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ORIGINAL ARTICLE

Changes in olfactory function after immersive exposure to odorants

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Abstract

Sniffing four different odorants, bi-daily, for at least 3 months can improve olfactory function. The aim of the current study was to examine whether a relatively short (2 week) exposure period, an immersive exposure to a large number of diverse odorants can improve olfactory function. Twenty-five patients with various olfactory dysfunctions were exposed to 72 different odorants dispersed into an air-controlled space, while in a group. Each odorant was singularly dispersed from one side of the room using a purpose-built apparatus. The odorant exposure period ran for 14 consecutive days, with daily sessions for approximately 24 min. Olfactory function (odor thresholds, discrimination, and identification) was tested before the odorant exposure sessions (i.e., baseline) and then again approximately 6 weeks and 25 weeks afterward. The results demonstrated a significant improvement in overall olfactory function test score, six, and 25 weeks after the odorant exposure sessions, compared to baseline. Specifically, 28% of participants experienced a clinically significant improvement in olfactory function.

Practical Application

Immersive exposure presents an opportunity to enhance olfactory function in various environments and may be an effective training methodology to increase the olfactory sensitivity of sensory panellists. Moreover, immersive odorant exposure may present a novel experimental approach to consumer testing.

1 | INTRODUCTION

The olfactory sense plays an important functional role in three broad behaviors; social communication, harm avoidance, and ingestion (Stevenson, 2010). Olfactory function can be compromised due to injury, disease, and age (Schiffman, 1997), and estimates indicate that approximately 20% of people have an olfactory dysfunction (Yang & Pinto, 2016), with around 1 in every 5,000–10,000 born without a sense of smell (Croy, Negoias, Novakova, Landis, & Hummel, 2012). The impact of olfactory loss or dysfunction can be far reaching, given its role in romantic relationships (Mahmut & Croy, 2019), the enjoyment of food (Croy, Nordin, & Hummel, 2014), and sexual pleasure (Bendas, Hummel, & Croy, 2018). However, there is encouraging evidence that daily odorant exposure exercises can enhance olfactory function and restore the positive experiences once lost.

The first published olfactory training (OT) study with patients (Hummel et al., 2009) included 40 patients who participated in the training and 16 patients who did not. The training group consisted of

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patients with various olfactory dysfunction etiologies (35 postinfectious; 14 idiopathic, and 7 posttraumatic), who completed daily odorant training by sniffing four different odorants (i.e., phenyl ethyl alcohol: rose, eucalyptol: eucalyptus, citronellal: lemon, and eugenol: cloves), twice daily for 12 weeks. The results showed that OT significantly improved olfactory test scores in about 30% of patients (Hummel et al., 2009).

Since the first OT publication in 2009, there have been a further 30 published studies and four reviews, including two meta-analyses which concluded that OT has a significant and positive effect on olfactory function (Pekala, Chandra, & Turner, 2016; Sorokowska, Drechsler, Karwowski, & Hummel, 2017). The most commonly used method of OT requires participants to sniff four odorants (i.e., rose, eucalyptus, lemon, and clove) in small jars, twice a day, for 10–30 s over a number of weeks, commonly at least 12 weeks. This standard protocol is consistent in its effectiveness—the complexity of training (e.g., altering sets of odorants, using multicompound mixtures) does not increase the effectiveness of OT (Oleszkiewicz, Hanf, Whitcroft, Haehner, & Hummel, 2018; Oleszkiewicz, Würfel, Han, & Hummel, 2018).

