Objective: To evaluate the potential utility of the Sniff Magnitude Test (SMT) as a clinical measure of olfactory function.

Design: Between-subject designs were used to compare the SMT and University of Pennsylvania Smell Identification Test (UPSIT) in study participants from a broad range of ages.

Subjects: A total of 361 individuals from retirement communities and an urban university and patients from an otolaryngology clinic.

Intervention: Study participants completed the SMT and UPSIT using standard procedures.

Main Outcome Measures: The UPSIT was scored using standard procedures to calculate the number of correctly identified odors; a score that can range from 0 to 40 correct. The measure of olfactory function generated by the SMT is the "sniff magnitude ratio," defined as the mean sniff magnitude generated by the odor stimuli divided by the mean sniff magnitude to nonodorized air blanks.

Results: The SMT generally showed good agreement with UPSIT diagnostic categories, although SMT scores were only modestly elevated in the mild and modest hyposmia range of the UPSIT. Age-related decline in olfactory ability was evident on the UPSIT at younger ages than that seen with the SMT. As predicted, otolaryngology patients with olfactory complaints were found to be impaired on both the UPSIT and SMT.

Conclusions: The SMT provides a novel method for evaluating the sense of smell that shows good general agreement with the UPSIT. Its minimal dependence on language and cognitive abilities provides some advantages over odor identification tests. There is some indication that the UPSIT may be more sensitive to olfactory (and/or nonolfactory) deficits. We conclude that sniffing behavior can be exploited for the clinical evaluation of olfaction. A comparison of performance on odor identification and sniffing tests may provide novel insight into the nature of olfactory problems in a variety of patient populations.

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IT IS ESTIMATED THAT SOME FORM of olfactory disorder afflicts at least 1% of the general adult population and 50% or more of people older than 65 years.1 Olfactory disorders can be traced to a diverse set of causes that include upper respiratory tract infections, nasal and sinus disease, developmental disorders, endocrine problems, head trauma, and neuropsychiatric diseases.1,3 Anosmia (loss of the sense of smell) and hyposmia (a diminished sense of smell) have been noted as early symptoms of Alzheimer disease and idiopathic Parkinson disease.4,5 These facts support the routine testing of olfactory abilities in older adults, especially in light of the finding that people are poor judges of their own olfactory abilities.6,7 In addition, effective treatments for conductive olfactory loss (ie, loss associated with poor airflow to the olfactory epithelium) are available,1 so accurate assessment is needed.

The most common clinical methods of olfactory evaluation are based on odor detection and identification.8-11 These methods have been used productively to characterize olfactory disorders in a variety of patient populations, but they have some drawbacks. Odor detection thresholds are only moderately reliable, are time consuming, involve complex series of odor presentation, and demand focused attention to an ephemeral stimulus. Odor identification tests require patients to sniff odorant samples and then identify or label them. The interpretation of these tests can become problematic when evaluating children, people with impaired cognitive function, and individuals from diverse cultural and linguistic backgrounds.12-14

The Sniff Magnitude Test (SMT) (CompuSniff, LLC, Cincinnati, Ohio) was de-
veloped to complement odor detection and identification tests by overcoming some of the limitations of the more traditional tests. The SMT is based on a well-established reduction in sniff magnitude that normally occurs in response to an odor. A number of studies have demonstrated that sniff vigor and duration play an important role in modulating odor perception.\cite{15,16} Laing\cite{17} reported that sniff volume is reduced as odorant concentration increases, an observation subsequently verified by investigators from several laboratories.\cite{18-21} Given the simple, rapid nature of the sniff response, it may be buffered from variations in age, language, culture, and cognitive ability. If odorant-induced modulation of sniffing can be used as a measure of the early events in olfactory processing, its combination with tests that rely on cognitive abilities (eg, odor identification tests) may provide a powerful approach to differentiating between olfactory deficits caused by loss of primary sensory input into the olfactory system and dysfunction of higher-order processing associated with tropsmia, phantosmia, or olfactory agnosia.

The SMT is based on the reduction in sniffing that normally occurs when an odor is encountered. Sniffs to stimuli composed of nothing but nonodorized air are longer and more vigorous compared with sniffs to odorized air, and this difference can be used as an indicator of smell function (Figure 1). When a patient’s sense of smell is impaired, this normal, odor-induced decrease in sniffing is reduced or eliminated.

