Smell, taste and trigeminal function: similarities and differences between results from home tests and examinations in the clinic*

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Abstract

Background: This study aimed to examine an easy-to-conduct home chemosensory test as a screening tool prior to clinical testing and to investigate the associations between home and clinical tests.

Methods: We examined 200 participants who performed a chemosensory test including subjective ratings as well as psychophysical smell, taste and trigeminal function tests at their homes. Following that, they were invited to the clinic for standardized testing using the Sniffin' sticks test for assessment of olfactory function, taste sprays and strips for taste function, and a lateralization test for trigeminal function.

Results: The home smell test correlated well with the Sniffin' sticks test. The home test had acceptable sensitivity for detecting smell loss (sensitivity of 67% at a specificity of 92%). The home test could distinguish between patients with olfactory loss and healthy controls. In contrast, the home tests for taste and trigeminal function did not provide valid results. When comparing home and clinical smell and taste tests older age and olfactory loss were the most influencing confounders in various models, while participants who had olfactory loss and admitted to drink alcohol regularly were more likely to have consistency between home and clinical smell measurements.

Conclusions: Although the standardized psychophysical tests are valid and reliable and should be recommended, simple methods used at home could reflect the patients' information to some degree and provide useful data prior to clinical testing. The present home chemosensory test allows motivated individuals to screen their olfactory function in a simple way at home. Results from smell tests, but not from tests of taste or trigeminal function, obtained at home correlate with tests obtained at the clinic. Moreover, tests conducted at home or in the clinic have confounders that should be considered by researchers and clinicians.

Key words: chemosensory test, home, smell, taste

Introduction

Olfaction plays an important role in people's daily life, involving food intake, avoidance of environmental hazards, or social relationships [1–3]. In this context it is important to note that olfactory loss is frequent. Depending on definitions, the prevalence of hyposmia in the general population is approximately 20%, increasing with age [4,5]. This often goes unnoticed, especially when the loss occurs gradually [6-8].

Olfactory loss associates closely with cognitive decline [9], psychiatric disorders (e.g., schizophrenia, major depressive disorder [10,11]) and neurodegenerative disorders [12]. Hence, it appears to be a potential early diagnostic marker for Alzheimer's disease [13]. Further, as a main symptom of COVID-19 [14], olfactory loss received plenty of attention.

Recent studies showed that very simple, rapid tests may be able to identify individuals with olfactory loss [15]. For example, after receiving the test via mail, participants could conveniently screen their olfactory function by themselves at home. In com-

parison to standardized smell tests, such simple screening tools seem to be an option for those who want to test themselves at home. Still, people who live in remote areas may face logistical difficulties and delays with the delivery of the test [16].
Self-ratings of olfactory function are also frequently used in research and in clinical contexts. Numerous studies have shown that self-ratings often fail to correlate with the outcome of standardized psychophysical smell tests probably because the ratings are biased at various levels [5,17,18]. These biases include age, gender, pre-existing illness, or subjective expectations, for example in medico-legal cases [19].
Taken together there seems to be the need to understand the discordance between subjective ratings and psychophysical measurements of chemosensory function, as well as between measurements conducted at home and in the clinic because of their importance in the early detection of chemosensory dysfunction. The present study aimed to (i) examine an easy-to-conduct chemosensory test which allows participants to screen themselves using common odours they can find at their homes, and (ii) to investigate the potential reasons of discrepancies between home tests and tests in a supervised, clinical environment.

Materials and methods

Ethical statement

All participants took part in the study voluntarily and gave informed written consent. The study was approved by the Ethics committee at the Medical Faculty Carl Gustav Carus of the Technische Universität Dresden. All aspects of the study were executed according to the Declaration of Helsinki.