OT has improved the olfactory function of people with olfactory dysfunctions due to various etiologies, including Parkinson's disease (Haehner et al., 2013; Knudsen, Flensborg Damholdt, Mouridsen, & Borghammer, 2015; Qiao, Wang, Li, Bai, & Zheng, 2019), infections (Geissler, Reimann, Gudziol, Bitter, & Guntinas-Lichius, 2014; Konstantinidis, Tsakiropoulou, & Constantinidis, 2016; Oleszkiewicz, Hanf, et al., 2018; Oleszkiewicz, Würfel, et al., 2018), age (Birte-Antina, Ilona, Antje, & Thomas, 2018; Lamira, Soler, & Schlosser, 2019; Schriever, Lehmann, Prange, & Hummel, 2014), and head trauma (Langdon et al., 2018; Yan et al., 2018). While recovery of olfactory function without training has been reported, for example, 9 years after loss (Mueller & Hummel, 2009), the research findings suggest that OT is more effective within one year of olfactory dysfunction onset (Damm et al., 2014; Yan et al., 2018). The possible mechanisms driving the improvement in olfactory function after OT may be physiological and/or cognitive. For example, neuroimaging studies have demonstrated an increased volume of neuroanatomical regions involved in olfaction after OT, including the olfactory bulbs (Negoias, Pietsch, & Hummel, 2017), right entorhinal cortex (right inferior frontal gyrus and right entorhinal cortex, and both fusiform gyri (Al Aïn et al., 2019), and orbitofrontal cortex (Delon-Martin, Plailly, Fonlupt, Veyrac, & Royet, 2013). Evidence for the involvement of cognitive processes in olfactory function enhancement come from studies showing higher cognitive abilities are associated with better odor discrimination and identification (Hedner, Larsson, Arnold, Zucco, & Thomas, 2010; Westervelt, Ruffolo, & Tremont, 2005). Moreover, successful completion of odor discrimination and odor identification tests require remembering and repeat testing therefore introduces practice effects associated with memory and strategy (Danthiir, Roberts, Pallier, & Stankov, 2001; Sulmont-Rossé, Issanchou, & Köster, 2005).

While it is encouraging to see ear, nose, and throat specialist are using OT as a treatment at a significantly higher rate than previously (Damm, Schmitl, Müller, Welge-Lüssen, & Hummel, 2019; Whitcroft & Hummel, 2019), there are some limitations to the standard training protocol of smelling four different odorants, twice per day. For example, compliance with the protocol can be difficult to accurately assess and adherence rates can be quite low (e.g., 52%; Schriever et al., 2014). Moreover, the long duration of training increases the chances of losing participants with the attrition rate as high as 45% in some 6-month studies (Lamira et al., 2019). The quality of the odorants used in the OT may also decline over time and at different rates for different odorants, depending on how they are maintained, making it difficult to isolate what covariates may drive or inhibit successful OT.

An innovative odorant exposure method removes many of the limitations inherent in the standard OT protocol and the current study's aim was to investigate if this novel methodology may be a viable approach to OT. Specifically, the new OT method requires a shorter (2 week) training period with 12–24 min individual sessions, with an immersive, full-body exposure to 72 different odorants in a group setting. Patients with various olfactory dysfunctions were recruited for this study given they have the most to gain from an enhanced olfactory function (Stevenson, 2010).

2 | METHODS

2.1 | Patients

Twenty-five patients (15 females, 10 males) with hyposmia or anosmia due to various etiologies (nine idiopathic, nine postviral infection, four sinonasal, three head trauma). The patients' ages ranged from 29 to 82 years (M = 54.4 years, SD = 12.9 years) and duration of olfactory loss ranged from 5 to 220 months (M = 43 months, SD = 45 months). Patients completed the study at the Department of Otolaryngology, Charité University Medicine Berlin, Germany, and were recruited from flyers and the outpatient's clinic of the Department of Otolaryngology where they sought counseling due to olfactory loss. This study was approved by Charité University Medicine Berlin Ethics Committee and all participants gave informed, written consent.

TABLE 1 Timeline for study progression

Part 1		6 weeks post-OT	Part 2	25 weeks post-OT	Part 3
Olfactory Tests 1 Objective and Subjective	Olfactory training 2-weeks of bi-daily odorant exposure		Olfactory Tests 2 Objective and Subjective		Olfactory Tests 3 Objective and Subjective

Abbreviation: OT, olfactory training.

TABLE 2 Descriptive statistics (means ± *SD*) and ANOVA results of olfactory function tests at baseline, 6 and 25 weeks after olfactory training (*N* = 25)

	Olfactory testing session		
Olfactory test type	**Test 1—baseline (pre-OT)**	**Test 2–6 weeks post-OT**	**Test 3–25 weeks post-OT**
Odor thresholds	2.32 ± 1.91	3.10 ± 2.19	2.96 ± 2.13
Odor discrimination	3.52 ± 2.24	7.04 ± 2.78*	6.12 ± 2.86*
Odor identification	6.20 ± 3.95	7.36 ± 3.55	6.84 ± 3.42
TDI	12.04 ± 6.32	17.5 ± 7.12*	16.08 ± 7.47*
Olfactory ability self-assessment	1.52 ± 1.69	3.28 ± 2.51*	3.40 ± 2.8*

Note: TDI, sum of odor thresholds, discrimination, and identification scores.
Abbreviations: ANOVA, analysis of variance; OT, olfactory training; TDI, threshold discrimination identification.
*Significant difference compared to Test 1, $p < .05$.