Initial studies demonstrated the feasibility of the SMT and some of its advantages. For example, it was shown that the odor-induced sniff suppression is not affected by deficits in memory or attention in older adults and that the SMT scores of children (who do poorly on odor identification tests) did not differ from those of adults.\cite{14,22,23} The present investigation had 2 main goals. One was to more fully characterize the SMT in a sample of people that was diverse by age and olfactory abilities. The University of Pennsylvania Smell Identification Test (UPSIT) also was administered to allow for a comparison with the SMT. Good general agreement between the SMT and UPSIT was expected for the adults tested in this study. The second goal was to demonstrate that a sample of patients with olfactory complaints would produce abnormal results on the SMT.

### Olfactory Tests

#### University of Pennsylvania Smell Identification Test

The UPSIT\cite{10} is the most widely used olfactory test in the world, having been administered to nearly 100 000 persons in the last decade. In this test, the patient is required to identify, in a 4-alternative multiple-choice format, each of 40 odors presented on microencapsulated “scratch and sniff” labels. The dependent measure is the number of items correctly answered. The UPSIT was completed in the presence of a research assistant who answered questions and offered help as requested. The UPSIT was scored using standard procedures to calculate the number of correctly identified odors, this being a score that can range from 0 to 40 correct.

#### Sniff Magnitude Test

The SMT was administered as described previously.\cite{14} The SMT device and a photograph of a person prepared to sniff are shown in Figure 2. The odor canisters contain either no odor (ie, they serve as nonodorized air blanks) or they contain 5.0 mL of an odor stimulus diluted in mineral oil. During testing, the participant wears a bilateral nasal cannula of the type used to provide oxygen to patients with limited respiratory capacity (as shown in Figure 2). A participant’s sniff creates a negative pressure that is sensed by a pressure transducer connected to the cannula and an analog-to-digital processing board located within a controller device. The digitized output signal of the board is sent to a laptop computer. Within milliseconds of detecting a sniff, the computer opens the lid of the testing canister, thereby exposing the participant to any odor stimulus within the canister. This all occurs very rapidly (within 1.5 milliseconds) once a sufficient sniff pressure is achieved, and sniff pressure measurements are recorded by the computer every 10 milliseconds until the transducer detects a return to ambient air pressure. Thus, data from a single sniff are recorded on each trial.

Four stimulus canisters were used in the present study: 1 was a no-odor stimulus (air blank); 1 contained 5.0 mL of a mixture composed of 1.0 mL of liquid methylthiobutyrate (MTB, also known as S-methylthiobutanate, 98% purity) in 99 mL of mineral oil (1.0% vol/vol); 1 contained 5.0 mL of a mixture composed of 3.0 mL of liquid MTB in 97 mL of mineral oil (3.0% vol/vol); and 1 contained 5.0 mL of a mixture composed of 1.0 mL of ethyl 3-mercaptopropionate (EMP, 99% purity) in 99 mL of mineral oil (1.0% vol/vol). The odorized air that is cre-
pants were not able to detect which of the 4 identical stimulus

procedure. The testing protocol was designed so that partici-

pant canister needed for the next trial and repeated the testing

trial. This measure is proportional to the area under the

pattern for individuals with unusually low levels of sniff

suppression.

The measure “sniff magnitude” was generated from the SMT
data and consisted of the sum of the negative pressure values

generated across the duration of the single sniff that occurs on
each trial. This measure is proportional to the area under the

sniff pressure-time curve. The measure of olfactory function

generated by the SMT is the “sniff magnitude ratio,” defined

as the mean sniff magnitude generated by the odor stimulii di-

vided by the mean sniff magnitude to nonodorized air blanks.

Figure 2. Photographs of the Sniff Magnitude Test device components (1, laptop computer; 2, controller box; 3, nasal cannula; 4, odor canister base; and 5, odor canister) (A), and an individual being tested with the nasal cannula and odor canister in place (B).

ated in the headspace of the canister for these odor stimuli is

moderately intense and easily detected by a person with a nor-

mal sense of smell. The MTB and EMP stimuli are flavor and

fragrance additives described as having a fecal, ripe cheese odor

and a burnt, skunky odor, respectively, at the concentrations

used in the test. Previous research and pilot studies done in

our laboratory demonstrated that the MTB and EMP stimuli

produce no nasal irritation as demonstrated by the inability to

localize the stimuli in a 2-nostril localization test.