Participants

A total of 211 participants signed up for the test. For technical reasons we excluded 11 of them leaving 200 participants for analysis (mean age: 45.1±17.0 years, range 18.1-83.3 years; 82 men). Guided through instructions on the internet (https://s2survey.net/Selbsttest_RiechenSchmecken/; Password: Selbsttest; Supplement 1), they were asked to complete questionnaires and to conduct chemosensory tests for smell, taste, and trigeminal function. Following this they were invited to examinations and counseling at the Smell and Taste Clinic at the Department of Otorhinolaryngology of the TU Dresden. At the clinic, demographic information including a detailed medical history was collected using standardized questionnaires (20).
We divided participants into patients with olfactory and/or gustatory loss (n=109) and healthy controls (n=91) according to complaints about smell and/or taste function. The patients were looking for counseling at our clinic. This separation was made according to the clinical situation where patients are those who seek counseling because of a subjective impairment. For example, if a person has an excellent sense of smell and loses some of this function, on an individual level this may be perceived as a major impairment although objectively these people still score in the normal range. In contrast, people born with a relatively low olfactory sensitivity or individuals with a slow, gradual loss with aging may not be bothered by that so that they do not seek counseling, although they have very low olfactory test scores [18,21].
Inclusion criteria were: (i) an age of 18 years or older; (ii) voluntary participation in the study; (iii) ability to give consent; (iv) for the healthy controls: a subjective normal chemosensory sense of smell and taste; and (v) for the patients: a subjective impairment of the sense of smell and/or taste. Exclusion criteria were: (i) severe diseases which can impact olfactory function (e.g., Parkinson's disease, renal failure), and (ii) for the healthy controls: acute or chronic inflammation of the nose.

Home tests

We asked participants to rate their ability to smell, taste and breathe through their nose using 1-10 numerical scales (from 1 = no such ability to 10 = extremely good ability). As for the smell test, we suggested 5 possible fragrance sources (coffee, honey, soap, wine or detergent). Participants then chose 4 of them according to availability at their homes. In addition, this regimen allowed them to exclude one odour in case they had an intolerance or allergy to the fragrance source. After placing a small amount of each source into a glass and blindfolding themselves, a second person was needed to hold the 4 glasses with the samples in front of the participants' nose one after the other in random order. Participants answered the questions "Do you smell anything?" and "Do you recognize the odour?" asked by the second person administering the odours. Only after the fourth odour the blindfold was removed and they received feedback on the correctness of their responses. The requested interval between presentation of each of the 4 odour samples was at least 1 minute to minimize adaptation. Taste testing at home was similar to the smell test. The odours were replaced with foods (suggestions were lemon, lime or grapefruit [for sour], coffee or tea [for bitter], sugar or honey [for sweet] and salt [for salty]). Each positive answer scored 1 point and the highest score was 8 for each sensory modality. The higher the score, the better the olfactory or gustatory function. Trigeminal function of the participants was assessed whether they perceived sensations of cooling, sharpness and / or irritation in their nose while sniffing vinegar or hot mustard. This provided a yes/no response.

Clinic tests

Self-rating

In the clinic participants rated their ability of smelling, tasting and nasal breathing from 1 (not at all) to 10 (extremely good) using a numerical scale. Mood state was rated by 5-item versions of WHO Well-being scales [22]. The highest score was 25 and sco-

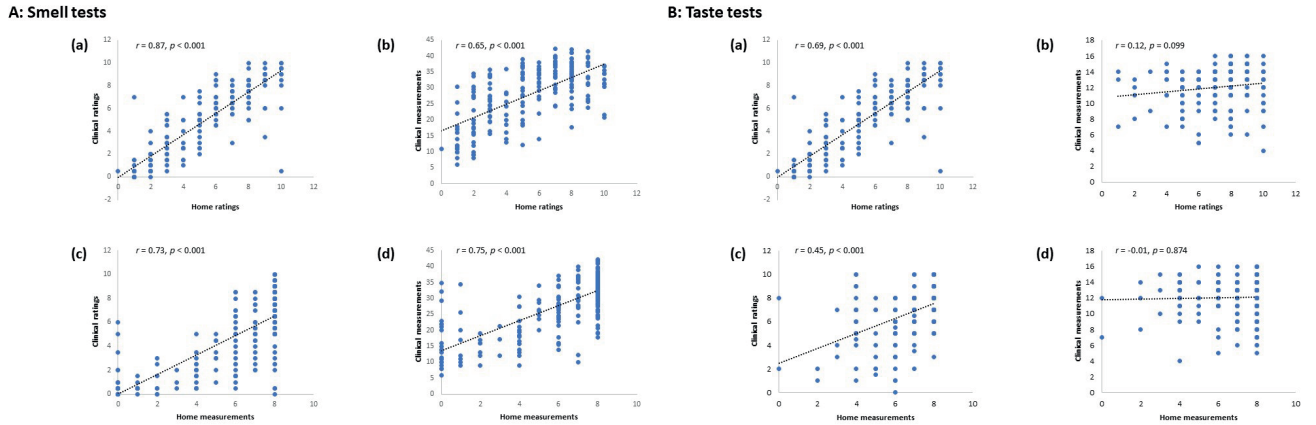

Figure 1. Correlation between smell and taste tests conducted at home and in the clinic. Note: Figure A is for the smell test, all correlations between the home and clinical smell test were significant; Figure B is for the taste test, significant relationships were only found between home vs. clinical ratings and home measurements vs. clinical ratings.

res below 12 indicate the presence of depression.