2.2 | Procedure

This was a three-part study (see Table 1). In part one, each patients' general health and olfactory status was assessed. This was followed by individual tests of each patient's olfactory function using the extended Sniffin' Sticks test battery (Oleszkiewicz, Schriever, Croy, Hähner, & Hummel, 2019) plus a subjective assessment of their olfactory function. After these individual assessments, patients began the OT session that involved 2 weeks of bi-daily odorant exposure. Approximately 6 weeks after OT had been completed, patients returned to complete part two study that involved another objective and subjective assessment of their olfactory abilities. Finally, patients returned once more approximately 6 weeks later to complete Part 3 which involved another assessment of their objective and subjective olfactory function.

2.3 | Materials: Olfactory function testing

Each patient's olfactory acuity was measured using a clinically established, psychophysical test battery called "Sniffin' Sticks" (Hummel, Sekinger, Wolf, Pauli, & Kobal, 1997; Kobal et al., 1996). This assessed the three main components of olfactory function, namely (a) the perception of odorants at low concentrations, which is the odor threshold, (b) the distinction of different smells, which is the ability of odor discrimination, and (c) the ability to name or associate an odorant, which is odor identification. The detailed procedure has been described previously (Hummel et al., 1997; Kobal et al., 1996). In brief, olfactory thresholds were obtained for the rose-like odorant phenylethyl alcohol at 16 successive 1:2 dilution steps starting at a solution of 4%. Using a three-alternative (one pen with the odorant and two blanks presented at intervals of 3 s in front of the nostril) forced-choice task and a staircase paradigm, two successive correct or one incorrect indications triggered a staircase reversal. The odorant threshold was the mean of the last four out of seven reversals (normal values >6; Oleszkiewicz et al., 2019).

Odor discrimination was determined with triplets of pens, two containing the same odorant and the third a different, "target" odorant, comprising a total of 16 different target/nontarget combinations (normal score ≥ 11 correct discriminations using a three-alternative, forced-choice task; for details see Table 2, Kobal et al., 1996). The odor identification subtest comprised of 16 commonly known odorants (Kobal et al., 1996) and required participants to select the correct name from a list of four (normal score: ≥ 12 correct identifications). The olfactory diagnosis was derived from the sum of all three subsets and referred to as the threshold discrimination identification (TDI) score (Kobal et al., 2000; Wolfensberger, Schnieper, & Welge-Lussen, 2000). A diagnosis of normosmia requires a score > 30.5 while hyposmia is defined at 30.5 ≥ TDI > 15.5 and functional anosmia at TDI ≤15.5 (Hummel, Kobal, Gudziol, & Mackay-Sim, 2007).

2.4 | Materials: Health assessment

Patients were interviewed about the nature and duration of their olfactory dysfunction using a detailed, structured medical history and a physical otorhinolaryngological examination including nasal endoscopy (Welge-Luessen, Leopold, & Miwa, 2013). Demographics variables such as age and sex were also recorded.

2.5 | Materials: Self-assessment of olfactory function

Knowing a patient's self-assessment of their olfactory function can be an important piece of clinical information although research suggests that people are unreliable judging their olfactory ability (Landis, Hummel, Hugentobler, Giger, & Lacroix, 2003; Lötsch & Hummel, 2019). Before each psychophysical test of a patient's olfactory function, they were asked to make a rating of their current olfactory function using a scale ranging from 0 (nonexistent) to 10 (excellent).

