ORIGINAL RESEARCH

Can immersive olfactory training serve as an alternative treatment for patients with smell dysfunction?

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Abstract

Objectives: Olfactory training (OT) has emerged as a first-line therapeutic approach to the management of olfactory dysfunction. Conventional OT (COT) involves the systematic home-based exposure to four distinct odors. Previous research has demonstrated that immersive OT (IOT) involving full-body exposure to dozens of distinct odors could also improve overall olfactory function. This study compared IOT and COT in terms of efficacy.

Methods: A total of 60 patients were enrolled and assigned to three groups. The IOT group ($n = 25$) underwent immersive exposure to 64 odors once daily in a specialized theater. COT participants ($n = 17$) sniffed four typical odors in a set of four jars twice daily at home. A control group ($n = 18$) underwent passive observation. Olfactory function was assessed before and after training.

Results: Significant improvements in composite threshold-discrimination-identification (TDI) scores were observed after training in both the IOT (mean difference = 2.5 ± 1.1. $p = .030$) and COT (mean difference = 4.2 ± 1.3, $p = .002$) groups. No changes were observed in the control group. A significantly higher proportion of patients in the COT group (41%) presented improvements of clinical importance (TDI ≥5.5) compared to the controls ($p = .018$). The improvements attained in the IOT group (20%) were less pronounced ($p = .38$).

Conclusion: While IOT did not exhibit the same efficacy as COT in restoring olfactory function, it still demonstrated promising outcomes. Future efforts to advance olfactory recovery should focus on cross-modal integration.

Level of Evidence: Level 3.

KEYWORDS
olfactory dysfunction, olfactory training, Sniffin' Sticks

1 | INTRODUCTION

Olfactory training (OT) has emerged as a first-line therapeutic approach to the management of olfactory dysfunction arising from various causes, particularly viral infection or head trauma.[1] This non-pharmacological rehabilitative treatment involves exposing patients to odorants at home in a set of four jars, each of which contains one aromatic compound (rose, eucalyptus, lemon, or cloves), twice daily for at least 3 months.[2] A number of studies and meta-analyses have corroborated the efficacy of conventional OT (COT)[3–6]; however, inconsistencies in the results have prompted efforts to refine the OT protocol. Refinements include extending the training duration,[7] altering the odor concentration[8] or molecular characteristics,[9] cycling through multiple sets of odors,[10,11] doubling the number of odors per training session,[12] concurrently applying visual and olfactory stimuli during training,[13,14] and incorporating smell diaries[15] and novel odor-presenting devices[16] to promote adherence.

Immersive olfactory training (IOT) is a notable innovation featuring an integrated olfactometer that automates the delivery of dozens of distinct odors within a spacious chamber. Multiple participants seated within the chamber are subjected to immersive olfactory exposure over a period of 24 min once daily for 14 days. In a previous study on 25 subjects with olfactory dysfunction of various etiologies, significant improvements in overall olfactory test scores were noted following this intervention.[17] This implies that the scope of OT could extend beyond simply sniffing a limited number of odors, toward more immersive exposure to a diverse variety of odorous stimuli.

Our objective in the current study was to verify the efficacy of IOT under an extended training duration. Building upon previous observations, the therapeutic efficacy of IOT was compared with that of COT. To rule out the potential influence of spontaneous recovery in olfactory function, we also included a control group, which did not undergo any structured training.

2 | MATERIALS AND METHODS

2.1 | Participants and study design

This study enrolled patients who reported subjective olfactory dysfunction. Patients who reported spontaneous recovery or fluctuations in olfactory function were excluded. To ensure a meaningful sample size, we opted not to exclude patients diagnosed with normosmia (based on objective measurements). We also retained patients with head trauma, based on previous reports pertaining to the efficacy of OT in these cases.[4] All participants underwent a comprehensive assessment, including a review of their medical history and a psychophysical olfactory testing.

The participants were divided into an IOT group, a COT group, and a control group of patients who did not undergo any form of OT during the study period. Note that patient assignment was based primarily on considerations of convenience, including ease of access to the training facility and availability for daily training. Follow-up olfactory assessment was conducted at no less than 2 months after the initial evaluation. Using G*Power software (version 3.1.9.7),[18] it was determined that a sample size of 66 subjects in total would be required to detect a moderate effect of $f = 0.25$[6,19] (alpha level set to .05) via repeated measures analyses of variance (rm-ANOVA) involving between–within group interactions.

The study procedures adhered to the Declaration of Helsinki and received approval from the ethics committee of the Charité University Medicine Berlin (application number EA2/070/22). Written informed consent was obtained from each participant.