Smell measurement: Sniffin' Sticks test

We utilized the Sniffin' Sticks test (SST) based on pen-like odour dispensing devices to measure olfactory function of participants [23]. SST is a reusable olfactory test, including three sub-tests: odour identification, threshold, and discrimination.

The odour identification test contains a total of 16 common odours. During the test, the examiner removes the cap and places the pen tip about 2 cm below the participants' nose to release the corresponding odour. If necessary, they can sniff multiple times to make a choice. Each stick is presented by the examiner with an interval of at least 30 seconds to prevent olfactory desensitization. Each correct recognition of the odour represents 1 point, with the highest identification score as 16.

The odour threshold test is comprised of 48 pens using a triple-forced-choice paradigm. During the test, 3 pens are a group, 2 of which contain propylene glycol, and the other pen contains diluted n-butanol. Participants need to select the odourant containing n-butanol. The score of the odour threshold test was calculated using a single staircase procedure, with two successful detections or a false one triggering a reversal of the staircase. The maximum score of the threshold test is also 16, using the mean value of the last 4 staircase reversal points (7 reversals in total) to estimate. The odour discrimination test contains a total of 48 probes. Again, 3 odours are presented with a 3-alternative forced choice task. Two of the pens have the same odour and one smells differently. Participants are asked to identify the different one, with each correct answer representing 1 point.

The scores from the 3 subtests are summated to a Threshold-Discrimination-Identification (TDI) score ranging from 1 to 48. Higher TDI scores represent better olfactory function. Normosmia was defined as TDI score above 31 points.

Taste measurements: Taste strips and spray test

Participants conducted two supra-threshold gustatory measurements, taste strips and taste sprays [24,25]. Taste strips include 16 filter papers impregnated with 4 different concentrations of the following 4 tastants: sucrose (sweet); citric acid (sour); sodium chloride (salty) and quinine hydrochloride (bitter). We chose the whole mouth test which reflects better general taste sensitivity compared with lateralized test [24]. After putting one strip onto the participates' tongue by the experimenter, they closed their mouth and were allowed to suck the strip, then they were forced to identify the taste from 4 possible options mentioned above. Rinsing the mouth by water was required after each strip. Hypogeusia was considered if the score was below the 10th percentile of healthy, young participants; a score of 8 and less.

The four taste sprays contained tastants dissolved in water (sweet: 10 g D-saccharose; sour, 5 g citric acid; salty, 7.5 g NaCl; and bitter, 0.025 g quinine hydro-chloride; all diluted in 100ml water). Similar to the taste strips test, participants received the spray on their tongue, closed their mouth slowly then identified the taste. Each spray was applied up to 3 times and rinsing of the mouth between each of the tastes was offered to the participants.

Trigeminal measurement

We quantified participants' trigeminal function using a lateralization task [26,27]. Two high-density polyethylene squeeze bottles (total volume 250 ml) form the device, with one bottle containing 30 ml odourant (e.g., pure eucalyptol (Sigma-Aldrich Co., St. Louis, MO, USA, C80601-500ML)) and the other containing 30ml odourless water. During the test, the experimenter blindfolded the participants. The spouts of the two polyethylene bottles were covered with disposable soft silicon tubing and participants held on to them preventing movements with the spouts reaching approximately 0.5 cm inside their nostrils. While asking

Table 1. Comparison of home and clinical tests between patients and controls.