2.6 | Methods: Odorant exposure

Odorants were delivered to patients using an olfactometer called Smeller 2.0 (Georgsdorf, Berlin, Germany; http://smeller.net). Smeller

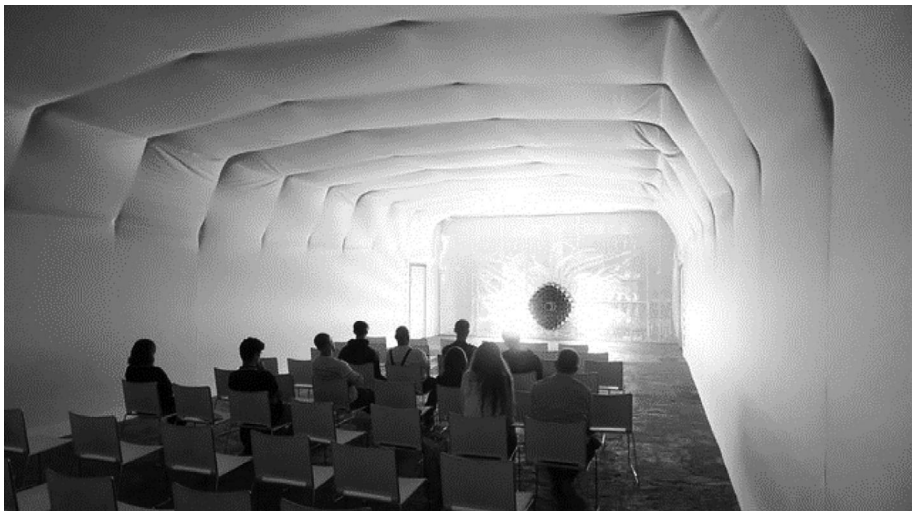

FIGURE 1 Smeller 2.0. This black and white photograph depicts the delivery apparatus of Smeller 2.0, seen in the background, with people sitting in the air-controlled marquee erected within a larger room

2.0 is a digitally controlled electronic smell projector, based on a pipe and chamber system and is designed for olfactory stimulation in spaces of 500 m^3 and larger (Figure 1). It was installed in a large space-in-space room within a marquee ceiling made of white parachute silk which encapsulated the installation, providing control of the air and airflow within it (dimensions: height 4 m × length 15 m × width 7 m). Smeller 2.0 consists of two major components on both ends of the room. On one end of the room, the main structure (6 × 2.5 × 4 m polypropylene and aluminum tubes, electronic valves, cables, electronic control devices) sits behind a perforated steel wall (7 × 4 m^2) and a main airflow guiding element integrated therein. On the opposing end of the room, hidden blowing units and airflow guiding elements were housed. Using electronically controlled valves, odorants were delivered from one end of the room and extracted from the opposing end.

Patients were presented with 72 odorants in four blocks of 18 odorants. Each odorant was presented for five seconds at a flow rate of 1.5 km/h, along with a stream of fresh, constantly flowing air. After each block of 18 odorants, the entire ambient air was extracted, taking approximately 90 s, which left no residue of previously presented odorants. The types of odorants employed varied and included, for example; rose, fish, sweat, raspberry, horse, short circuit, railway station, hay, natural and urban environments smells, body odorants, animal odorants, flowers, fruits, technical devices, hygienic products, lubricants, fuels, and basic materials, such as wood, earth, grass, concrete, and tar. Patients stood or sat in the middle of the space and were instructed to breathe normally to avoid hyperventilation. Each odorant exposure session lasted for approximately 12 min and each patient typically completed two sessions per day. Patients returned on 14 consecutive days and completed the same odorant exposure experience on each occasion.

2.7 | Data analysis

The data were analyzed using SPSS (Statistical Packages for Social Sciences, version 25, SPSS Inc., Chicago, IL). A one-way repeated measures multivariate analysis of variance (MANOVA) was initially conducted to test whether the three olfactory function tests scores (odor thresholds, discrimination, and identification) differed across the three test sessions. The MANOVA yielded significant results so post hoc testing was carried out. Three, one-way repeated MANOVA were conducted separately for each of the three olfactory function tests scores to determine if they differed across the three olfactory test sessions (the within-subjects factor). To determine whether self-assessments of olfactory function improved after the odorant exposure sessions, another one-way repeated MANOVA was conducted. To explore whether a participant's age, the duration of their olfactory dysfunction and their assessment of olfactory function improvement are associated with the increase in olfactory function, we examined the Pearson's correlations between age and TDI scores at each of the three olfactory test sessions.

3 | RESULTS

The descriptive statistics for each of the five dependent variables (i.e., odor thresholds, odor discrimination, odor identification, TDI, and self-assessment of olfactory function scores) at each of the three testing sessions are presented in Table 2.

