
Olfactory Ability in the Healthy Population: Reassessing Presbyosmia

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Abstract

Age-associated loss of olfactory function, or presbyosmia, has been described in many studies of olfactory ability. Presbyosmia has been ascribed to idiopathic causes despite recognition that many neurodegenerative diseases also induce loss of olfactory function and increase in incidence in the aged population. Often this olfactory loss is unnoticed or unreported by affected individuals. More effective olfactory function in women compared with men is another common feature of many studies of olfactory function. Here we report on normative data from an Australian population study ($n = 942$) that has been divided into 2 sub-populations and reassessed as (included) a population of healthy, nonmedicated, nonsmokers with no history of nasal problems ($n = 485$) and (excluded) a population of participants who were either medicated, smokers or had a history of nasal problems ($n = 457$). The “included” data set shows a strong relationship between self-reporting of olfactory sensitivity and olfactory function score. The included data set shows a small but significant decline in olfactory ability after 65 years of age and better olfactory function in females compared with males. Data from the excluded population show a marked decline in olfactory ability after 65 years of age, no difference between males and females, and a weak relationship between self-reporting of olfactory function and actual olfactory function. The power of this approach is that it provides a normative data set against which many factors such as medication schedules and pathological conditions can be compared.

Key words: aging, gender, human olfaction, self-assessment of smell, smell test

Introduction

The gradual, idiopathic, decrease in sensory function as humans age has been described in many studies and in many contexts (Nusbaum 1999). Significantly reduced sensory sensitivity, even ability, is considered by many to be a normal consequence of aging. This decrease in sensory function seems to occur irrespective of the sensory system under examination. In 1984, Doty described an age-related loss of olfactory function based on a large-scale population study in the United States (Doty et al. 1984). In that he described a peak of olfactory function in the third and fourth decades of life and a subsequent gradual, monotonic decline in olfactory function. In the same paper, he recognized that “despite the likelihood of different physiological bases for these changes, the quality of suprathreshold sensory perception diminishes similarly in these 3 (vision, audition, and olfaction) senses in the later years,” while also recognizing that olfactory ability is extremely vulnerable to environmental insult and neurodegenerative change. Since this seminal work,

increasing numbers of studies have recognized decreased olfactory function as a key diagnostic feature in, even representative of, a number of neurodegenerative disorders, most particularly Parkinson’s Disease (Hawkes et al. 1997; Kovacs 2004).

Parkinson’s disease is thought to be the second most common neurodegenerative disease, after Alzheimer’s disease, affecting 2% of the population over 60 years (Gasser 2005). Alzheimer’s disease affects about 3% of Australians aged 65–74 years, about 19% of those aged between 75 and 84 years, and 47% of those over 85 years (McCusker Foundation for Alzheimer’s Disease Research, 2005). This is critical because, like Parkinson’s disease, Alzheimer’s disease is also known to reduce olfactory function (Doty 1991). There is some evidence which suggests that, in both of these diseases, olfactory deficit is associated with abnormalities in olfactory processing apparatus including olfactory epithelium, olfactory bulb, and olfactory cortices

(Christen-Zaech et al. 2003; Kovacs 2004). Many studies of olfactory function have described apparently age-related declines in olfactory function but rarely is the health status of the participants considered (Murphy et al. 2002). Moreover, regular administration of some very common pharmaceutical agents, such as antihypertensive and antihyperlipidemic medications, is also known to significantly reduce olfactory ability (Doty et al. 2003). The potential contribution to normative values from persons with disease- or medication-reduced olfactory function seems apparent (even embedded) in published data and is indicated by the data spread (represented by interquartile range or standard deviation) associated each successive decade (Doty et al. 1984; Murphy et al. 2002; Mackay-Sim et al. 2004). The aim of the present study was to investigate whether the age-related decrease in olfactory function in a population can be partly attributed to underlying age-related health problems rather than idiopathic changes in healthy subjects.

Superior performance by women, of all ages, is another common feature of many studies of olfactory function (Doty et al. 1985; Choudhury et al. 2003). However, there is a relationship between age and incidence of neurodegenerative conditions such as Alzheimer's disease in women and men (Gatz et al. 2003; Barnes et al. 2005). Moreover, women are often more represented in the older age groups in population studies of olfactory function, suggesting that they may contribute disproportionately to the study findings (see Murphy et al. 2002). Thus, we were also interested in how healthy women of various ages might compare with healthy male counterparts.

The study examined in detail the various elements of a normal test battery for olfactory function, comparing scores achieved for olfactory threshold, olfactory discrimination, and olfactory identification to examine interrelationships between these kinds of olfactory capability (Hummel et al. 1997; Kobal et al. 2000). The power of a large data set is that it enables such interrelationships to be examined as potential predictors for reduced or abbreviated olfactory tests of use to a clinician.