	Patients (n=109)	Controls (n=91)	df	T/χ^2	p
Age (years)	**46.03±16.65**	**44.05±17.47**	**198**	**0.82**	**0.41**
Gender (female: male)	**63:46**	**55:36**	**1**	**0.14**	**0.71**
Home tests					
Smell self-rating	3.51±2.25	7.52±1.59	198	-14.22	<0.001
Taste self-rating	6.51±2.20	7.93±1.37	198	-5.34	<0.001
Smell measurement	4.77±2.74	7.71±0.66	198	-10.01	<0.001
Taste measurement	5.91±1.71	7.73±0.67	198	-9.53	<0.001
Nasal self-rating	6.70±2.03	6.92±1.90	198	0.18	0.86
Trigeminal measurement (R: U)	76:32	75:16	1	3.92	0.048
Clinic tests					
Smell self-rating	3.03±2.54	7.19±1.70	195	-13.23	<0.001
Taste self-rating	5.75±2.37	7.88±1.26	185	-7.55	<0.001
TDI	22.55±8.39	33.93±4.62	198	-11.56	<0.001
Taste spray	3.84±0.51	3.96±0.21	145	-2.10	0.037
Test strips	12.12±2.50	12.04±2.51	186	0.22	0.83
Nasal self-rating	6.70±2.03	6.92±1.90	195	-0.77	0.45
Trigeminal measurement	15.85±3.79	15.59±4.03	183	0.45	0.65

R = Number of participants who received trigeminal stimulus, U = Number of participants who did not receive trigeminal stimulus; TDI = Total score of Sniffin' sticks test.

the participants to breathe in, the experimenter gently squeezed the device releasing 12 ml of odourized air from each bottle simultaneously. Participants identified the bottle containing the odourant. Stimuli were presented 20 times in a pseudo-randomized order to the left and right nostril, with an interval of at least 30 seconds. The score was the number of correctly identified stimulus presentations.

Data analysis

SPSS v 27.0 (IBM, Armonk, NY, USA) was conducted to analyze the data. We used the Pearson correlation analysis, sensitivity and specificity analysis between the home and clinical tests to validate it. Meanwhile, we compared both smell and taste tests completed at home and in the clinic between patients and control group by Independent T test. We also divided participants into a "consistent group" (CONS) and a "discrepancy group" (DISCR) based on the distribution of scores (|Participants' real scores of test 1 / maximum score of test 1 - Participants' real scores of test 2 / maximum score of test 2| * 100%). Participants scoring under the 25th percentile were attributed to the CONS group while those above the 25th percentile were labeled as DISCR group. Binary Logistic Regression Analysis was utilized to investigate the possible reasons (according to previous studies [19,28], as well as the significant difference in single factor analysis, confounding factors might be age, gender, smoking, alcohol abuse, pre-exiting illness, subjective olfactory loss and so on) why participants had a discrepant performance with high scores on the home test and low scores on clinical tests, or vice versa. $P < 0.05$ denoted significance.

Results

Validation of the home test

Smell test

Coffee (96%) was the most popular item in home-test, followed by honey (94%), detergent (91%), soap (82.5%) and wine (76.5%). Results from the smell part of the home test exhibited a good relationship with clinical assessment (home and clinical ratings: $r = 0.87$; home ratings and clinical measurements: $r = 0.65$; home measurements and clinical ratings: $r = 0.73$; home and clinical measurements: $r = 0.75$, clinical ratings and measurements: $r = 0.72$, all $p < 0.001$, Figure 1). Compared with controls, patients had lower scores on smell self-ratings and measurements both at home and in the clinic (home: ratings: $t[198]=14.22$; measurement: $t[198]=10.01$; clinic: ratings: $t[195]=13.23$; TDI: $t[198]=11.56$; all $p < 0.001$, Table 1). People with olfactory loss were identified at the score of 7 points and lower in the home smell test at a sensitivity of 67% and specificity of 92%.

Taste test

Taste ratings in the clinic correlated closely with ratings and measurements at home (home and clinical ratings: $r = 0.69$, $p < 0.001$; home measurements and clinical ratings: $r = 0.45$, $p <$

