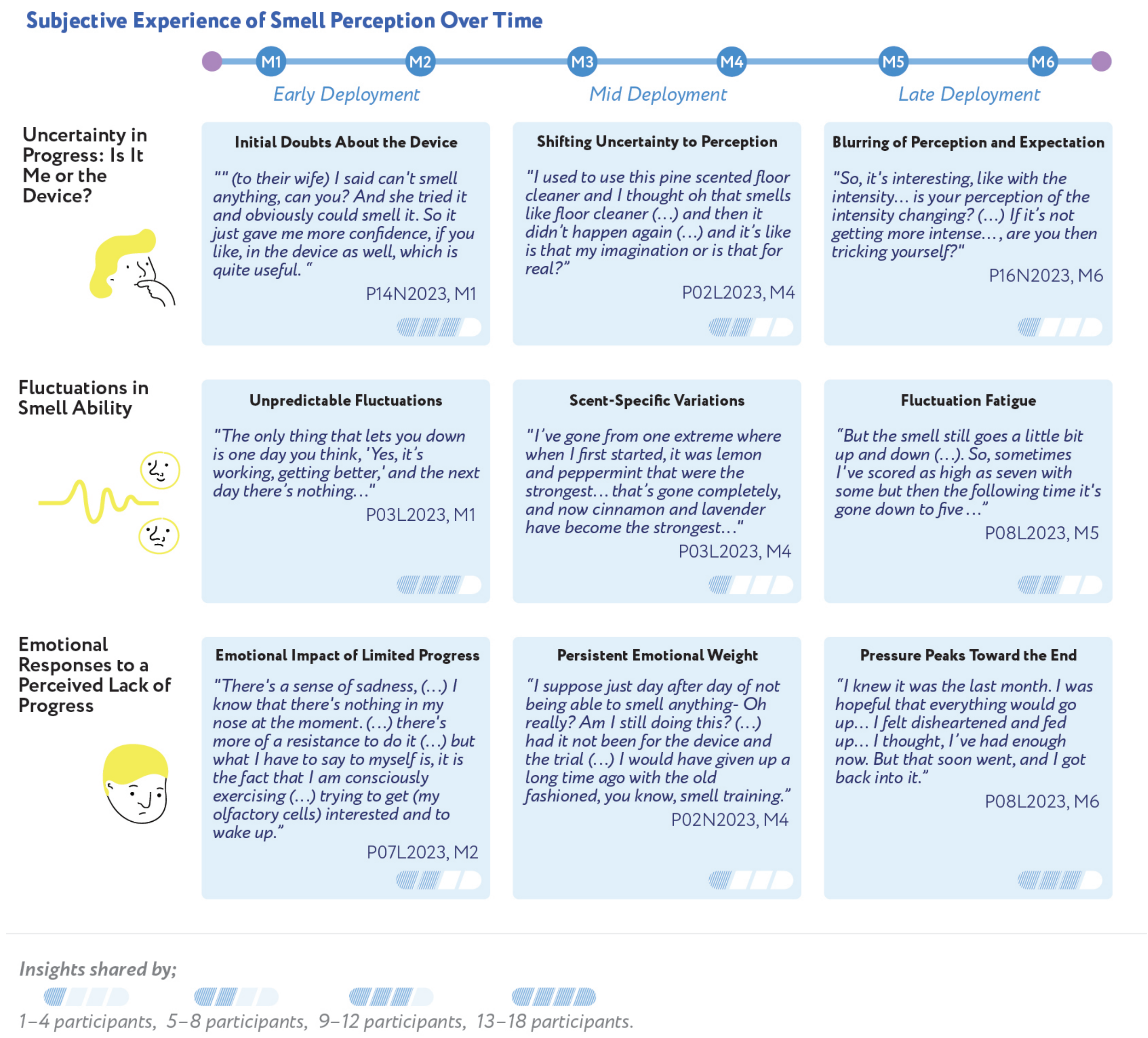

Figure S3. 'Subjective Experience of Smell Perception Over Time', presented across three phases of deployment: early (M1–2), mid (M3–4), and late (M5–6). The sectioned bars below each box indicate how many participants mentioned each insight: 1 bar = 1–4 participants, 2 bars = 5–8 participants, 3 bars = 9–12 participants, 4 bars = 13–18 participants.