Finally, we were also interested in self-reporting of olfactory ability in various age and gender groups. Self-assessment of olfactory ability has generally been shown to be unreliable and poorer in women than in men (Murphy et al. 2002; Nordin et al. 2004). Thus, we included a self-reported assessment of sensitivity in our study.

Materials and methods

Data to be reinterrogated were taken from the database of Australian norms (Mackay-Sim et al. 2004); participants recruited in Brisbane and Melbourne, Australia. On the basis of a questionnaire (previously unreported) associated with that study, the data on olfactory function from the original study population were divided into subpopulations according to factors that, a priori, might reasonably be expected

to alter olfactory ability, such as medication (MED; listed in Table 1), history of nasal problem (nasal problem; NP), and smoking (SMOK) status. An abbreviated version of the questionnaire showing the questions associated with the "inclusion/exclusion" criteria and the olfactory self-assessment is shown in Table 2. It should be noted that use of medication is, for the purposes of this study, simply a proxy marker for some other (nonnasal) underlying pathology. This study opted to take a very conservative approach to exclusion criteria, such that if participants described themselves as receiving any medication at all, they were excluded from the "healthy" (included) data set. Some kinds of medication history reported by participants are shown in Table 1. Although some of these medications do not, of themselves, indicate "ill-health" (e.g., the contraceptive pill) they do indicate repeated use of chemical substances that may alter inherent olfactory ability. Equally conservative inclusion criteria were applied to histories of smoking or nasal problems. Irrespective of the frequency or recency of smoking behavior/nasal problems, participants who reported some incidence of either were excluded. This conservative approach was taken to ensure that data were truly representative of olfactory function in healthy people.

Thus, data were allocated into an "included" group of participants (healthy, no existing history of neurological condition; nonsmoking, nonmedicated volunteers, with no

Table 1 Medications reported by participants

Class	Specific drugs (where provided*)
Antihyperlipidemic drugs	Atorvastatin calcium, Simvastatin (lipex and zocor)
NSAIDs	Celecoxib
Antianginals	Nifedipine (adefin, adalat)
Antihypertensive drugs	Beta blockers including propanolol, angiotensin converting enzyme inhibitors including captopril
Anticoagulants	Warfarin, aspirin
Hormone-replacement therapy	Hiprex
Diuretics	Frusemide, amiloride
Oral contraceptives	Estrogens
Insulin	
Antidiabetics	Biguanides, sulfonylureas
Ventolin	
Thyroxine sodium (T4), thyroxin	
Antidepressants	Citalopram, sertraline, chlorpromazine, fluoxetine
Gastric Ulcer medication	omeprazoles
Gastro-intestinal agents	Tegaserod, mesalazine, sulfasalazine

*Specific drugs were not always noted by the participants (e.g., participants stated medication use as "blood pressure medication").

Table 2 Abbreviated participant history form

Smoker: (please tick)	No <input type="checkbox"/>	Yes <input type="checkbox"/>	If yes, have you smoked within the last 15 mins?	No <input type="checkbox"/>	Yes <input type="checkbox"/>
Handed: (please tick)	Left <input type="checkbox"/>	Right <input type="checkbox"/>			
Sex: (please tick)	Male <input type="checkbox"/>	Female <input type="checkbox"/>			
Do you suffer from any of the following conditions? (please tick) No <input type="checkbox"/> Yes <input type="checkbox"/>					
Epilepsy <input type="checkbox"/>	Acute Asthma <input type="checkbox"/>			Hayfever <input type="checkbox"/>	
Influenza <input type="checkbox"/>	Upper respiratory tract disease <input type="checkbox"/>			Common cold <input type="checkbox"/>	
Other: <input type="checkbox"/>	Please specify:				
How do you consider your sense of smell in relation to others? (please tick)					
Less sensitive <input type="checkbox"/>	Normal <input type="checkbox"/>			More sensitive <input type="checkbox"/>	
How do you normally breath?					
Through nose <input type="checkbox"/>	Through mouth <input type="checkbox"/>				
Are you currently taking any medications (including the contraceptive pill)? (please tick)				No <input type="checkbox"/>	Yes <input type="checkbox"/>
Please provide details					
Do you suffer from any neurological disorders? That is, Parkinson's, Alzheimer's, etc. (please tick).				No <input type="checkbox"/>	Yes <input type="checkbox"/>
Please provide details					
Do you have a history of respiratory or nasal problems (e.g., asthma, colds, coughs, sinusitis)? (please tick)				No <input type="checkbox"/>	Yes <input type="checkbox"/>
If so, please provide further information, including frequency and how recently					

reported history of a nasal problem) to provide a data set of olfactory function that is not influenced by factors such as regular drug use, existing medical conditions, or smoking behavior. Comparison data were drawn from the remainder of the original study population, again, on the basis of response to questionnaires. Included women ($n = 202$) and men ($n = 283$) and “excluded” women ($n = 267$) and men ($n = 190$) aged across the first to eighth decade of life were tested for olfactory function with the approval of the University Ethics Committee and in accordance with the guidelines of the National Health and Medical Research Council of Australia. As noted above, all participants completed a self-assessment questionnaire on the test day, covering areas such as their perceived sense of smell and taste, their age, gender, smoking habits, and general health on the day of testing (see Table 2). Potential subjects reporting symptoms of an upper respiratory tract infection on the test day had been excluded from the study.