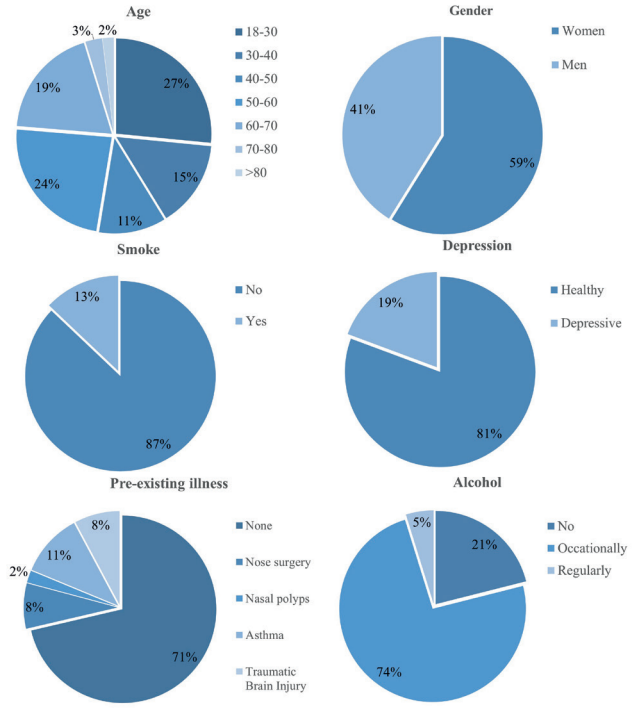

Figure 2. The distribution of each possible predictor.

0.001). However, no significant correlation was found for taste measurements (both with taste spray and strips) between home and clinical tests (all $p > 0.05$). Compared with controls, lower scores were found in patients in taste ratings and measurements conducted at home (rating: t [198]=5.34; measurement: t [198]=9.53, all $p < 0.001$) and also in the clinic (rating: t [185]=7.55, $p < 0.001$; taste spray: t [145]=2.10; p =0.037), while no difference was found in taste strips between patients and controls ($p > 0.05$). People with gustatory dysfunction were identified at the score of 7 points and less in the home taste test at a sensitivity of 25% and specificity of 66%.

Trigeminal test

Rating of nasal patency at home showed a good relationship with clinical ratings ($r = 0.69$, $p < 0.001$), while no significant correlation was found between trigeminal measurements at home and clinical trigeminal measurements ($p > 0.05$). A higher percentage of patients reported that they did not receive trigeminal stimuli in their home trigeminal test ($\chi^2 = 3.92$; $p = 0.048$). No differences were found between patients and controls in home and clinical trigeminal tests (all $p > 0.05$). As for sensitivity, we divided participants into two groups and scores above the mean score of 16 indicated good trigeminal function. We found that bad trigeminal function was identified in the home trigeminal test reporting not perceived trigeminal irritation at a sensitivity of 22% and specificity of 74%.

Potential reasons of discordance between home and clinical tests

The distribution of the selected covariates is presented in Figure 2. For both smell and taste functions, we compared home and clinical self-ratings and measurements using binary logistic regression analysis. As for smell, results of comparison between home ratings and clinical measurements showed that patients with olfactory loss had a trend to be more likely to have discrepant olfactory performance (Omnibus $\chi^2 = 3.94$, $p = 0.047$; odds ratio [OR], 1.92; 95% confidence interval [CI], 0.99-3.69; Table 2). When comparing home and clinical smell measurements, participants whose age was between 60-70 years were more likely to have discrepant results (Omnibus $\chi^2 = 15.83$, $p = 0.070$; OR, 2.95; 95% CI, 1.20-7.27), while those with olfactory loss and those who self-reported to drink alcohol regularly were less likely to have discrepant results (Olfactory loss: OR, 0.54; 95% CI, 0.29-0.99; admittance of regular alcohol intake: OR, 0.14; 95% CI, 0.03-0.82). Similarly, patients with olfactory loss were more likely to show discrepancies between home measurements and clinical ratings in smell (Omnibus $\chi^2 = 4.80$, $p = 0.028$; OR, 1.88; 95% CI, 1.07-3.33). No significant covariates were found in the binary logistic regression analysis between home and clinical smell ratings. When comparing home and clinical ratings for taste function, patients with olfactory loss and participants who had a history of traumatic brain injury were more likely to have a discrepancy (Omnibus$\chi^2 = 21.88$, $p = 0.001$; Olfactory loss: OR, 8.16; 95% CI, 1.75-37.99; Traumatic brain injury history: OR, 3.77; 95% CI, 0.97-14.73). Similarly, patients with olfactory loss, and participants with older age were more likely to have a discrepancy between home rating and taste strips measurements (Omnibus $\chi^2 = 24.33$, $p = 0.002$; Olfactory loss: OR, 2.82; 95% CI, 1.29-6.16; Age between 60- and 70-years: OR, 2.67; 95% CI, 0.96-7.46; Age between 70- and 80-years: OR, 8.186; 95% CI ,1.02-54.77). Participants whose age was between 60 and 70 years, who were male and who had asthma were more likely to show a discrepancy between home measurement and taste strips measurement (Omnibus $\chi^2 = 21.16$, $p = 0.026$; Age: OR, 3.35; 95% CI, 1.20-9.37; Gender: OR, 1.98; 95% CI, 0.95-4.11; Asthma history: OR, 2.85; 95% CI, 1.01-4.79). Patients with olfactory loss were more likely to show a discrepancy between home measurement and clinical rating for taste function (Omnibus $\chi^2 = 18.43$, p =0.018; Olfactory loss: OR, 2.32; 95% CI, 1.1-4.79).