2.2 | Measurement of olfactory function

Participants were asked to rate their olfactory and gustatory function using visual analog scales (left hand end—0—no smell/taste; right hand end—100—excellent function).[20] Olfactory function was assessed using the Sniffin' Sticks test (Burghart Messtechnik GmbH, Holm, Germany), comprising subtests for detection threshold, discrimination, and identification.[21,22] The olfactory detection threshold was determined through an adaptive staircase procedure employing stepwise dilutions of phenylethyl alcohol (rose-like odor). Participants were required to discern the one pen that contains an odor versus two blanks (three-alternative forced choice). Odor discrimination ability was assessed using 16 pen triplets in which two pens contained the same odor and the third pen contained a different odor. The participants were required to choose the odd pen with the pens presented in random order. Odor identification ability was assessed using 16 common odors. This involved selecting the correct term for a given pen from a list of four descriptors. The scores of each subtest were summed to produce a composite TDI score (threshold + discrimination + identification), where normosmia was defined as a TDI score > 30.5, hyposmia was defined as 30.5 ≥ TDI > 16.5, and functional anosmia was defined as TDI ≤16.5.[23]

2.3 | Assessment of well-being and cognitive function

Olfactory function can have a profound effect on one's overall well-being.[24] This study used the World Health Organization Well-Being Index (WHO-5) for the assessment of subjective well-being, in which five items are rated using a 6-point Likert-type scale ranging from 0 (at no time) to 5 (all the time).[25] The participants were tasked with evaluating the degree to which the five statements resonated with their experiences over the previous 14 days. Cumulative WHO-5 score ranged from 0 to 25, with higher scores indicating a higher subjective assessment of well-being.

We also explored the effect of OT on perceived cognitive function.[26] Participants were asked to rate their perceived age based on four dimensions: perception of how one feels ("I feel like I'm ____ years old"), outward appearance ("My appearance aligns with that of a ____-year-old"), activities ("I engage in activities similar to those of a

____-year-old"), and personal interests ("My interests resemble those of a ____-year-old").[27] A composite cognitive age was derived as the average of the scores across the four subscales.

2.4 | Conventional olfactory training

Patients in the COT group were instructed to perform the training regimen at their homes twice daily until their second clinical visit. Training was performed using four odorants sourced from Sigma-Aldrich in Steinheim, Germany, including rose (phenylethanol, #77861), eucalyptus (eucalyptol, #C80601), lemon (citronellal, #27470), and cloves (eugenol, #W246700). Undiluted odorants were applied to cotton pads and placed in individual brown glass jars. Exposure involved sniffing the content of each jar for 20 to 30 s.

2.5 | Immersive olfactory training

Participants in the IOT group attended an immersive odor-presenting theater once daily, 6 days a week (excluding Mondays). During each session, the participants were exposed to 64 odors (four 12-min blocks of 16 odors each). Odor delivery was performed using an electronically controlled olfactometer (Smeller 2.0; Georgsdorf, Berlin, Germany; http://smeller.net, patent number: DE10308619A1).[17] An odor inlet operated by digitally automated valves was integrated within a perforated steel wall (measuring 7×4 m^2) located at one end of a chamber formed by a suspended tent made of white sail fabric, measuring 25 m (length) $\times$ 7 m (width) $\times$ 4 m (height) (Figure 1A). Suction units and an exhaust vent concealed at the opposite end of the chamber wafted the odors from one end of the chamber to the other.

Each individual odor was issued in 5-s waves to form a continuous stream of fresh airflow moving at 1.5 km/h. Between each block

of 16 odors, all of the ambient air within the chamber was expelled and then replaced with fresh air. This 90-s flushing process was meant to remove all remnants of previously introduced odors. The participants were instructed to sit in the central seating area of the chamber (Figure 1B) and breathe naturally to prevent hyperventilation.

The odors covered a wide range of categories: including rose, fish, sweat, raspberry, horse, short circuit, railway station, hay, natural and urban environment smells, body odors, animal odors, flowers, fruits, technical devices, hygienic products, lubricants, fuels, and basic materials, such as wood, earth, and grass.

IOT could be performed only during the operation of the odor-presenting theater (July 1 to October 7, 2022). Following the completion of the event, the patients were scheduled for a second visit to the lab for post-training evaluation (Figure 2).

2.6 | Statistical analysis

Statistical analysis was conducted using IBM SPSS Statistics for Windows, version 28 (IBM Corp., Armonk, N.Y., USA). In dealing with between-group demographic and behavioral data, one-way
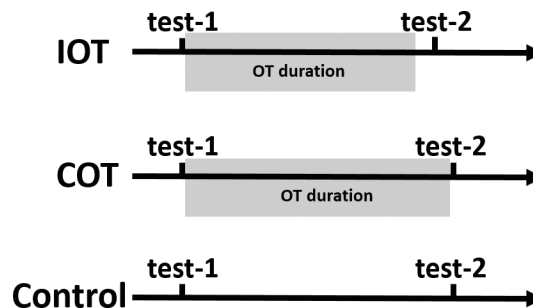
FIGURE 2 Experimental timeline of each group. OT, olfactory training.