Once informed consent was obtained, participants com-

pleted a short health and demographics questionnaire. Next they

completed the UPSIT and the SMT. For the SMT, the nasal can-

nula was fitted into place, and the participant was told that sev-

eral different canisters would be provided for sniffing and that

his or her task was to report whether an odor was present. The
test administrator placed the canister approximately 2.0 cm di-

rectly beneath the nose, and once in position, the participant

was instructed to “sniff until you smell something.” It was em-

phasized that a single, natural sniff was appropriate, such as

would be taken when sampling a perfume or food. Several prac-
tice trials were completed prior to data collection. Once an ad-

equate pressure was generated by a sniff, the lid of the canister

remained open until the participant’s sniff ended (ie, the nega-
tive pressure produced by the inspiration was no longer de-
tected by the transducer).

Once a sniff trial ended, the test administrator connected

the canister needed for the next trial and repeated the testing

procedure. The testing protocol was designed so that partici-

pants were not able to detect which of the 4 identical stimulii
canisters was being used prior to taking a sniff. Each test started
with 3 trials using the nonodorized air (blank) canister. This

established a no-odor sniffing baseline. The next 3 trials ex-
posed the participant to 1.0% MTB. If the sniff magnitude ra-
tio comparing 1.0% MTB and the no-odor trials was 0.75 or
greater (ie, 25% suppression to ≤1.0% MTB), 6 additional trials
were run. The first 3 used 3.0% MTB, and the second 3 used
1.0% EMP. These additional trials were included to verify the
sniff pattern for individuals with unusually low levels of sniff

suppression.

The measure “sniff magnitude” was generated from the SMT
data and consisted of the sum of the negative pressure values

generated across the duration of the single sniff that occurs on
each trial. This measure is proportional to the area under the

sniff pressure-time curve. The measure of olfactory function
generated by the SMT is the “sniff magnitude ratio,” defined

as the mean sniff magnitude generated by the odor stimulii di-

vided by the mean sniff magnitude to nonodorized air blanks.

Figure 3. Mean sniff magnitude ratios as a function of University of Pennsylvania Smell Test (UPSIT) diagnostic categories. The score range of each UPSIT diagnostic group is given in parentheses. The bars depict 1 SEM.

Of the 361 people tested, 137 were recruited from the

retirement communities, 89 from the ENT clinic, and 135

from the University of Cincinnati community. The mean

age of the participants was 53.4 years (range, 18-94 years),

and the sample was 74% female.

The relationship between UPSIT diagnostic catego-

ries and sniff magnitude ratios is depicted in Figure 3.

As sniff magnitude ratios increase (indicating less odor-

induced sniff suppression and a poorer sense of smell), one

would expect UPSIT scores to decrease (indicating fewer correctly identified odors). This pattern of results

was observed. Statistical analyses revealed that the SMT

scores of participants who scored in the UPSIT norm-
osmic range were significantly different from the scores

of the other UPSIT groups except for the mild hyposmia

group (F₁,₁₃ₕ = 22.4, P < .001; Tukey HSD (Honestly Sig-

ificant Difference) post hoc test, P < .05 [SPSS 12.0 for

Windows; SPSS Inc, Chicago, Ill]).

The relationships between age and scores on the ol-

factory tests are shown in Figure 4. The mean UPSIT

scores of participants in their teens, twenties, and thir-
ties did not differ from each other but were significantly higher than the mean UPSIT scores for people 40 years and older ($F_{8,352} = 10.47$, $P < .001$; Tukey HSD post hoc test, $P < .05$ [SPSS 12.0 for Windows]). Sniff magnitude ratios increased significantly with age, but the SMT measure was not significantly elevated from the levels of people in their thirties until age reached the sixties ($F_{8,352} = 8.40$, $P < .001$; Tukey HSD post hoc test, $P < .05$ [SPSS 12.0 for Windows]). Thus, the UPSIT appears to be more sensitive to age-related decline in olfactory abilities compared with the SMT.