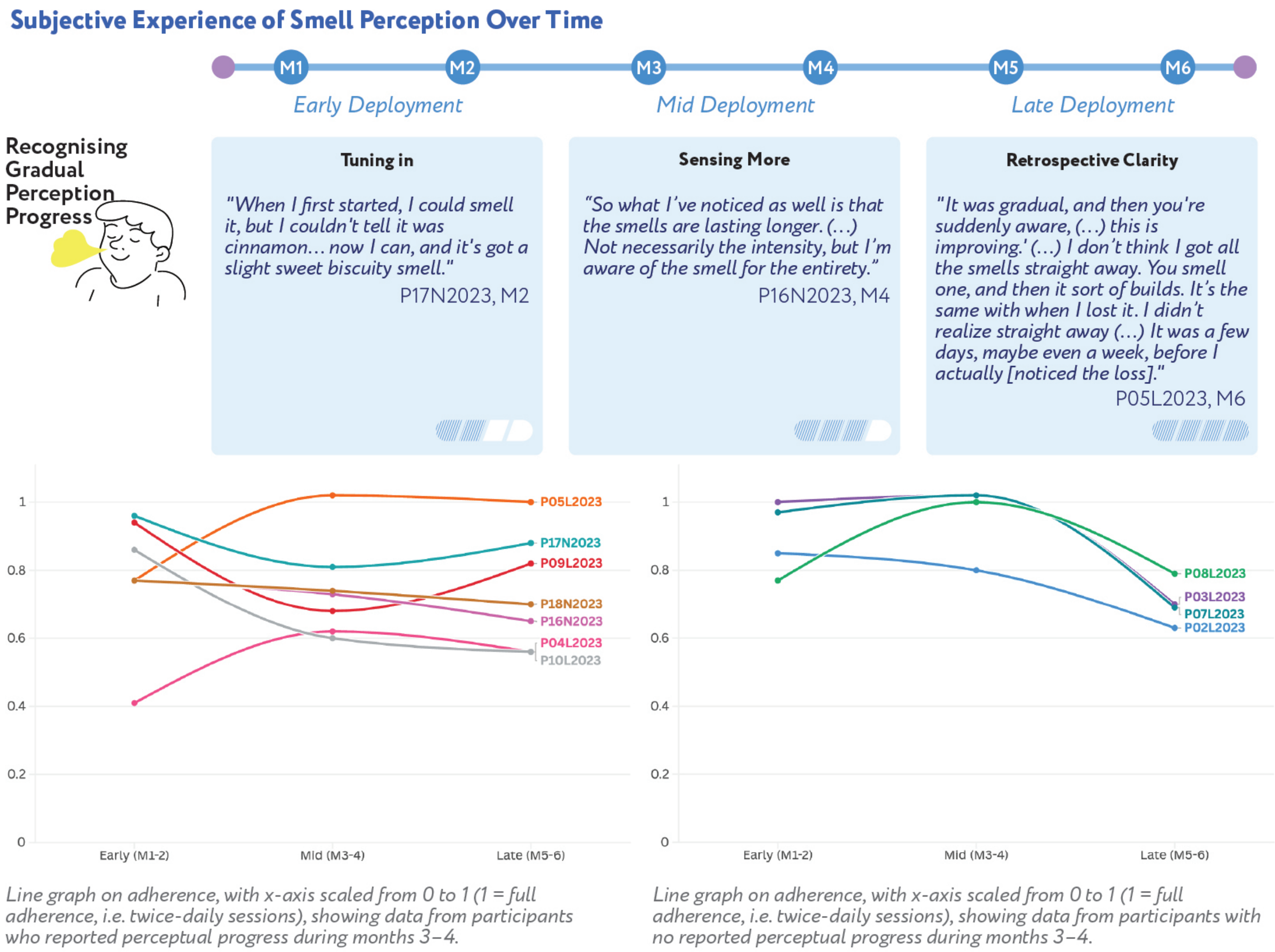

Figure S4. 'Subjective Experience of Smell Perception Over Time with a focus on Recognising Gradual Perception Progress' illustrated across three deployment phases (M1–2, M3–4, M5–6), with nested line graph showing adherence (0–1 scale; 1 = full twice-daily sessions) among participants with and without mid-phase perceptual progress. The sectioned bars below each box indicate how many participants mentioned each insight: 1 bar = 1–4 participants, 2 bars = 5–8 participants, 3 bars = 9–12 participants, 4 bars = 13–18 participants.

Supplementary Text 1: Selection of scents used in the field study and Table S1.

The scent list was developed with project partners. Four core scents (Lemon, Peppermint, Lavender, Cinnamon) remained constant for all participants during the six-month study, based on established olfactory training protocols [24,25]. The research team selected additional scents to allow personalisation and expand the olfactory experience [37], with guidance from Ear, Nose & Throat (ENT) specialists and the Fifth Sense charity supporting smell and taste disorders. Participants chose two custom scents monthly from the predefined list (Table S1) to maintain novelty, with a restriction of no more than two consecutive months per scent [24].
For each visit, fresh cellulose sponge absorbers were prepared by dispensing 300 μL of odorant onto each, covering both fixed and custom scents. These were inserted into the device's odour reservoirs (cartridges) [33].

Table S1. Scent options used in the feasibility study, drawn from established literature or selected with input from ENT specialists and Fifth Sense representatives. Scents supplied by Miaroma.

Scent Name	Type	Reference / Source
Lemon	Fixed	Hummel et al. (2009) [19]
Peppermint	Fixed	Hummel et al. (1997) [50]
Lavender	Fixed	Pieniak et al. (2022) (20)
Cinnamon	Fixed	Hummel et al. (1997) [50]
Rose	Customisable	Hummel et al. (2009) [19]
Geranium	Customisable	Author-defined
Melissa	Customisable	Author-defined