3.1 | TDI score across three olfactory testing sessions

The first ANOVA was run to determine whether overall olfactory function, as measured by the TDI score, improved after the odorant exposure sessions (see Figure 2). The results revealed a significant main effect of olfactory test, $F_{(2, 48)} = 25.55$, $p < .001$, indicating a difference in TDI scores after the odorant exposure sessions. Post hoc tests using a Bonferroni adjustment for multiple comparisons revealed the TDI score was significantly higher 6 weeks (mean difference 5.46, $p < .001$) and 25 weeks (mean difference 4.04, $p < .001$) after the odorant exposure sessions, compared to baseline. While TDI score dropped slightly between the second the third testing session, this difference was not significant (mean

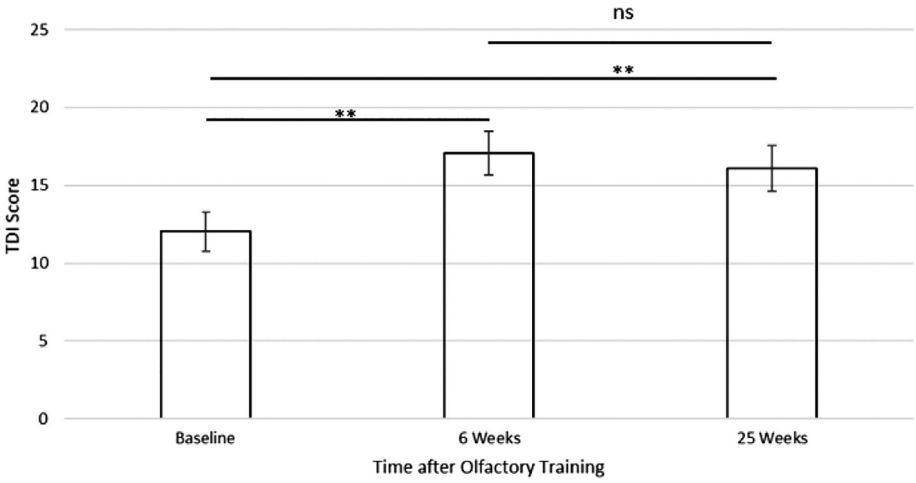

FIGURE 2 TDI score (possible range 1 – 48) at baseline and 6 and 25 weeks after olfactory training, with errors bars (SEM). **significance difference between weeks, $p < .001$. NS, non-significant

difference .14, $p = .22$; see Table 1 summary). The subsequent ANOVAs were conducted to determine which specific components of olfactory function (i.e., thresholds, discrimination, and identification) improved using three separate, one-way repeated MANOVAs.

3.2 | Odor thresholds, discrimination, and identification scores across three olfactory testing sessions

The results of the 3 × 3 MANOVA revealed there was a statistically significant difference in olfactory function tests scores across the three test sessions, $F_{(2, 48)} = 8.81$, $p < .0001$, Wilk's $\Lambda = .403$. Given the significance of the MANOVA results, further tests (i.e., one-way repeated MANOVAs) were conducted to precisely determine the nature of the changes in the three olfactory function tests scores. The first ANOVA tested whether odor thresholds scores improved after the odor exposure sessions, which revealed a nonsignificant main effect, $F_{(2, 48)} = 3.12$, $p = .053$, indicating no significant improvement (although the result was marginally significant). The second analysis tested whether odor discrimination scores improved after the odorant exposure sessions, revealing a significant main effect, $F_{(2, 48)} = 27.14$, $p < .001$, indicating a significant improvement in discrimination scores. Post hoc tests indicated the odor discrimination score was significantly higher after six (mean difference 5.46, $p < .001$) and 25 weeks (mean difference 3.52, $p < .001$) after the odorant exposure sessions, compared to baseline. Despite a slight drop in the odor discrimination score between the second and third olfactory function tests, this difference was not significant (mean difference .92, $p = .052$). The ANOVA of the odor identification scores revealed a nonsignificant main effect of olfactory test, $F_{(2, 48)} = 2.31$, $p = .11$, so post hoc testing was not conducted.