Discussion

This study aimed to examine a chemosensory home test including subtests for smell, taste and trigeminal function, and then to explore the similarities and differences between results from home and clinical tests. We found that (i) both smell and taste home self-ratings had good relationships with clinical self-ratings and measurements, and the smell measurement of the

Table 2. Binary Logistic regression analysis of predictors of discordance between home and clinical tests.

	Model	Predictors	B	OR	95% CI	Wald	p
Smell:	Home self-rating vs. clinical measurement	Olfactory dysfunction	0.65	1.92	[0.99, 3.69]	3.81	0.051
	Home vs. clinical measurement	Olfactory dysfunction	-0.62	0.54	[0.29,0.99]	3.86	0.050
		Age between 60-70	1.08	2.95	[1.20, 7.27]	5.55	0.019
		Regular alcohol drinking	-1.94	0.14	[0.03-0.82]	4.76	0.029
	Home measurement vs. clinical self-rating	Olfactory dysfunction	0.63	1.88	[1.07, 3.33]	4.74	0.029
Taste:	Home vs. clinical self-rating	Olfactory dysfunction	2.10	8.16	[1.75, 37.99]	7.16	0.007
		Traumatic brain injury history	1.33	3.77	[0.97, 14.73]	3.64	0.056
	Home self-rating vs. clinical measurement	Olfactory dysfunction	1.04	2.82	[1.29, 6.16]	6.77	0.009
		Age between 60-70	0.99	2.67	[0.96, 7.46]	3.51	0.061
		Age between 70-80	2.10	8.19	[1.02, 54.77]	4.70	0.030
	Home vs. clinical measurement	Age between 60-70	1.21	3.35	[1.20, 9.37]	5.30	0.021
		Male gender	0.68	1.98	[0.95, 4.11]	3.35	0.067
		Asthma	1.05	2.85	[1.01, 8.05]	3.92	0.048
	Home measurement vs. clinical self-rating	Olfactory dysfunction	0.84	2.32	[1.12, 4.79]	5.17	0.023

OR = Odds Ratio; 95% CI = Confidence Interval.

home test correlated closely with the TDI score as well. (ii) Home tests could distinguish patients with olfactory loss from healthy controls. (iii) Subjective olfactory loss and older age were the most important confounders of the consistency between rated and measured smell function in home vs. clinical smell tests, while participants admitting to drink alcohol regularly and those with subjective olfactory loss were less likely to exhibit a discrepancy between psychophysical home and clinical smell tests. In contrast, pre-existing illness, subjective olfactory loss and male gender could be risk factors for the occurrence of a discrepancy between home and clinical taste tests.

The present chemosensory home test showed a good validity correlating with standard clinical tests [23], especially the home smell test. Unlike other home tests [15], the present one includes fragrant sources that are cheap and convenient to find in daily life, which allows people to screen themselves for olfactory function whenever they want, with valid results. Nevertheless, it has to be noted that taste measurements at home and trigeminal home tests were not correlated with the clinical tests. Previous studies suggested that rated function and psychophysical test results do not always correlate [29,30]. A possible explanation is that people's perception of taste is confounded by retronasal olfaction which increases the difficulty for testing themselves at home [31].

In line with previous studies [32,33], the huge difference presented between patients with olfactory loss and healthy controls on both smell and taste self-ratings and measurements, as well as home trigeminal measurement, indicates the possibility of the clinical usage of the present home screening test. The present home smell test is able to predict olfactory loss with a sensitivity of 67% and a specificity of 92% when using the cutoff point of 7, suggesting that the home smell test can be used to screen olfactory function [7,19,34]. Because olfactory function can decline gradually, those scoring under 7 in the home smell measurement should be cautious about the subjective impression of a normal olfactory function and seek clinical counseling if necessary. In contrast, the presently used taste (sensitivity of 25%, specificity of 66%) and trigeminal home tests (sensitivity of 22%, specificity of 74%) have limited functionality to screen chemosensory function. As for home taste measurement, patients had significantly worse performance than controls. Similarly, compared to controls there were more patients who did not perceive trigeminal stimuli. These results in some degree support the methods at home are efficient and reliable in spite of relative low sensitivity and specificity compared with validated clinical tests of taste and trigeminal function [25,27], suggesting that additional tests need to be developed and validated for these chemosensory aspects.