Olfactory function tests

Sniffin' Sticks

The Sniffin' Sticks olfactory function tests (Burghardt, Wedel, Germany) require presentation of odorants from the tips of specialized felt-tipped pens. During testing, the experimenter removes the lid of the pen and positions the pen tip centrally

and about 2 cm in front of the participant's nose for 3 s, taking care not to touch the pen tip themselves or to touch the participant with the pen tip. A variety of liquid odorants or odorants dissolved in propylene glycol of known concentration are contained in the barrel of the pen (Kobal et al. 2000). Blind or distracter pens contain only the diluent. In all the tests performed at least 30 s elapsed between each presentation of the target odor to prevent olfactory adaptation.

The Sniffin' Sticks test is made up of 3 separate parts each of which examines a specific form of olfactory function. These tests directly assess odor threshold, odor discrimination, and odor identification. Test results can be examined individually or as summative totals (threshold, discrimination, identification, or total discrimination index [TDI]) in order to assess olfactory function (Hummel et al. 1997; Kobal et al. 2000).

Odor threshold is measured for *n*-butanol diluted in a 16 set geometric series in a propylene glycol, beginning at 4% *n*-butanol. Each dilution set is presented in turn, in triplets, with 2 pens containing only diluent. Participants are blindfolded, to prevent visual cues assisting during testing. Each pen from each triplet was then presented for sniffing. Following each sniff, participants were required to identify which one of the 3 pens in each triplet presented contained the odorant.

This test used a forced-choice ascending and then descending “staircase” methods so that “odor-pen” identification began with the pen triplet containing the lowest dilution

of the odorant and continued with pen triplets of increasing *n*-butanol concentration until the subject successfully identified the odorant-containing pen in 2 successive trials (ascending concentration). The process was then reversed (descending concentration) until the participant incorrectly identified the odorant-containing pen in one trial. Ascending and descending concentration identification trials were then repeated successively, each until the participant made an incorrect choice, for a total of 7 trials (7 reversal trials). The threshold is calculated as the average concentration of the last 4 reversal points (incorrect selections). This enables each participant to be assigned a score out of 16, indicating the concentration level associated with that person's olfactory detection threshold.

Odor discrimination was identified using a forced-choice triangle test with 16 sets of odorant pen triplets. Each participant was presented with each pen from an odorant triplet, again bilaterally for around 3 s, asked to sniff the pen and then required to identify the pen in that triplet containing a different odor. Again, participants were blindfolded prior to the test to ensure visual cues did not alter participant responses. The number of correctly discriminated odors for each participant is recorded and converted into a score out of 16. The odors included in this test included: butanol, isoamylacetate, anethole, limonene, carvone, eugenol, dihydro rosenoxide, acetaldehyde, citronellal, pyridine, eucalyptol, dipyrityl, and octylacetate in various mixed pairs (<http://www.burghart.net/medizintechnik/index.php>).

The odor identification test uses 16 individual pens, each of which contained a different odorant. Each participant is presented with a single pen-odorant, asked to sniff the pen, and then asked to select, in a multiple-choice test-like procedure, one word from a selection of 4 that best describes the odor. Each participant gain a score out of 16, 1 point for each correctly identified odor. The odors in this test included pineapple, banana, apple, cinnamon, leather, lemon, orange, licorice, turpentine, peppermint, cloves, garlic, coffee, rose, anise, and fish (<http://www.burghart.net/medizintechnik/index.php>).

These tests were conducted by a trained and experienced assistant. They were performed in a quiet and well-ventilated room and completed in around 20–30 min. As the tests are completely noninvasive, a medical qualification was not required to administer or interpret the test results. Each full test, scored for threshold, discrimination, and identification, was used to provide detailed information about individual participant's olfactory capabilities. The scores were also summed, out of a total of 48 points, to give an overall composite test score for each subject or TDI (sum of threshold, discrimination, and identification). The same Sniffin' Sticks test kit was used multiple times with multiple participants but was replaced every 6 months.

Analysis

The data were filtered according to the following criteria: MED, history of NP, and SMOK status. Initial analysis

showed no significant effect of handedness thus data were not divided into left- and right-handed participants. Data were analyzed with independent analyses of variance for age and gender. Statistical analyses were performed with SPSS statistical software (SPSS for windows version 12.01).