A final evaluation of the olfactory tests was performed for the ENT patients with olfactory complaints. There were 14 of these patients evenly divided between men and women with an average age of 52.1 years (range, 24-67 years). All of these patients were referrals for complaints about not being able to taste and/or smell. An evaluation of medical histories and physical examination findings produced diagnoses of allergic rhinitis, nasal polyps, post–upper respiratory tract infection anosmia, posttraumatic injury anosmia, potential anosmia related to toxic chemical exposure, chronic sinusitis, and idiopathic anosmia. Of the 14 patients, 2 produced normal scores on both the UPSIT and SMT on testing. Mean olfactory test scores for 3 groups of study participants are given in the Table. The scores of the patients with olfactory complaints were significantly poorer on the UPSIT and SMT compared with the scores of the other 2 groups: (UPSIT, $F_{2,358} = 18.1$, $P < .001$; Tukey HSD post hoc test, $P < .05$; and SMT, $F_{2,358} = 3.66$, $P < .05$; Tukey HSD post hoc test, $P < .05$ [SPSS 12.0 for Windows]).

### Table. UPSIT and SMT Scores for ENT Patients With Olfactory Complaints Compared With Other Study Participants*

<table>
<thead>
<tr>
<th>Sample</th>
<th>No. of Patients</th>
<th>UPSIT</th>
<th>SMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olfactory complaint patients</td>
<td>14</td>
<td>19.6 (2.10)</td>
<td>0.81 (0.075)</td>
</tr>
<tr>
<td>Other ENT patients</td>
<td>75</td>
<td>28.6 (1.92)</td>
<td>0.61 (0.068)</td>
</tr>
<tr>
<td>Other study participants</td>
<td>272</td>
<td>30.8 (1.03)</td>
<td>0.64 (0.037)</td>
</tr>
</tbody>
</table>

Abbreviations: ENT, ear, nose, and throat; SMR, sniff magnitude ratio (the measure of olfactory function generated by the Sniff Magnitude Test [SMT], which is the mean sniff magnitude generated by the odor stimuli divided by the mean sniff magnitude to nonodorized air blanks); UPSIT, University of Pennsylvania Smell Identification Test.

*Data are given as mean (SEM) score unless otherwise specified.

The findings of the present study bolster previous research supporting the validity of the SMT as a clinical test of olfaction. As expected, sniff magnitude ratios indicated more olfactory impairment as people did more poorly on the UPSIT. The well-known deterioration of olfactory abilities with age was reflected in elevated SMT scores for older adults, and it was shown that the age-related effects were not due to aging per se but more likely indicative of olfactory impairment. Finally, the sniff magnitude ratios were significantly elevated for a clinical group likely to have olfactory problems, that is, patients with olfactory complaints. We conclude that sniffing behavior can be exploited for the clinical evaluation of olfaction.

The SMT and UPSIT showed generally good agreement in the present study, but some differences in performance are worthy of note. Study participants identified as normosmic and mildly hyposmic on the UPSIT were not significantly different on the SMT, and those with moderate UPSIT hyposmia scores had only slightly elevated sniff magnitude ratios. The UPSIT also showed earlier age-related impairment of olfaction compared with the SMT. These results may reflect a greater sensitivity of the UPSIT to loss of olfactory abilities. One reason for this could be the odor intensity levels used for UPSIT and SMT stimuli. The SMT odor stimuli are more intense, and therefore may elicit responses more readily that the microencapsulated odors used for the UPSIT. Another reason that the UPSIT may be more sensitive to olfactory loss is that odor identification tests rely more heavily on odor memory and discrimination abilities compared with the SMT. This would make the UPSIT sensitive to a wider variety of olfactory problems compared with the SMT. A final possibility is that UPSIT performance may partially reflect general (as opposed to olfaction-specific) problems with attention and memory. Moderately impaired attention and memory are known to correlate with performance on odor identification tests but do not influence the SMT. This makes the SMT especially use-
ful for testing older adults who often experience olfactory losses and declining cognitive abilities. In addition, cultural differences can result in some patients being unfamiliar with odorant labels used in the UPSIT, producing poor performance. This would suggest the SMT may provide a more specific measure of true olfactory loss. Additional studies are needed to assess the contribution of these sensory, perceptual, and cognitive factors to differences in performance on the SMT and UPSIT. This information is important to a more sophisticated understanding of the causes of olfactory loss in general and may also provide important clues to the etiology of a number of specific disorders that share olfactory dysfunction as an early symptom.2,4

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