Subjective olfactory loss predicted the discordance between smell self-rating and measurement. Consistently with previous studies, the performance of subjective smell ratings does not always relate to psychophysical measurements [5,19]. Our results extend this thought to the point that people who subjectively believed their olfactory function was impaired were more likely to show a discrepancy between ratings and measurements, no matter whether the test was conducted at home or in the clinic. Between psychophysical home and clinical smell measurements, those between 60- and 70-years of age were more likely to perform adversely. The typically lower cognitive function of older individuals might confound the performance in home

tests because it aggravates the understanding of instructions and the execution of the test according to given instructions [35]. In contrast, in a clinical environment there are always professionals present to supervise the procedure, answer questions and correct possible mistakes.

It is interesting that people who admitted to drinking alcohol regularly and those who subjectively believed themselves having olfactory loss could perform more consistently between home and clinical smell measurements, with marginal significance of this model. Under the assumption that the majority of people in Germany drink alcohol regularly [36], those who admit doing so seem to be more straightforward and therefore are able to perform more consistently in the psychophysical home and clinical smell test. On the other hand, psychophysical smell test has more sensitivity to detect olfactory loss compared with subjective ratings [32,33], that might be the reason that patients with olfactory loss showed consistency between home and clinical psychophysical smell measurement.

We also found that olfactory loss, history of pre-existing illness such as traumatic brain injury and asthma, older age and male gender were risk factors for more discrepant results between home and clinical taste tests. In line with previous study, although patients with olfactory loss complained about their taste loss, taste function was intact. This is probably due to the common flavor-taste confusion [31]. All confounders mentioned above predispose to olfactory loss which results in loss of flavor perception which may have become obvious when performing the screening test. In turn this might have biased the taste self-ratings.

The present study has several limitations. Firstly, it was designed as a cross-section study and cannot be used to infer the cause of olfactory and gustatory dysfunction and their related factors. Secondly, since participants completed the home test on their own, there is a possibility of existing recall and reporting bias and the inaccuracies due to different products used and varying concentrations of the fragrance sources. The instructions for the home taste measurement did not specify in which way the foods should be presented (e.g., dissolved in water). Different textures and amounts of the foods used could have helped identify them and therefore biased the results, which could be considered in future studies. In addition, people in different countries might not have the same ingredients in their houses, future researches are recommended to adapt different versions of the home tests for other regions of the world due to varying availabilities of fragrant sources. Finally, there might have been a certain sample bias because only a certain group of patients might feel drawn to perform chemosensory tests at home which might have worked in favor of the relatively good correlation between home and clinical smell tests.

Conclusion

We examined a quick and easy-to-conduct home screening test for smell, taste and trigeminal functions. It seems that people can utilize this home test to screen their olfactory function quickly and effectively. Because the test proved to be suitable for the detection of olfactory dysfunction, it can be used as a screening tool prior to clinical testing. Importantly, in the investigated cohort the home test does not produce valid results for the quantification of gustatory and trigeminal functions. Hence, additional tests would have to be developed and validated for these chemosensory aspects. In combination with a structured history and physical examination, validated and reliable clinical chemosensory tests are no doubt the best choice for diagnostics which is important for an estimate of the prognosis and follow-up during the course of the disorder. However, these tests can be complex and time-consuming. We recommend the simple and quick home smell test which, when conducted by motivated and diligent individuals, should support people to make the decision for seeking clinical support.

Concerning discrepancies between results from home and clinical tests, olfactory loss and older age are important confounders, both in smell and taste testing. Interestingly, the self-awareness of olfactory loss and the willingness to admit the regular intake of alcohol are "protective" factors in terms of a coherent performance between home and clinical smell measurements. To some degree, these factors probably reflect the motivation and honesty of individuals to properly perform the home tests. Our findings suggest that results of subjective and psychophysical tests conducted at home or in the clinic have mixed confounders.