FIGURE 1 Immersive odor-presenting theater. (A) Electronically controlled olfactometer, Smell 2.0. (B) Spacious chamber in which the participants underwent immersive exposure to odors.

ANOVA was employed for continuous variables, while Chi-squared tests were employed for categorical variables. rm-ANOVA was used to assess changes in T, D, I and composite TDI scores, as well as subjective ratings of olfactory/gustatory function, WHO-5 scores and assessments of cognitive age between pre- and post-training sessions.

Sessions were treated as within-subject variables, groups were treated as a between-subject factor, and chronological age was treated as a covariate. The Bonferroni method was adopted for post hoc pairwise analysis with the mean difference (MD) reported. The participants were categorized as responders (ΔTDI ≥5.5) or non-responders (ΔTDI <5.5) in ascertaining whether the effects of OT reached the threshold of clinical significance (minimal clinically important difference; MCID).[28] We then compared the numbers of responders in the IOT and COT groups to those in the control group using the Fischer exact test. The threshold for statistical significance was set at $p < .05$.

3 | RESULTS

3.1 | Patient demographics data

We enrolled a cohort of 60 patients complaining of olfactory dysfunction (35 women and 25 men, mean age: 51.6 ± 14.8 years old, range: from 18 to 85 years). The patients exhibited various etiologies, including upper respiratory tract infections (60%), head trauma (5%), chronic rhinosinusitis (5%), and idiopathic cases (30%). The severity of olfactory dysfunction varied among the patients, as assessed by the composite TDI scores: anosmia (12 patients; 20%), hyposmia (31 patients; 52%), and normosmia (17 patients; 28%).

As shown in Table 1, all participants were divided into three groups: IOT group (25 patients; 42%), COT group (17 patients; 28%), and control group (18 patients; 30%). The fact that mean patient age was significantly higher in the IOT group ($p = .016$) prompted us to treat "age" as a covariate of non-interest in subsequent rm-ANOVA.

TABLE 1 Patient demographic data and baseline function.

Mean ± SD	IOT (n = 25)	COT (n = 17)	Control (n = 18)	F	χ^2	p
Age (year)	57.9 ± 14.2	46.9 ± 13.8	47.1 ± 13.8	4.46		.016[a]
Gender, n (%)					0.75	.686
Women	13 (52%)	11 (65%)	11 (61%)			
Men	12 (48%)	6 (35%)	7 (39%)			
Cause, n (%)					–	–
URI	14 (56%)	13 (76%)	9 (50%)			
Idiopathic	9 (36%)	2 (12%)	7 (38%)			
Trauma	2 (8%)	0	1 (6%)			
CRS	0	2 (12%)	1 (6%)			
Test interval (week)	10.1 ± 2.8	16.2 ± 4.0	14.4 ± 3.4	18.1		<.001[a]
Baseline function					–	–
Threshold	5.7 ± 3.1	3.5 ± 2.6	4.4 ± 2.6	2.96		.060
Discrimination	9.8 ± 3.3	9.2 ± 3.9	11.2 ± 2.6	1.62		.206
Identification	9.7 ± 3.8	8.6 ± 4.3	11.8 ± 3.3	3.34		.042[a]
Composite TDI	25.1 ± 8.5	21.4 ± 8.8	27.4 ± 7.1	2.48		.093
Normosmia	8 (32%)	2 (12%)	7 (39%)			
Hyposmia	11 (44%)	11 (65%)	9 (50%)			
Anosmia	6 (24%)	4 (23%)	2 (11%)			
Rated olfaction	(n = 19)	(n = 10)	(n = 14)	1.95		.156
	0.8 ± 2.1	1.5 ± 3.0	−0.3 ± 0.9			
Rated gustation	(n = 20)	(n = 10)	(n = 14)	1.63		.209
	0.9 ± 3.3	2.1 ± 4.2	−0.8 ± 3.2			
WHO-5	(n = 25)	(n = 15)	(n = 18)	2.06		.137
	16.3 ± 3.8	12.1 ± 5.7	15.7 ± 3.3			
Cognitive age	(n = 25)	(n = 15)	(n = 17)	3.19		.049[a]
	46.0 ± 12.1	40.0 ± 12.8	38.5 ± 11.8			

Abbreviations: COT, conventional olfactory training; CRS, chronic rhinosinusitis; IOT, immersive olfactory training; TDI, threshold + discrimination + identification; URI, upper airway infection; WHO-5, questionnaire for well-being.
[a]Statistical significance.