Bergamot	Customisable	Altundag et al. (2015) [32]
Rosemary	Customisable	Altundag et al. (2015) [32]
Patchouli	Customisable	Author-defined
Juniper	Customisable	Author-defined
Eucalyptus	Customisable	Hummel et al. (2009) [19]
Ginger	Customisable	Altundag et al. (2015) [32]
Clove	Customisable	Hummel et al. (2009) [19]
Clary Sage	Customisable	Author-defined
Cardamom	Customisable	Author-defined
Vanilla	Customisable	Author-defined

Supplementary Text 2: Extended qualitative analysis and findings with supporting quotations.

Detailed qualitative analysis methods

We conducted semi-structured interviews at seven time points: once before deployment, and then monthly during the six-month DST period. The final interview included additional questions reflecting on the overall experience. Each interview lasted ~40 minutes, yielding approximately 4,680 minutes of recorded data. All interviews were transcribed verbatim and analysed using NVivo (version 14).
We used a hybrid thematic analysis approach, combining deductive codes based on prior literature and study objectives with inductively derived codes emerging from the data [41]. To capture changes over time, we incorporated trajectory analysis methods [42]. Coding was led by the first author, with three other researchers independently reviewing a subset of transcripts to validate the evolving codebook. Team meetings supported intercoder reliability and resolved coding discrepancies.
Given the longitudinal design, each month's interview data was first analysed separately using consistent high-level themes: motivations, daily DST challenges, smell perception, and interactions with the technology. As new subthemes emerged inductively, the codebook was iteratively updated and retrospectively applied to earlier interviews.
To support temporal analysis, we created a time-ordered matrix, where each row represented a theme and each column a time point. Matrix cells contained representative quotes with parti-

cipant IDs, helping to visualise thematic progression without imposing fixed assumptions.