Results

Careful filtering of the participant population into included and excluded groups resulted in differential data exclusion across the various age groups (see Figure 1A). The distribution of included ($n = 485$) subjects decreased with increasing age, reflecting an age-associated increase in use of medication (see Figure 1B). Concomitant increases in the excluded population also varied with age, reflecting increased use of MEDs ($n = 271$) and decreased incidence of SMOK ($n = 89$) with increasing age. There was a slight decrease in the numbers of people with a history of nasal problems with increasing age, NP ($n = 236$). There was some overlap in the data set from excluded participants such as MED + NP ($n = 106$), SMOK + MED ($n = 19$), and SMOK + NP ($n = 9$) (see Figure 1B).

TDI scores, the sum of scores from threshold (T), discrimination (D), and identification (I) sections of the Sniffin' Sticks tests, were calculated for included and excluded

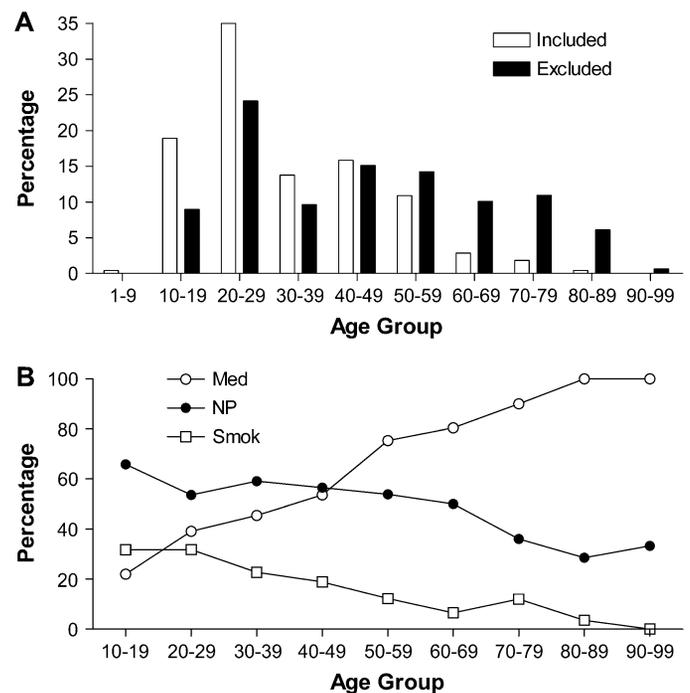


Figure 1 The proportion of participants included ($n = 486$) in the normative data set and those excluded (SMOK; currently taking MED; with a history of NPs, $n = 456$) is shown in (A). Displayed in the lower panel (B) are the proportion of participants excluded in each category by age. Note: reported use of medications resulting in removal from the included data set included use of medications such as antihyperlipidemic drugs, antihypertensive drugs, oral contraceptives and hormone-replacement therapy, insulin, Ventolin, and antidepressants; see Table 1.

participants and then partitioned by age and by gender. As shown in Figure 2, the decline in TDI with age is more marked in the excluded population and much less steep in the included population, although both showed significant decline with age (included: $F_{8,484} = 2.5$, $P = 0.01$; excluded: $F_{8,456} = 28.2$; $P < 0.001$). Overall there was a significant effect of exclusion criteria on the TDI scores ($F_{1,952} = 17.2$, $P < 0.001$). There was a significant interaction between exclusion criteria and age ($F_{1,7} = 3.6$, $P < 0.001$), which suggests that excluded participants have lower TDI scores with increasing age. Regression analysis confirmed that more people in the excluded group are older ($t = 2.9$, $P = 0.004$). It also showed, as expected, that people with a history of a respiratory condition have lower TDI scores ($t = -2.1$, $P = 0.04$).