The average interval between the two test sessions was 94 ± 30 days (range: 50 to 163 days). The average training duration in the IOT group was 58.7 ± 13.8 days, and the average training duration in the COT group was 115.0 ± 28.9 days. Note that the training period was significantly shorter in the IOT group than in the COT group ($p < .001$), due to time constraints pertaining to the operations of the odor-presenting theater.

3.2 | Baseline olfactory function

The baseline olfactory function in the three groups is shown in Table 1. One-way ANOVA revealed a significant inter-group difference in odor identification performance ($F = 3.34$, $p = .042$). Subsequent rm-ANOVA also revealed a significant main effect of group on the odor detection threshold ($F [2, 56] = 6.2$, $p = .004$), wherein the IOT group outperformed the COT group in the pre-training session (MD $= 2.7 ± 0.9$, $p = .012$) (Figure 3A). Odor identification scores were significantly lower in the COT group than in the control group (MD $= 3.3 ± 1.2$, $p = .031$) (Figure 3C). The mean composite TDI score was significantly higher in the IOT group than in the COT group (MD $= 6.7 ± 2.4$, $p = .025$) (Figure 3D). Overall, The IOT participants outperformed COT participants in baseline measures.

3.3 | Changes of olfactory function: Between-group differences

The between-group differences in olfactory performance were initially analyzed using one-way ANOVA (Table 2). We observed only sub-significant differences between the groups in terms of changes in odor identification ($F = 2.80$, $p = .070$) and composite TDI score ($F = 2.70$, $p = .076$). Most of these differences involved IOT and COT participants improving, while the controls remained at the same level or declined.

In subsequent rm-ANOVA (Figure 3), detection threshold testing did not reveal significant interaction effects between group and session, except for a trend of improvement in the IOT group (MD $= 1.2 ± 0.7$, $p = .086$). Odor discrimination testing did not reveal significant main effects, except for a trend of improvement in the COT group (MD $= 1.1 ± 0.6$, $p = .051$). Odor identification testing revealed a trend of interaction between group and session ($F [2, 56] = 2.8$, $p = .069$), including a significant improvement in the COT group (MD $= 1.8 ± 0.7$, $p = .010$). The composite TDI score also exhibited a trend of interaction between group and session ($F [2, 56] = 2.5$, $p = .089$) with significant improvements observed in both the IOT (MD $= 2.5 ± 1.1$, $p = .030$) and COT (MD $= 4.2 ± 1.3$, $p = .002$) groups.
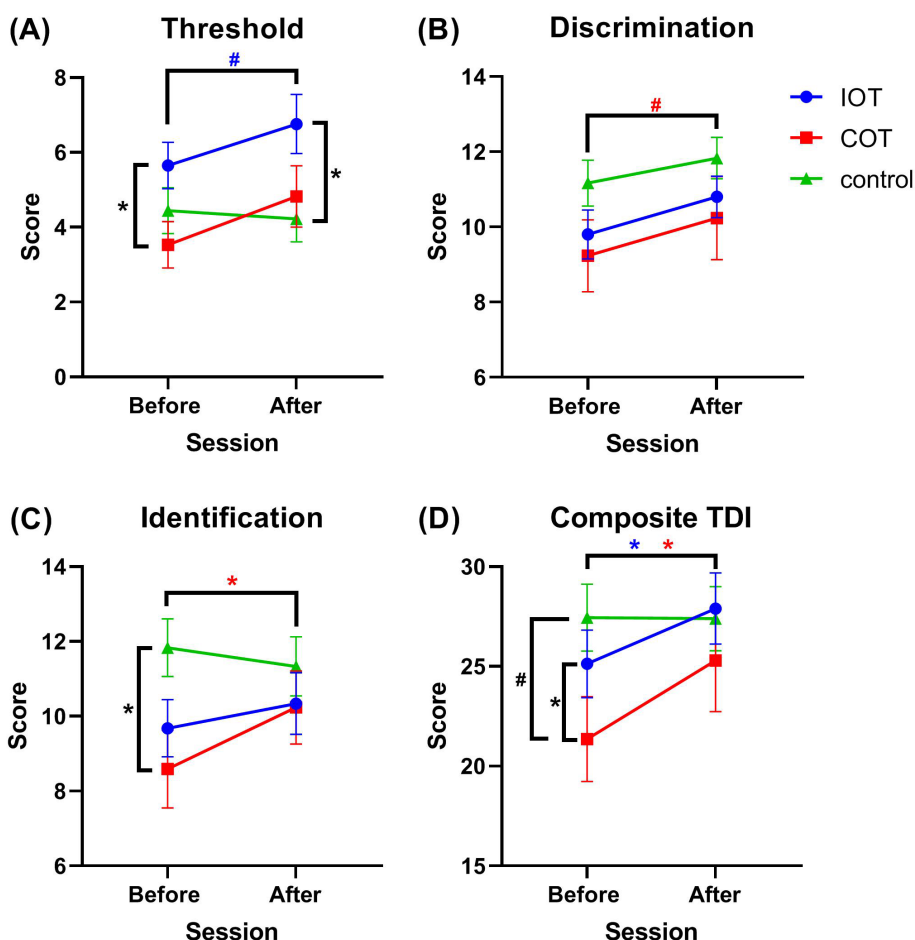
FIGURE 3 Difference between training sessions in terms of measured olfactory function. Error bars represent standard error of the mean. * $p < .05$; #$0.05 \leq p < .1$. The color of asterisk and hashtag represent the corresponding group of significance. TDI, threshold-discrimination-identification.