After coding all transcripts, we conducted trajectory analysis to trace how individual and group-level experiences evolved. This approach revealed patterns in engagement, motivation, and perception across the six-month study period (Figures S2–S4 for illustrative examples).

Qualitative findings

Motivations and factors driving engagement: At the outset, participants reported varying motivations for engagement (Figure S2). Those without significant olfactory difficulties (i.e., high smell ability, Table 1) were largely driven by a desire to support research, while participants with self-reported smell loss often joined in the hope of regaining their sense of smell. For many, even subtle moments of scent detection were described as encouraging and meaningful, particularly in the early stages. Others (i.e., low smell ability, Table 1) remained hopeful despite slow or uncertain progress, motivated by the deep emotional and sensory role that smell played in their daily lives:

> *"...I'd do whatever to get my taste back... I really missed the smell and the taste and especially the food... And my kids, kissing them and everything..." [P4L2023, Month 5].*

Social support also played a key role in sustaining engagement (Figure S2). Participants frequently mentioned the value of peer support, family encouragement, and in-person community meetups. These connections offered reassurance, normalised individual variation, and helped maintain motivation during low points. In contrast, participants who lacked these supports sometimes felt isolated or less confident in their progress. Sharing the experience, whether in person or with close others, was described as grounding and motivating:

> *"If we didn't have them (the meetups) it would have been quite isolating and you wouldn't really have known what was actually going on (...) I wouldn't meet anyone else and even though you come and tell me how things are - it wouldn't be the same."[P03L2023, Month 6].*

Daily engagement and DST routines: Participants generally found DST easy to use and simple to integrate into their daily routines (Figure 3). The short session duration (under five minutes) was viewed as a major strength, with many participants weaving DST into existing habits, such as while brewing tea or opening blinds, making it easier to remember and sustain. Visible placement of the SDD further supported habit formation by serving as a visual cue.

However, the ability to integrate DST smoothly was shaped by participants' living environments (Table 1). Some lacked scent-neutral, visible spots away from kitchens or bathrooms, while others, particularly those sharing their homes with family or frequent guests, faced challenges in finding an undisturbed time and location for training. These spatial and social constraints occasionally disrupted engagement but were often mitigated through careful planning and strategic placement, when feasible.

External disruptions such as holidays or demanding work schedules, especially common among younger participants, also impacted adherence. To cope, participants developed compensatory strategies like setting reminders, batching sessions, or involving household members for accountability. Many expressed a desire for a more portable version of the device to support continued use during travel or on less structured days.

By the third and fourth months, however, sustaining daily engagement became more difficult, especially for participants who perceived little progress in their olfactory ability. Some reported growing fatigue and described how their intensity ratings had become habitual rather than grounded in genuine sensory experience. A few addressed this by slowing their pace and adopting a more mindful approach during training:

> *"I just wonder if you set your mind and think, 'Today, I'm a five.' But I try not to do that. I try to think, 'No, let's check.'" [P06L2023, Month 6].*

Participants without significant olfactory difficulties, whose primary motivation was contributing to research, found their engagement waned once the initial novelty wore off. As one noted:

> *"I've sort of become a bit less conscientious with it... I suppose that if you had a smell loss and you began to notice that the smell was improving by doing the training, then it would be a pretty big incentive to carry on doing it." [P15N2023, Month 3].*

To address this, participants suggested integrating motivational features such as streaks, challenges, or progress tracking (Figure 3).