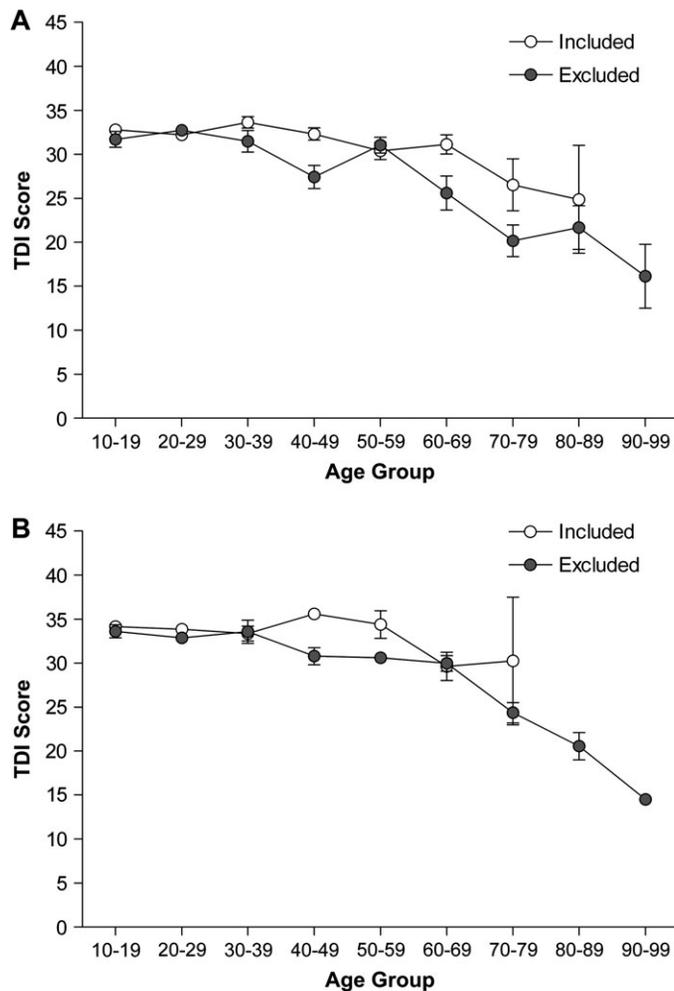


Figure 2 Total discrimination index (TDI) score for male (A) and female (B) participants divided into included (healthy, nonmedicated, nonsmoking participants with no history of nasal problems) and excluded (participants who gave a positive response to one or more of the following questionnaire items: history of nasal problems, smoking, taking medication; see Table 2) presented by age decade. Note the variation (steepness) in TDI decline across decades in the included compared with the excluded groups. Data are expressed and mean \pm standard error (SE). The absence of SE indicates that it is smaller than the resolution of the graph.

Regression analysis confirmed that TDI declined significantly with age in both excluded males and females (-1.7 and -1.6 , respectively).

Women had a consistently more sensitive olfactory function, scoring significantly higher overall TDI scores than age-matched men in the included population ($F_{1,484} = 5.5$, $P = 0.02$; see Figure 2). This did not vary with age, as there was no significant age by gender interaction in the included group ($F_{6,484} = 1.4$, $P = 0.2$). There was no overall significant difference between TDI scores from men and women in the excluded population ($F_{1,456} = 2.5$, $P = 0.11$) and no significant age by gender interaction ($F_{8,456} = 1.6$, $P = 0.12$; see Figure 3). These results may well reflect the higher number of subjects contained in the excluded group. Average TDI scores in each decade reflected these results, with excluded men in their sixth (average TDI = 25.7) and men and women in their seventh decade (average TDI = 20.7 and 24.2, respectively) dropping below previous TDI classifications of normosmia (Mackay-Sim et al. 2004). Normosmia has previously been defined operationally as TDI scores of greater than 29 for females and greater than 27 for males contrasting significantly with that for anosmia of TDI < 16 (Mackay-Sim et al. 2004). By contrast, in the included group, only men in their seventh decade dropped below “normosmic” TDI scores with average TDIs of 26.2. Thus, the average loss of TDI from 50 to 79 in the included group was 2.1 in women and 2.0 in men, compared with 3.2 (women) and 5.2 (men) in the excluded group.

TDI is made up of 3 separate test elements: threshold score, discrimination score, and identification score, and so TDI was obviously significantly correlated with all 3 elements. There was marginally better correlation between threshold and TDI ($r_{952} = 0.81$) than between discrimination ($r_{952} = 0.79$) or identification ($r_{952} = 0.77$), suggesting that threshold might be the most reliable measure of olfactory function if

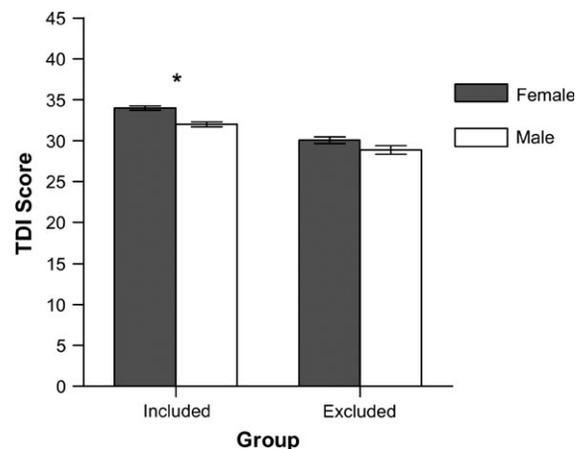


Figure 3 TDI of included and excluded participants by gender. Note the significant difference in TDI between males and females in the included but not the excluded groups ($*P < 0.001$). Data are expressed and mean \pm standard error (SE). The absence of SE indicates that it is smaller than the resolution of the graph.