3.3 | Self-assessment of olfactory functions score across three olfactory testing sessions

The data violated assumptions of sphericity so the results are based on a Greenhouse–Geisser correction. The results of this analysis revealed a significant main effect for odorant exposure, $F_{(1.52, 36.47)} = 29.36$, $p < .001$, indicating a significant difference in self-assessed olfactory function scores after the OT sessions. Post hoc tests indicated the self-assessed olfactory function score was significantly higher 6 weeks (mean difference 1.76, $p < .001$) and 25 weeks (mean difference 1.88, $p < .001$) after the OT sessions, compared to baseline. However, there was no significant difference in self-assessed olfactory function score between the second and third testing sessions (mean difference .12, $p = 1.00$).

3.4 | What percentage of patients experienced clinically significant improvements in olfactory function?

Based on previous research (Gudziol, Lotsch, Hahner, Zahnert, & Hummel, 2006), an objective increase of 5.5 in TDI score is deemed clinically significant because it is associated with a subjective experience of an increase of olfactory function. Using an increase of 5.5 in TDI score as the benchmark for improvement in olfactory function, we found that 6 weeks after the odorant exposure sessions, 44% of participants demonstrated a clinically significant improvement, which dropped to 28% 25 weeks after the odorant exposure sessions.

3.5 | Does age affect the impact of OT?

The results indicated that age was not associated with the baseline TDI score ($r_{(25)} = -.04$, $p = .84$), nor the TDI score 6 weeks ($r_{(25)} = -.15$, $p = .47$) or 25 weeks ($r_{(25)} = -.16$, $p = .45$) after OT. Moreover, age was not significantly correlated with a change in TDI score from baseline to TDI score at 6 weeks ($r_{(25)} = -.22$, $p = .29$) or 25 weeks ($r_{(25)} = -.20$, $p = .33$).

3.6 | Does dysfunction duration impact OT?

As previous studies have indicated that treating patients within one year of their olfactory loss increases the chances of improvement

(Yan et al., 2018), we explored whether the duration of a patient's olfactory dysfunction was related to the efficacy of the odorant exposure sessions. To do so, we examined the Pearson's correlations between the duration of olfactory dysfunction and the TDI score at each of the three olfactory function testing sessions. The results indicated that olfactory dysfunction duration was not associated with the TDI score at baseline ($r_{(25)} = -.25$, $p = .23$), 6 weeks ($r_{(25)} = -.20$, $p = .35$) nor 25 weeks ($r_{(25)} = -.27$, $p = .18$) after the odorant exposure sessions.

3.7 | Do psychophysical measures of improvement in olfactory function predict self-assessed improvements in olfactory function?

In order to determine whether patients' subjective perceptions of their olfactory function were consistent with objective measures taken with the Sniffin' Sticks, we examined whether (objective) change in TDI score from baseline to 25 weeks after OT were correlated with the subjective change from baseline to 25 weeks after OT. This Pearson's correlation analyses revealed a significant, positive correlation ($r_{(25)} = .56$, $p = .003$) the objective changes in olfactory function correlated with subjective assessments of olfactory function.

4 | DISCUSSION

The findings of the current study demonstrated that a novel OT methodology, namely, an immersive, full-body exposure to odorants, resulted in a statistically significant increase in psychophysical and self-assessed olfactory function. Specifically, patients demonstrated a significant increase in olfactory function, evidenced by increased TDI scores, after both OT sessions, compared to baseline. There was also a commensurate increase in participants' subjective ratings of their olfactory function after odorant exposure. These findings are consistent with our hypothesis and with that of previous research, despite differences in the length of odorant exposure plus the number, category and delivery of the odorants employed.

In terms of the length of odorant exposure, patients in the current study completed 14 consecutive days of training. In contrast, the vast majority of previous studies required participants to engage in a minimum of 84 days of daily odorant exposure (Sorokowska et al., 2017). However, it is noteworthy the improvements patients demonstrated in the current study are similar to those found in the study with the shortest length of training (e.g., 84 days; Hummel et al., 2009) and longest training duration (i.e., 392 days; Konstantinidis et al., 2016). While we do not know how long the apparent enhancement of olfactory function will last beyond the measured 12-week period, our findings suggest that there may be a tapering off with time. Previous research suggests the improvements in olfactory function are maintained for long periods but continued training provides a further boost (Konstantinidis et al., 2016).