The number of patients with MCID was significantly higher in the COT group than in the control group ($p = .018$), while the difference between the IOT group and the controls did not reach the level of significance (Table 2).

3.4 | Changes of self-ratings: Between-group differences

All participants completed the olfactory function test; however, some of the self-rating data were inadvertently lost due to human error.

Table 1 lists the precise number of patients for whom rating data is available. As shown in Figure 4, we observed a significant main effect of group on self-rated olfactory and gustatory function (olfaction: $F [2, 48] = 3.6$, $p = .034$; gustation: $F [2, 45] = 4.0$, $p = .024$), including a pairwise difference between the COT and control groups (olfaction: MD = 0.4 ± 0.1, $p = .029$; gustation: MD = 0.4 ± 0.1, $p = .008$). The COT group exhibited significant improvements in self-rated olfactory function (MD = 0.2 ± 0.1, $p = .021$) and gustatory function (MD = 0.4 ± 0.1, $p = .008$). A significant interaction effect between group and session was also observed in rated gustatory function ($F [2, 45] = 3.4$, $p = .044$).

TABLE 2 Olfactory change.

Mean ± SD	IOT ($n = 25$)	COT ($n = 17$)	control ($n = 18$)	F	p
ΔThreshold	1.1 ± 3.8	1.3 ± 3.2	−0.2 ± 1.7	1.29	.284
ΔDiscrimination	1.0 ± 2.5	1.0 ± 2.5	0.6 ± 1.9	0.13	.880
ΔIdentification	0.7 ± 3.1	1.6 ± 3.1	−0.5 ± 1.3	2.80	.070
ΔComposite TDI	2.8 ± 5.9	3.9 ± 6.2	−0.1 ± 3.1	2.70	.076
MCID, n (%)					
IOT vs. control	5 (20%)		1 (6%)		.375[a]
COT vs. control		7 (41%)	1 (6%)		.018[a,b]

Abbreviation: MCID, minimal clinical important difference (TDI≧5.5).
[a]Fischer exact test.
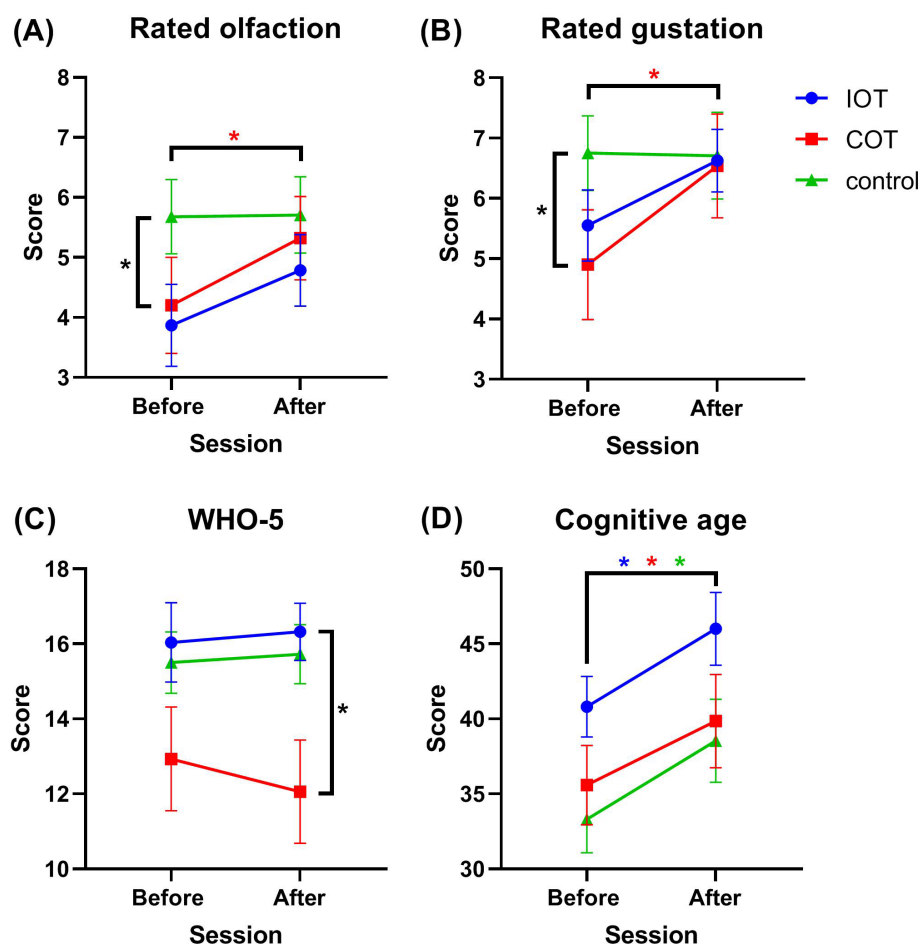[b]Statistical significance.