a reduced test were to be considered; however, r^2 was comparable in all cases. This was particularly evident in the included compared with the excluded population (threshold: $r_{440} = 0.77$ included, $r_{512} = 0.83$ excluded; discrimination: $r_{440} = 0.69$ included, $r_{512} = 0.83$ excluded; identification: $r_{440} = 0.63$ included, $r_{512} = 0.82$ excluded), supporting the notion that olfactory and not verbal or general cognitive ability dropped in the excluded versus the included population. Moreover, regression analysis of the elements contributing to TDI (T, threshold; D, discrimination; and I, identification) showed that ability to perform in all 3 test elements declined with age in the excluded groups (males: T -0.7 , D -0.53 , I -0.49 ; females: T -0.58 , D -0.51 , I -0.52). However, the same pattern of findings did not hold on examination of the included groups, where it actually increased as a function of age in female subjects (I, $b_1 = 0.36$, $F = 0.002$). These results are presented graphically in Figure 4.

We then assessed TDI scores from the subpopulations of excluded participants (NP, MED, SMOK) and compared this with data from included participants. There was a significant overall reduction in TDI in the NP ($t_{553} = 4.4$, $P < 0.001$) and MED ($t_{586} = 8.3$, $P < 0.001$) populations,

but no significant effect evident in the SMOK populations (see Figure 5). Although there were fewer smokers in the aged population ($t = -3.1$, $P = 0.002$), this did not affect TDI scores or individual TDI components. The percentage of people rating their sense of smell as less than normal, normal, or better than normal was similar in all the subpopulations (approximately 15:70:15 in each population).

Discussion

There is a large variation in measured olfactory ability across the population of participants, representative of the Australian urban population (Doty et al. 1984; Murphy et al. 2002; Choudhury et al. 2003; Mackay-Sim et al. 2004). The main finding of this study is that idiopathic, age-related decline in olfactory function (presbyosmia) is relatively small in the healthy, nonmedicated, nonsmoking population in their sixth and seventh decade; this decline is smaller than previously reported (Doty et al. 1984; Murphy et al. 2002; Mackay-Sim et al. 2004). In contrast, persons taking medications or with a history of nasal problems showed the well-reported, age-related decline (Doty et al. 1984; Murphy et al.