Subjective experience of smell perception over time: As the deployment progressed, participants' perception of smell evolved in nuanced and sometimes ambiguous ways (Figure S3). During the first months, many expressed uncertainty about whether perceived changes reflected their actual olfactory ability or if the scents themselves had changed. Some asked family members to confirm the intensity of the scents. Over time, doubts shifted inward, rather than questioning the device, participants began to question themselves, wondering if they were truly perceiving scents or merely imagining them:

> *"So, it's interesting, like with the intensity… is your perception of the intensity changing? (…) If it's not getting more intense, are you then tricking yourself?" [P16N2023, Month 6].*

Fluctuations in perception were commonly reported. Participants described "good days" and "bad days," noting their scent perception "going up, down, up, down." Some participants, particularly early on, wished for more support from the app, such as reassurance that perception fluctuations were normal:

"At the end of it (the DST session), the App says, you know, well done (…) And then you could mention, you know, not every day is going to be a good day. You will have a bad day, and then the next day will be good and then the next day could be bad again. (…) Because I was thinking, oh, is it just me and this is not meant to happen." [P03L2023, Month 1].

By Month 3, several participants reported more consistent improvements in scent intensity or the emergence of new scent qualities (Figure S4). These changes were often slow and difficult to detect in real time but became clearer in retrospect by Month 6:

"I think it wasn't instant (...). It was gradual, and then you're suddenly aware, 'Oh, actually, yeah, this is improving.' (...) In my experience, I don't think I got all the smells straight away. You smell one, and then it sort of builds... It's the same with when I lost it. I didn't realize straight away (...) It was definitely a few days, maybe even a week, before I actually (noticed the loss)." [P05L2023, Month 6].

However, a small number of participants felt disappointed by the lack of improvement toward the study's end and described growing pressure to see progress. Even so, most continued the training, motivated by hope, habit, or a sense of commitment:

"I knew it was the last month, I was hopeful that everything would go up... I felt disheartened and fed up... I thought, I've had enough now. But that soon went, and I got back into it." [P08L2023, Month 6].

Reflection on the DST journey: At the end of the study, participants were asked to reflect on DST in comparison to traditional, analogue smell training. Eleven of the eighteen had previously attempted analogue training, but few sustained it beyond a few weeks. Reported challenges included a lack of structure, minimal perceived progress, and the inconvenience of setup. By contrast, DST was viewed as simpler, more structured, easier to maintain and fostered a sense of accountability:

"And then well, it's just nice to have the smell coming to you and machine and randomized, controlled. And then you give a rating. I think it sort of puts you in the right sort of scientific state of mind. Also, the fact that it comes for a few seconds, it pushes you to be with it, whereas when you open the jar, you might just do and you put it back and you move on quickly. But this gives you a rhythm..." [P06L2023, Month 6].

Participants appreciated its scientific framing, time-limited sessions, and digital logging features, which supported focused engagement:

"When you've got the digital machine there, you have to sit there and stay there. When I (was doing traditional smell training)... I cut strips of paper to put it on before. So there you could smell one smell and get distracted, go up and do something, come back again. With this one, you have to sit and stay put. Can't go off, can you? And it was a lot easier, far less messy, I just needed to press my phone. So I think it's easy to be more compliant." [P18N2023, Month 6].

In their closing reflections, participants also offered advice for future users. Suggestions included placing the device in a visible location, pairing DST with daily routines, and staying flexible amid fluctuations in perception. Those with olfactory difficulties emphasised the importance of patience and persistence, noting that progress was often slow. Others encouraged a mindset of curiosity and openness to olfactory experiences beyond the formal sessions. For many, DST became more than a tool, it served as a prompt to re-engage with the sensory world, even when that process was gradual, uncertain, or incomplete.

Several participants expressed a desire to continue using DST beyond the study period and asked whether the device would become commercially available. This interest was reaffirmed during a follow-up in-person community gathering held six months after the study concluded (December 2024), where participants shared ongoing experiences and reiterated their wish to access the technology independently.