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Authorship contribution

ZL analyzed, interpreted the data, and wrote the manuscript; SS ran the study, interpreted the data, and wrote the manuscript; JD designed the online questionnaire for self-testing and wrote the manuscript; TH and AH designed and ran the study, analyzed and interpreted the data, and wrote the manuscript. All authors critically reviewed the manuscript before submission.

Conflict of interest

The authors declare no competing financial interests.

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This manuscript contains online supplementary material

SUPPLEMENTARY MATERIAL

Please rate your ability to smell and taste (sweet, sour, salty, bitter).

	none									extreme good
	1	2	3	4	5	6	7	8	9	10
Smell	○	○	○	○	○	○	○	○	○	○
Taste (sweet, sour, salty, bitter)	○	○	○	○	○	○	○	○	○	○

Please rate your nasal breathing.

	none									extreme good
	1	2	3	4	5	6	7	8	9	10
nasal breathing	○	○	○	○	○	○	○	○	○	○

Welcome to the smell test!

Note: If you have an intolerance or allergy to one or more of the following fragrance sources, please use another one from the list below or skip one fragrance source.

Please be prepared to:

· 4 of the following fragrance sources:

- Coffee

- Honey

- Soap

- Wine

- Detergent

- Vinegar or mustard
- Blindfold (e.g., a scarf)
- 5 glasses/bowls
- a second person to help you

Now it's time to get started!

Select 4 fragrance sources and fill some of them into a glass (see below).

Now please blindfold yourself.

Now ask a second person to hold the 4 glasses with the fragrance sources one after the other in front of your nose. Please wait at least 1 minute between the glasses.

Your answers will be noted by the examiner, but will not be commented on. Only after the fourth fragrance is the blindfold loosened and correct or false results announced.

Please read the instructions for each question.

Do you smell anything?

The fragrance sources in the glass are now held under your nose by a second person in random order. The order does not have to match the one below.

You should now indicate whether you smell something or not. The fragrance source that is not tested with, just leave unanswered.

	something smelled	nothing smelled
Coffee	○	○
Wine	○	○

Detergent	○	○
Honey	○	○
Soap	○	○

Do you recognize the fragrance source?

If you have smelled something in the question before, which of the 4 possible fragrances is it each?

The order of the scents should be chosen by the second person exactly as in the question before. It does not have to match the order below.

	recognized correctly	recognized incorrectly
Coffee	○	○
Wine	○	○
Detergent	○	○
Honey	○	○
Soap	○	○

Do you receive sharpness, irritation or cold in your nose from vinegar or mustard?

Please sniff vinegar or mustard. You should now indicate whether you perceive coldness, sharpness and/or irritation in your nose when sniffing.

Note: Please do not use balsamic, raspberry vinegar or sweet mustard.

	Yes	No
Cold, irritation and/or sharpness perceived?	○	○

Welcome to the taste test!

If you have an intolerance or allergy to one or more of the following foods, please use another one from the list below or skip one food.

Please be prepared to:

· 4 of the following foods (one from each line):

- Lemon, lime or grapefruit

- Coffee or tea powder (from a can or from a tea bag)

- Sugar or honey

- Salt

· Blindfold (e.B. a scarf)

· 4 (small) spoons

· 1 glass of water

· a second person to help you

Now it's time to get started!

Select 4 foods from the list. It is important that there is one from each line. Now please blindfold yourself.

Now ask a second person to give you the food on a (small) spoon one after the other. Please wait at least 1 minute between foods and drink a little water to neutralize the taste in the mouth.

Your answers will be noted by the second person, but not commented. Only after the fourth food, the blindfold is loosened and correct or false results are announced.

Please read the instructions for each question.

Do you taste anything?

The food on the spoon will now be handed to you by a second person in random order. The order does not have to match the one below.

You should now indicate whether you taste something or not. Please drink a little water after each spoon to neutralize the taste.

	something tasted	nothing tasted
Lemon/lime or grapefruit	○	○
Coffee or tea	○	○
Sugar or honey	○	○
Salt	○	○

Do you recognize the taste?

If you have tasted something in the question before, which of the 4 possible foods is it each?

The order of the food should be chosen exactly as in the question before. It does not have to match the order below. Please drink a little water after each spoon to neutralize the taste.

	recognized correctly	recognized incorrectly
Lemon/lime or grapefruit	○	○
Coffee or tea	○	○
Sugar or honey	○	○
Salt	○	○