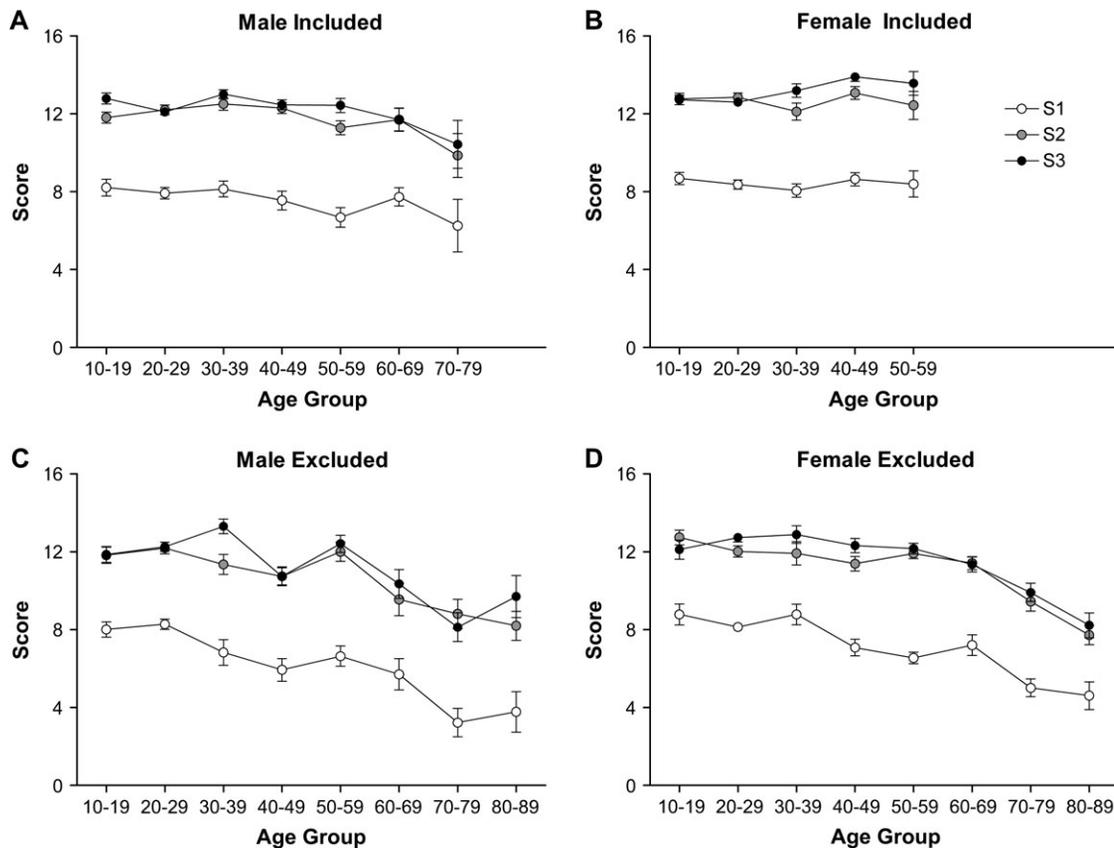


Figure 4 Participants' ability to assess their own olfactory sensitivity varied significantly (compared with their actual olfactory sensitivity; TDI). Self-assessed olfactory ability was altered in people with a previous history of NPs (**A**), most significantly by concurrent use of MEDs (**B**) but not by SMOK (**C**). The * indicates an overall significant reduction from included data set ($P < 0.05$). The hatched line at TDI of 28 scores above a previously reported cutoff point for normosmia (Mackay-Sim et al. 2004). Data are expressed as mean \pm standard error (SE). The absence of SE indicates that it is smaller than the resolution of the graph.

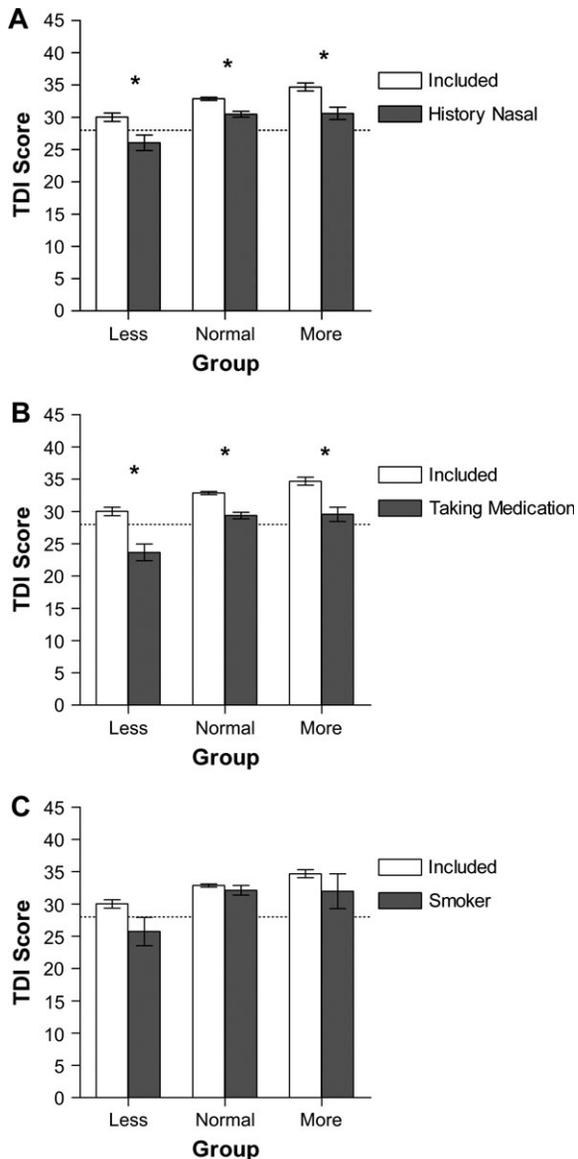


Figure 5 TDI scores shown in Figures 2 and 3 are a cumulative measure of threshold scores (T), discrimination scores (D), and odor identification scores (I). These scores, each out of a possible total of 16, are presented here individually for the group of “included men” (A), “excluded men” (B), “included women” (C), and “excluded women” (D). Data are expressed and mean \pm standard error (SE). The absence of SE indicates that it is smaller than the resolution of the graph.

2002; Choudhury et al. 2003; Mackay-Sim et al. 2004). The proportion of participants who reported conditions known to alter olfactory ability, such as having a history of nasal problems (Dunlop et al. 1999; M. Reiss and G. Reiss 2000) and use of medications (Ship and Weiffenbach 1993; Stevens 2001; Doty et al. 2003; LeWine 2005), was large and increased cumulatively with age (see Figure 1). We conclude that the commonly observed, age-related decline in olfactory function may result from age-related increases in other factors that independently affect olfactory function,

such as medications and history of nasal disease; the direct effect of “age” olfactory function may be relatively small.