FIGURE 4 Difference between training sessions in terms of self-rating scales. Error bars represent standard error of the mean. *$p < .05$. The color of asterisk represents the group of significance.

We observed a significant main effect of group on WHO-5 score (F [2, 54] = 3.3, p = .043), which included a difference in post-training scores between the IOT and COT groups (MD = 4.1 ± 1.5, p = .023). We did not observe significant main effect or interactions between group and session in cognitive age scores. Pairwise comparisons revealed a significant increase in cognitive age across sessions in all groups (IOT: MD = 4.3 ± 0.9, p < .001; COT: MD = 5.5 ± 1.1, p < .001; control: MD = 5.5 ± 1.1, p < .001).

4 | DISCUSSION

The current study assessed the effects of three treatment regimens for olfactory dysfunction, including IOT with full body odor exposure, COT with home-based odor exposure from jars, and a passive observational approach (control). In comparison to the control group, both IOT and COT demonstrated significant improvements in olfactory function (composite TDI score). By regularly exposing patients to odors in close proximity to the nostrils, COT is clinical in nature. In contrast, by exposing the entire body to a wide variety of odors, IOT is seen as a more natural approach to olfactory perception.[17]

Exposure to a wider range of odors in IOT may be beneficial. It is important to consider that different odor molecules elicit a unique pattern of neural activation by binding to specific sets of olfactory receptor neurons. Repeated exposure to a single odorant has been shown to enhance the detection threshold for that particular scent.[29,30] A modified OT protocol in which multiple sets of odors were used throughout the training course has been shown to improve outcomes.[10,31] Note that those studies were similar to the current study in terms of study design and sample size; however, exposure in those studies was performed at home, unlike the group-based IOT in a central location in the current study.

Adherence is crucial to OT treatment outcomes.[16] Patients in the IOT group were required to establish a daily schedule to ensure attendance at the odor-presenting theater, thereby increasing the likelihood of adherence. Conversely, patients in the COT group conducted their training at home, which rendered them susceptible to interruptions.[32] Patients in the IOT group also underwent training in a group setting, which provided the opportunity to connect with others facing similar challenges and has proven particularly effective in many behavioral studies.[33] A group setting allows people to exchange experiences, cultivate empathy, and foster a sense of belonging, thereby mitigating feelings of isolation. The advantages of such group therapy have the potential for olfactory recovery.

Contrary to expectations, our results revealed that IOT is less effective than COT in overcoming olfactory dysfunction, based on the number of individuals who achieved significant improvements. Note that the patients in the COT group started with lower baseline olfactory function, thereby providing more room for improvement.[34,35] Future research should include more patients with lower baseline olfactory function in order to evaluate the efficacy of IOT within these specific patient subgroups. Note also that the participants in the IOT group were older than those in the COT group. Attempts were made to account for age as a covariate in our analysis; however, age remained a potential source of bias in our results. Considering that advanced age has been linked to poor olfactory recovery following OT,[34] a more modest improvement in the IOT group could be anticipated.