Whether the enhancement of olfactory function is attributable to physiological and/or cognitive changes could not be determined. Given patients only demonstrated a significant increase in the odor discrimination subtest, a test that involves higher cognitive functions, their increased ability to discriminate odors may be due to top-down process involving focused and conscious processing (Negoias et al., 2017). Moreover, the same odor discrimination test was administered three times, so the boost in olfactory function may in part be due to practice effects. However, due to its verbal basis the odor identification is arguably more susceptible to practice effects given the same four response options are given for each odorant, yet patients did not demonstrate a significant increase in performance on this test. Therefore, the boost in olfactory function demonstrated by participants cannot solely be attributable to practice effects.

In terms of the number and category of odorants, most previous studies (Birte-Antina et al., 2018; Haehner et al., 2013) used only four odorants from four different categories (i.e., flowery, fruity, spicy, and resinous; Oleszkiewicz, Hanf, et al., 2018; Oleszkiewicz, Würfel, et al., 2018). Given previous studies have demonstrated using molecularly diverse odorants may promote threshold sensitivity (Oleszkiewicz, Würfel, et al., 2018) and using a small sample of odorants may reduce sensitivity due to adaptation effects (Yoder et al., 2013), having a large variety of olfactory stimuli to train with is important. In the current study, 72 different odorants from 10 categories were presented to patients. In terms of the duration of the odorant exposure, most previous studies required participants to spend approximately two min, twice per day, actively sniffing odorants (Sorokowska et al., 2017). In contrast, the patients in this study spent approximately 24 min per day actively sniffing odorants. Finally, the biggest difference between the current study and all previous studies was the method of odorant delivery. In all previous studies, participants self-administered the OT by placing small jars containing odorants under their nostrils and sniffing (Lamira et al., 2019). In contrast, the odorant exposure in the current study was delivered by an automated and independent apparatus that dispersed odorants throughout an entire room and required participants to sniff the air around them.

It is important to note that while we found patients demonstrated a statistically significant increase in objective olfactory function, only 28% of patients evidenced a clinically significant increase in olfactory function (i.e., >5.5 TDI score; Gudziol et al., 2006). While previous studies have found similar rates of clinically significant improvement; for example, 20% (Haehner et al., 2013) and 33% (Konstantinidis, Tsakiropoulou, Bekiaridou, Kazantzidou, & Constantinidis, 2013), perhaps a more important consideration is the disparity between objective and subjective assessments of olfactory function. While referring to normative data are important for gauging clinically significant changes in olfactory function, subjective assessments of change are equally important. In order to understand the interplay between subjective and objective olfactory assessments, future studies would benefit from asking participants the importance of their sense of smell and the expectations they have of the OT.

In terms of the study's limitations, there are a number of notable considerations. The first is the lack of control group to compare the patient results against. In previous studies, a common activity for those in the control group to complete is a cognitive task such as a

mathematical puzzle Sudoku (Birte-Antina et al., 2018). However, the positive impact of OT is well-established (Damm et al., 2014; Pekala et al., 2016; Sorokowska et al., 2017) and the control group in such studies have never demonstrated a significant increase in olfactory function as per the patient group (Sorokowska et al., 2017). Moreover, and the increase in TDI score in studies with similar patient groups has been of the same magnitude as per our patient group (e.g., 4.09 TDI increase; Fleiner, Lau, & Göktas, 2012) buttressing our conclusion that the enhancement in olfactory function is due to the odorant exposure.

Finally, while the sample size may be considered relatively small, we were able to detect a significant odor discrimination effect consistent with previous studies (Sorokowska et al., 2017) and not uncommon in studies with patients where the incidence rate is low. For example, similarly small samples have been used in other studies; for example, sample sizes of three (Fleiner et al., 2012) and 11 (Kollndorfer et al., 2014). Given there were only a small number of patients with each of the various olfactory dysfunction etiologies, we could not reliably compare whether odorant exposure benefitted, for example, the sinonasal group more than the idiopathic group.

5 | CONCLUSION

The preliminary findings of this study suggest that odorant exposure exercises need not be restricted to smelling odorants from jars in the privacy of one's home for a minimum of 3 months. Both indoor and outdoor environments provide are with various odorants that can cocoon one's entire body, providing continuous opportunities to engage in olfactory exposure. However, the current results suggest that enhancement in olfactory function after short-term odorant exposure may be due to cognitive processes associated with conscious processing of odorants and memory. To further grow our knowledge in this area, replication and exploration of the parameters of effective OT are required.

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