The relatively small decline in olfactory ability with age in otherwise healthy adults (“true” presbyosmia) fits with our current understanding of the regenerative capacity of the olfactory sensory neurons, often suggested as a primary target for presbyosmia. The continuance of neurogenesis (Wolozin et al. 1992; Roisen et al. 2001; Murrell et al. 1996) and the presence of olfactory stem cells within the nasal mucosa at all ages (Roisen et al. 2001; Murrell et al. 2005) argue for a continued maintenance of olfactory function throughout adult life, as reported in 2 studies in humans (Elsner 2001; Kraemer and Apfelbach 2004). Our results suggest that the population of nonsmoking, nonmedicated people (with no other identified underlying pathology) with no history of nasal problems should be taken as the appropriate normative population with which to compare other subpopulations. Participants with unreported age-related conditions and who are unaware of their decline in olfactory function could potentially contribute to many study populations (Doty et al. 1984; Murphy et al. 2002; Choudhury et al. 2003; Mackay-Sim et al. 2004), thereby biasing or distorting population-based studies of olfactory ability and reduce the power of those studies in examining other conditions which may alter olfactory ability—such as Parkinson’s or Alzheimer’s disease (Meshulam et al. 1998; Mackay-Sim et al. 2004).

There was a significant effect of gender on olfactory ability in the included group (see Figure 3), which was not present in the excluded group. The lack of difference in the “excluded” group may have arisen from a “floor” effect in the test as more participants were hyposmic and anosmic in this group, particularly in the fourth to eighth decade (see also Figure 2). Additionally, because use of medication is a proxy marker for an underlying pathology, it is possible that the test may get subtly more difficult with age in this group, for example, if verbal competency or semantic encoding were affected (Lehrner et al. 1999).

Participants with no known confound of olfactory ability, such healthy, nonsmoking, nonmedicated participants with no history of nasal problems, were mostly able to assess their own olfactory ability as “normal.” Their assessment of their own olfactory ability clearly reflected their actual TDI scores, and 85% assessed their own ability as normal or above normal. Extrapolation of this data to the general population suggests that most healthy people would be aware of their olfactory abilities. A similar percentage of participants taking medication or with a history of nasal problems assessed their own olfactory abilities as normal or better, but this assessment was not concordant with their measured olfactory ability (TDI scores; see Figure 4). Thus, these participants commonly overrated their olfactory ability, shown in Figure 4. Moreover, their measured olfactory ability was consistently lower than that of the included group, potentially leaving them at risk for decreased appetite, food intake,

and weight and at greater risk for development of depression (Doty et al. 2003). This raises concerns about the unintended effects of medications on quality of life of medicated individuals (Doty et al. 2003).

Olfactory abilities of smokers were similar to the included group, indicating that smoking did not reduce olfactory performance or self-assessment of olfactory ability in this group, contrary to previous findings (Frye et al. 1990; Sugiyama et al. 2002), (see Figure 4, lower panel). It is probable that the participants in our study population had not smoked for long enough for an effect on olfactory function to be measurable. Although our participants did not provide information about how long they had smoked and or how many per day, the majority of the smokers were less than 40 years old. The negative effect of smoking on olfactory ability is small, measured in pack years (Frye et al. 1990). In contrast to the long-term effects of smoking, post hoc examination of our data indicated that TDI scores were altered significantly when subjects had smoked within 15 min of beginning the olfactory test. The average TDI of smokers who had a cigarette in 15 min prior to test ($n = 13$, $TDI = 25.4 \pm 2.3$) was significantly lower than regular smokers who had a cigarette more than 15 min prior to the test ($n = 78$, $TDI = 31.9 \pm 0.7$; $t_{1,87} = 3.5$, $P = 0.001$) and not different to the general included population, supporting the notion that smoking-related olfactory disruption is, in the short-term, dose related (Frye et al. 1990). Moreover, smokers were as aware as healthy nonsmoking participants of their own olfactory abilities, suggesting that smoking may not impede members of the population from potentially detecting changes in their own olfactory ability.

Summary and conclusions

We assessed olfactory function in a healthy population across decades and compared it with olfactory function in a “normative” population across decades. Olfactory function scores assessed in healthy participants (nonsmoking participants not on medication and with no history of nasal problems) were drawn out from a normative data set (Mackay-Sim et al. 2004) and compared with olfactory function from participants who either smoked, took medication, or had a history of nasal problems. Overall, we found that idiopathic age-related decline in olfactory function, presbyosmia, is far smaller and more gradual than previously reported. Olfaction contributes significantly to quality of life and to reductions in population mortality and morbidity. Thus, a clear, “clean” normative data set of olfactory ability against which potential olfactory deficits can be assessed is a significant clinical requirement. Moreover, as a greater understanding of the diagnostic, even predictive power of olfactory ability for various disease states, such as Alzheimer’s disease, Parkinson’s disease, and schizophrenia, emerges, the need for a standardized normative tool for olfactory assessment and data comparison emerges. We argue that this constitutes good reason to adopt

the selective process we have used in this study in future formulations of normative or control population studies. Moreover, it argues for a need for greater understanding of the mechanisms of olfactory decline in the population as a whole in order to understand (and potentially compensate for) the effects of medications and/or nonneurological conditions (such as hypertension) on olfactory ability.

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