This study was subject to a number of limitations; therefore, the results should be interpreted with caution. First, the fact that all IOT sessions were conducted in a single location may have limited the diversity of patient recruitment in terms of age distribution, OD etiology, and/or baseline olfactory function. It is also likely that the limited timeframe for the operation of the odor-presenting theater affected the interval between testing sessions and the overall duration of OT in the IOT group, with corresponding effects on the generalizability of our findings. Despite these limitations, patients in the IOT group still demonstrated significant improvements in composite TDI scores. Note also that the proportion of patients who achieved MCID was comparable to that observed in a previous study employing a similar immersive approach.[17]

Immersive training can also include multisensory stimulation, which may promote cross-modal integration[36] and thereby enhance the efficacy of treatment. The introduction of visual stimulation during OT has shown promise in improving olfactory outcomes.[13,14] Recent advances in visual reality technology could potentially be used to enhance the immersivity of the olfactory experience, particularly when implemented in the form of a game[37] and learning task.[38] It is also likely that engaging in activities that involve gustatory and trigeminal perceptions, such as cooking and food preparation, could help patients to regain their olfactory capacity and enjoyment of foods.[39,40] Future research could focus on expanding the range of OT tasks incorporating multisensory stimulation aimed at amplifying the immersive experiences.

5 | CONCLUSIONS

In the current study, the efficacy of IOT did not reach the level of COT in restoring olfactory function; however, it still appears to be a promising approach to the development of treatments. Further research focusing on cross-modal integration has considerable potential for the advancement of olfactory recovery strategies.

CONFLICT OF INTEREST STATEMENT
No potential conflict of interest was reported.

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REFERENCES

1. Whitcroft KL, Altundag A, Balungwe P, et al. Position paper on olfactory dysfunction: 2023. *Rhinology*. 2023;31:1-108.
2. Hummel T, Rissom K, Reden J, Hahner A, Weidenbecher M, Huttenbrink KB. Effects of olfactory training in patients with olfactory loss. *Laryngoscope*. 2009;119:496-499.
3. Kattar N, Do TM, Unis GD, Migneron MR, Thomas AJ, McCoul ED. Olfactory training for postviral olfactory dysfunction: systematic review and meta-analysis. *Otolaryngol Head Neck Surg*. 2021;164: 244-254.
4. Huang T, Wei Y, Wu D. Effects of olfactory training on posttraumatic olfactory dysfunction: a systematic review and meta-analysis. *Int Forum Allergy Rhinol*. 2021;11:1102-1112.
5. Pekala K, Chandra RK, Turner JH. Efficacy of olfactory training in patients with olfactory loss: a systematic review and meta-analysis. *Int Forum Allergy Rhinol*. 2016;6:299-307.
6. Sorokowska A, Drechsler E, Karwowski M, Hummel T. Effects of olfactory training: a meta-analysis. *Rhinology*. 2017;55:17-26.
7. Konstantinidis I, Tsakiropoulou E, Constantinidis J. Long term effects of olfactory training in patients with post-infectious olfactory loss. *Rhinology*. 2016;54:170-175.
8. Damm M, Pikart LK, Reimann H, et al. Olfactory training is helpful in postinfectious olfactory loss: a randomized, controlled, multicenter study. *Laryngoscope*. 2014;124:826-831.
9. Poletti SC, Michel E, Hummel T. Olfactory training using heavy and light weight molecule odors. *Perception*. 2017;46:343-351.
10. Altundag A, Cayonu M, Kayabasoglu G, et al. Modified olfactory training in patients with postinfectious olfactory loss. *Laryngoscope*. 2015; 125:1763-1766.
11. Lamira JM, Soler ZM, Schlosser RJ. A pilot study of olfactory training in older Hyposmic adults. *Am J Rhinol Allergy*. 2019;33:650-656.
12. Pires ÍAT, Steffens ST, Mocelin AG, et al. Intensive olfactory training in post-COVID-19 patients: a multicenter randomized clinical trial. *Am J Rhinol Allergy*. 2022;36:780-787.
13. Denis F, Septans AL, Periers L, et al. Olfactory training and visual stimulation assisted by a web application for patients with persistent olfactory dysfunction after SARS-CoV-2 infection: observational study. *J Med Internet Res*. 2021;23:e29583.
14. Khan AM, Piccirillo J, Kallogjeri D, Piccirillo JF. Efficacy of combined visual-olfactory training with patient-preferred scents as treatment for patients with COVID-19 resultant olfactory loss: a randomized clinical trial. *JAMA Otolaryngol Head Neck Surg*. 2023;149:141-149.
15. Chao Y-T, Woosch D, Pieniak M, Hummel T. Gender difference in ratings of odor intensity during olfactory training. *J Sens Stud*. 2022;37: e12784.
16. Saatci O, Altundag A, Duz OA, Hummel T. Olfactory training ball improves adherence and olfactory outcomes in post-infectious olfactory dysfunction. *Eur Arch Otorrinolaringol*. 2020;277:2125-2132.
17. Mahmut MK, Uecker FC, Göktas Ö, Georgsdorf W, Oleszkiewicz A, Hummel T. Changes in olfactory function after immersive exposure to odorants. *J Sens Stud*. 2020;35:e12559.
18. Faul F, Erdfelder E, Lang AG, Buchner A. G*power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39:175-191.
19. Oleszkiewicz A, Hanf S, Whitcroft KL, Haehner A, Hummel T. Examination of olfactory training effectiveness in relation to its complexity and the cause of olfactory loss. *Laryngoscope*. 2018;128:1518-1522.
20. Landis BN. Ratings of overall olfactory function. *Chem Senses*. 2003; 28:691-694.
21. Hummel T, Sekinger B, Wolf SR, Pauli E, Kobal G. Sniffin' sticks': olfactory performance assessed by the combined testing of odor identification, odor discrimination and olfactory threshold. *Chem Senses*. 1997;22:39-52.
22. Oleszkiewicz A, Schriever VA, Croy I, Hähner A, Hummel T. Updated Sniffin' sticks normative data based on an extended sample of 9139 subjects. *Eur Arch Otorrinolaringol*. 2019;276:719-728.
23. Hummel T, Kobal G, Gudziol H, Mackay-Sim A. Normative data for the "Sniffin' sticks" including tests of odor identification, odor discrimination, and olfactory thresholds: an upgrade based on a group of more than 3,000 subjects. *Eur Arch Otorrinolaringol*. 2007;264: 237-243.
24. Mai Y, Menzel S, Cuevas M, Haehner A, Hummel T. Well-being in patients with olfactory dysfunction. *Physiol Behav*. 2022;254:113899.
25. Topp CW, Østergaard SD, Søndergaard S, Bech P. The WHO-5 well-being index: a systematic review of the literature. *Psychother Psychosom*. 2015;84:167-176.
26. Birte-Antina W, Ilona C, Antje H, Thomas H. Olfactory training with older people. *Int J Geriatr Psychiatry*. 2018;33:212-220.
27. Barak BSL. Cognitive age: a nonchronological age variable. *Adv Consum Res*. 1981;8:602-606.
28. Gudziol V, Lötsch J, Hähner A, Zahnert T, Hummel T. Clinical significance of results from olfactory testing. *Laryngoscope*. 2006;116: 1858-1863.
29. Dalton P, Doolittle N, Breslin PA. Gender-specific induction of enhanced sensitivity to odors. *Nat Neurosci*. 2002;5:199-200.
30. Jiang RS, Twu CW, Liang KL. The effect of olfactory training on the odor threshold in patients with traumatic anosmia. *Am J Rhinol Allergy*. 2017;31:317-322.
31. Rezaeyan A, Asadi S, Kamrava SK, Khoei S, Zare-Sadeghi A. Reorganizing brain structure through olfactory training in post-traumatic smell impairment: an MRI study. *J Neuroradiol*. 2022;49:333-342.
32. Pieniak M, Hummel T. Do people stop conducting olfactory training when their olfaction recovers? *Rhinology*. 2024;62:127-128.
33. Montgomery C. Role of dynamic group therapy in psychiatry. *Adv Psychiatr Treat*. 2002;8:34-41.
34. Liu DT, Pellegrino R, Sabha M, et al. Factors associated with relevant olfactory recovery after olfactory training: a retrospective study including 601 participants. *Rhinology*. 2021;59:91-97.
35. Oleszkiewicz A, Bottesi L, Pieniak M, et al. Olfactory training with Aromastics: olfactory and cognitive effects. *Eur Arch Otorrinolaringol*. 2022;279:225-232.
36. Peter MG, Porada DK, Regenbogen C, Olsson MJ, Lundström JN. Sensory loss enhances multisensory integration performance. *Cortex*. 2019;120:116-130.
37. Archer NS, Bluff A, Eddy A, et al. Odour enhances the sense of presence in a virtual reality environment. *PLoS One*. 2022;17:e0265039.
38. Andonova V, Reinoso-Carvalho F, Jimenez Ramirez MA, Carrasquilla D. Does multisensory stimulation with virtual reality (VR) and smell improve learning? An educational experience in recall and creativity. *Front Psychol*. 2023;14:1176697.
39. Fjaeldstad A, Smith B. The effects of olfactory loss and parosmia on food and cooking habits, sensory awareness, and quality of life—a possible avenue for regaining enjoyment of food. *Foods*. 2022;11: 1686.
40. Fjaeldstad A, Bredahl R, Bøjlund C. *Cooking with a Smell Loss—A Cook Book on Senses, Guidance and Recipes*. Apple Books; 2023.